Appendix P

Human health risk assessment

Woodlawn Advanced Energy Recovery Centre: Human Health Risk Assessment

Prepared for: Veolia Environmental Services (Australia) Pty Ltd and EMM

6 October 2022

Document History and Status

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Limitations

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It is prepared in accordance with the scope of work and for the purpose outlined in the Section 1 of this report.

The methodology adopted, and sources of information used are outlined in this report. Environmental Risk Sciences has made no independent verification of this information beyond the agreed scope of works and assumes no responsibility for any inaccuracies or omissions. No indications were found that information contained in the reports provided for use in this assessment was false.

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Glossary of Terms and Abbreviations

Term	Definition
AAQ	Ambient air quality
ABS	Australian Bureau of Statistics
Acute exposure	Contact with a substance that occurs once or for only a short time, typically an hour but may be up to 14 days [compare with chronic exposure and intermediate duration exposure].
Absorption	The process of taking in. For a person or an animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs
Adverse health effect	A change in body function or cell structure that might lead to disease or health problems
APC	Air pollution control
APCr	Air pollution control residues
ARC	Advanced Energy Recovery Centre
ATSDR	Agency for Toxic Substances and Disease Register
ANZECC	Australia and New Zealand Environment and Conservation Council
Background level	A pre-existing average or expected amount of a substance or material in a specific environment, or typical amounts of substances that occur naturally in an environment.
BAT	Best available techniques
Biodegradation	Decomposition or breakdown of a substance through the action of micro-organisms (such as bacteria or fungi) or other natural physical processes (such as sunlight).
Bioreactor	Woodlawn Bioreactor
Body burden	The total amount of a substance in the body. Some substances build up in the body because they are stored in fat or bone, or because they leave the body very slowly.
C&I	Commercial and industrial
Carcinogen	A substance that causes cancer.
CEP	Community Engagement Plan
CLC	Community Liaison Committee
Chronic exposure	Contact with a substance or stressor that occurs over a long time (more than one year) [compare with acute exposure and intermediate duration exposure].
CO	Carbon monoxide
Crisps Creek IMF	Crisps Creek Intermodal Facility (IMF)
DAWE	Department of Agriculture, Water and the Environment
DEC	Department of Environment and Conservation
DECC	Department of Environment Climate Change
DECCW	Department of Environment Climate Change and Water
DEFRA	Department for Environment, Food & Rural Affairs
DEH	Australian Department of Environment and Heritage
Detection limit	The lowest concentration of a substance that can reliably be distinguished from a zero concentration.
Dose	The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An 'exposure dose' is how much of a substance is encountered in the environment. An 'absorbed dose' is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.
DPIE	Department of Planning, Industry and Environment
Eco Precinct	Woodlawn Eco Precinct
ED	Evaporation Dam
EIS	Environmental Impact Statement
enHealth	Environmental Health Standing Committee (Department of Health)
EfW	Energy from waste

Term	Definition
EMM	EMM Consulting Pty Limited
EMPs	Environmental monitoring programs
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPA	Environment Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
ERF	Energy recovery facility
Exposure	Contact with a substance by swallowing, breathing, or touching the skin or eyes. Also includes contact with a stressor such as noise or vibration. Exposure may be short term [acute exposure], of intermediate duration [intermediate exposure], or long term [chronic exposure].
Exposure assessment	The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.
Exposure pathway	The route a substance takes from its source (where it began) to its endpoint (where it ends), and how people can come into contact with (or get exposed) to it. An exposure pathway has five parts: a source of contamination (such as chemical substance leakage into the subsurface); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.
FOGO	Food organics and garden organics
FGT	Flue gas treatment
GDR	Great Dividing Range
Genotoxic carcinogen	These are carcinogens that have the potential to result in genetic (DNA) damage (gene mutation, gene amplification, chromosomal rearrangement). Where this occurs, the damage may be sufficient to result in the initiation of cancer at some time during a lifetime.
Guideline value	Guideline value is a concentration in soil, sediment, water, biota or air (established by relevant regulatory authorities such as the NSW Department of Environment and Conservation (DEC) or institutions such as the National Health and Medical Research Council (NHMRC), Australia and New Zealand Environment and Conservation Council (ANZECC) and World Health Organization (WHO)) that is used to identify conditions below which no adverse effects, nuisance or indirect health effects are expected. The derivation of a guideline value utilises relevant studies on animals or humans and relevant factors to account for inter and intra-species variations and uncertainty factors. Separate guidelines may be identified for protection of human health and the environment. Dependent on the source, guidelines would have different names, such as investigation level, trigger value and ambient guideline.
HHRA	Human health risk assessment
HI	Hazard Index
IARC	International Agency for Research on Cancer
IBA	Incinerator bottom ash
IBAA	Incinerator bottom ash aggregates
Inhalation	The act of breathing. A hazardous substance can enter the body this way [see route of exposure].
Intermediate exposure	Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].
IMF	Crisps Creek Intermodal Facility
LFG	Landfill gas
LGA	Local Government Area
LHD	Local health District
LOR	Limit of Reporting

Term	Definition
LPB	Liquid paperboard
LTP	Leachate treatment plant
MBT	Woodlawn Mechanical Biological Treatment Facility
Metabolism	The conversion or breakdown of a substance from one form to another by a living organism.
MJ/kg	Megajoules per kilogram
MRF	Materials recycling facility
MSW	Municipal solid waste
Mtpa	Million tonnes per annum
MW	Mega watt
MWth	Mega watt thermal
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council
NO_2	Nitrogen dioxide
NOx	Nitrogen oxides
NSW	New South Wales
NSW EPA	NSW Environment Protection Authority
OEH	NSW Office of Environment and Heritage
OEHHA	Office of Environmental Health Hazard Assessment, California Environment Protection Agency (Cal EPA)
PET	Polyethylene terephthalate
PFAS	Per- and polyfluoroalkyl substances
PM	Particulate matter
$PM_{2.5}$	Particulate matter of aerodynamic diameter 2.5 µm and less
PM_{10}	Particulate matter of aerodynamic diameter 10 µm and less
POEO Act	*Protection of the Environment Operations Act 1997*
Point of exposure	The place where someone can come into contact with a substance present in the environment [see exposure pathway].
Population	A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).
Receptor population	People who could come into contact with hazardous substances [see exposure pathway].
Risk	The probability that something would cause injury or harm.
Route of exposure	The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].
SEARs	Secretary's Environmental Assessment Requirements
SEIFA	Socio-Economic Index for Areas
SO_2	Sulfur dioxide
SSD	State significant development
TADPAI	Tarago and District Progress Association Incorporated
TCEQ	Texas Commission on Environmental Quality
Toxicity	The degree of danger posed by a substance to human, animal or plant life.
Toxicity data	Characterisation or quantitative value estimated (by recognised authorities) for each individual chemical substance for relevant exposure pathway (inhalation, oral or dermal), with special emphasis on dose-response characteristics. The data are based on available toxicity studies relevant to humans and/or animals and relevant safety factors.
Toxicological profile	An assessment that examines, summarises, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.
Toxicology	The study of the harmful effects of substances on humans or animals.

Term	Definition
tpa	tonnes per annum
TSP	Total suspended particulates
UK	United Kingdom
US	United States
USEPA	United States Environmental Protection Agency
Veolia	Veolia Environmental Services (Australia) Pty Ltd
VOC	Volatile organic compound
WARR Act	*Waste Avoidance Resource and Recovery Act 2001*
WARR Strategy	*Waste Avoidance and Resource Recovery Strategy 2014-2021*
WHO	World Health Organization
$\mu g/m^3$	Micrograms per cubic metre

Executive Summary

Introduction

Veolia owns and operates the Woodlawn Eco Precinct (the Eco Precinct), located near Tarago, NSW, which is approximately 50 km south of Goulburn and 70 km north of Canberra. The Eco Precinct has provided sustainable and innovative waste management services for the last 20 years and has been developed to include a range of complementary waste management and resource operations and technologies.

Veolia is proposing to develop and operate the Woodlawn Advanced Energy Recovery Centre (ARC), an energy recovery facility (ERF), at the existing Woodlawn Eco Precinct. The ARC will be designed to recover energy from residual municipal solid waste (MSW) and commercial and industrial (C&I) waste that would otherwise be disposed of to landfill. The ARC would treat up to 380,000 tonnes per annum of the residual waste to produce up to 240,000 megawatt hours of electricity per annum.

This human health risk assessment (HHRA) has been developed for the project by identifying and estimating the health impacts of the proposed project, as a result of emissions to air, on the health of the surrounding (local and regional) community.

Assessment Approach

The HHRA has been conducted as a desktop assessment in accordance with national guidelines available from enHealth (enHealth 2012b, 2017). The focus of the assessment has been the assessment of exposures that may occur as a result of emissions to air from the proposed ARC. As a result, the HHRA has relied on the air modelling presented in the Air Quality Impact Assessment (AQIA) (EMM 2022).

The area surrounding the Project site largely comprises rural residential and residential land where a range of agricultural activities occur. The surrounding community also includes school, church and other community areas. The HHRA has considered the various land uses and activities that may occur in these areas.

The HHRA has been undertaken to address the following:

Emission sources

The assessment has focused on modelled impacts from emissions to air from the ARC as well as from other sources in and adjacent to the Eco Precinct, which includes the mine, so that impacts from all sources are considered. This way all the sources of air emissions, not just the ARC, have been considered.

ARC emissions

This assessment has considered impacts in the off-site community for two worst-case emissions scenarios relevant to the operation of the ARC. These include:

- **Scenario 2 – reference case emissions – maximum emissions**:
    - The reference case scenario is based on maximum stack emission parameters and maximum measured emissions from Veolia's United Kingdom (UK) facility in Staffordshire which utilises similar feedstock (with very similar breakdown of key aspects of residual MSW and C&I waste), moving grate technology and flue gas and emissions control technology.
    - The results obtained for Scenario 2 provide a highly conservative upper bound estimation of potential air quality impacts from the Project. This scenario is sufficiently conservative to also address periods of plant shutdown and start-up (as these conditions were covered in the data from 2016-2020).
- **Scenario 3 – NSW EfW Policy regulatory case emissions**:
    - Scenario 3 assumes the combination of maximum stack emission parameters and the NSW Energy from Waste Policy Statement (EfW Policy) (NSW EPA 2021) emission concentration standards.
    - The results obtained for Scenario 3 represent the highest potential impacts from the project if operating at the maximum allowable emission rates, at all times, under the NSW EfW Policy and is therefore another highly conservative scenario.

Scenario 1 relates to the reference case with average measured emissions. This scenario is considered more representative of long-term emissions to air from the ARC. However, the focus of this assessment relates to the worst-case emission scenarios, hence the average emissions scenario was not evaluated further.

<u>Chemicals evaluated</u>

The chemicals evaluated include $PM_{2.5}$, nitrogen dioxide, sulfur dioxide, carbon monoxide, gases (hydrogen chloride, hydrogen fluoride, ammonia and volatile organic compounds as benzene), metals, polycyclic aromatic hydrocarbons (PAHs), dioxins and furans, and dioxin-like polychlorinated biphenyls (PCBs).

<u>Toxicity of chemicals evaluated in emissions</u>

The assessment of toxicity for all the chemicals evaluated has adopted values that are protective of exposures by all members of the community including sensitive groups such as children and the elderly.

<u>Location of exposure</u>

The HHRA has considered whether exposure to air emissions occurs within the commercial/ industrial areas close to or in the area of the ARC, or in the surrounding community areas where there are rural residential areas, residential towns and areas used for recreational purposes. The assessment has also considered potential exposure to emissions from the ARC that may occur during maintenance of wind-turbines located at 80 m height in the area of the Eco Precinct.

The focus of all risk calculations is the location of maximum predicted impacts (relevant to the exposure evaluated) as modelled in the AQIA.

Time period of exposure

For the assessment of inhalation exposures, the HHRA has considered health impacts associated with both acute and chronic exposures. Acute exposures are assessed assuming anyone may be exposed to the maximum 1-hour average concentration for each chemical in air. Chronic exposures are assessed based on the maximum annual average air concentration anywhere, in commercial/industrial areas and in rural residential or residential areas.

Adopted conservative assumptions for assessing chronic inhalation exposures

When assessing chronic inhalation exposures, the following has been assumed:

- at the location of maximum concentrations in air in commercial industrial areas and on the site boundary - it is assumed that workers spend 8 hours per day, every workday (240 days per year) for 30 years
- at the location of maximum concentrations in air in rural residential and other residential areas - it is assumed that residents spend 24 hours per day, every day of the year (365 days) for 70 years. The exposure duration of 70 years is longer than the expected operation time for the ARC.

Consideration of other pathways of exposure

In addition to assessing inhalation exposures, metals and persistent organic pollutants bound to dust may deposit to the ground or settle on roof areas where the following exposure may occur:

- incidental ingestion and dermal contact with chemicals deposited to soil and indoor dust
- uptake of these chemicals into home grown and consumed produce including fruit and vegetables, eggs, fish, milk and meat
- accumulation in rainwater tanks used for drinking water.

The above exposures are assessed using worst-case assumptions that include:

- the concentration in soil and indoor dust is a cumulative concentration following emissions and continual deposition for 70 years with no cleaning indoors, no addition of fertiliser or other soil to gardens, no washing of produce prior to consuming
- rainwater tanks are used as potable water, there is no first flush device used on the tank and all the deposition that occurs onto the roof over a year accumulates into the tank
- residents are at the location of maximum deposition at all times that they may live in the area, i.e. 24 hours per day, 365 days of the year for 70 years (which includes individuals who may grow up and then work on a family property).

The HHRA has also considered impacts on groundwater quality, recreational water quality (and fishing) in Lake George and Lake Bathurst and the sale of crops and produce into the market (including impacts on organic produce).

Outcomes of the HHRA

Based on the available data and conservative assumptions adopted in this assessment, the following has been concluded for the assessment of the worst-case emissions scenarios (Scenarios 2 and 3):

- Inhalation exposures
  - All risks to human health are considered negligible for the duration of the Project. More specifically the following has been concluded:
    - no acute inhalation risk issues of concern
    - no chronic risk issues of concern
    - exposure to particulates (as $PM_{2.5}$) derived from the ARC within the community are considered negligible.
- Multi-pathway exposures
  - All chronic risks to human health are considered negligible for the duration of the Project. More specifically the following has been concluded:
    - all calculated risks for individual exposure pathways are negligible and essentially representative of zero risk
    - all calculated risks for combined multiple pathway exposures are negligible and essentially representative of zero risk.
  - Emissions from the ARC would have a negligible impact on water quality in rainwater tanks used for drinking water
  - Emissions from the ARC would have a negligible impact on recreational water quality within Lake Bathurst and Lake George
  - Emissions from the ARC would have a negligible impact on crops and produce grown in the area.

Section 1. Introduction

1.1 Background

Veolia Environmental Services (Australia) Pty Ltd (Veolia) owns and operates the Woodlawn Eco Precinct (the Eco Precinct), located on Collector Road, approximately 6 kilometres (km) west of Tarago, approximately 50 km south of Goulburn and 70 km north of Canberra (refer to **Figure 1.1**).

The Eco Precinct is located in the Goulburn Mulwaree local government area (LGA). The Eco Precinct has provided sustainable and innovative waste management services since 2004.

The Eco Precinct comprises integrated waste management operations, energy recovery technologies and energy generation, and other sustainable land uses, including the following:

- Woodlawn Bioreactor (the Bioreactor) – a landfill in which leachate is recirculated to help bacteria break down the waste, enhancing the early generation, capture and extraction of landfill gas, including leachate and landfill gas management systems.
- Woodlawn BioEnergy Power Station – utilises landfill gas from the Bioreactor to generate electricity.
- Woodlawn Mechanical Biological Treatment (MBT) Facility – extracts the organic content from a portion of the municipal solid waste (MSW) for use in tailings dam remediation.
- Agriculture – includes a working farm that applies sustainable management practices.
- Aquaculture and horticulture – utilises captured waste heat from the BioEnergy Power Station for use in sustainable fish farming and hydroponic horticulture at the Eco Precinct.
- Renewable energy generation – the Woodlawn Wind Farm (operated by Iberdrola) which has an installed capacity to generate up to 48.3 MW, and a solar farm with installed capacity to produce up to 2.3 MW.

The Eco Precinct also provides a range of support facilities including a Leachate Treatment Plant (LTP).

The Eco Precinct is served by the Crisps Creek Intermodal Facility (IMF) near the village of Tarago. The Crisps Creek IMF is located approximately 8.5 km to the east of the Eco Precinct (by road). Operations are augmented by two waste transfer terminals located in Sydney; the Clyde Transfer Terminal, which commenced operation in 2004 with the Bioreactor and Crisps Creek IMF, and the Banksmeadow Transfer Terminal, which commenced operating in 2016.

Waste is transported from the Sydney transfer terminals in purpose-built shipping containers by rail on the Goulburn-Bombala Railway line to the Crisps Creek IMF on the way to the Eco Precinct. At the Crisps Creek IMF the containers are loaded on to trucks for delivery to the Eco Precinct. Waste from the local area is also approved to be transported to the Eco Precinct by road.

Veolia proposes to develop and operate the Woodlawn Advanced Energy Recovery Centre (ARC) (the project), an energy recovery facility (ERF), at the Eco Precinct. This involves the development of an additional waste management technology at the Eco Precinct, treating a portion of the waste stream which is already approved to be received as part of integrated waste management operations, and recovering energy from the process.

Compared to other developed countries, energy recovery from waste is relatively new in Australia. Energy recovery is a well-established and recognised waste management technology globally, generally acknowledged to be a preferable method of waste management, diverting waste from landfill.

1.2 Project overview

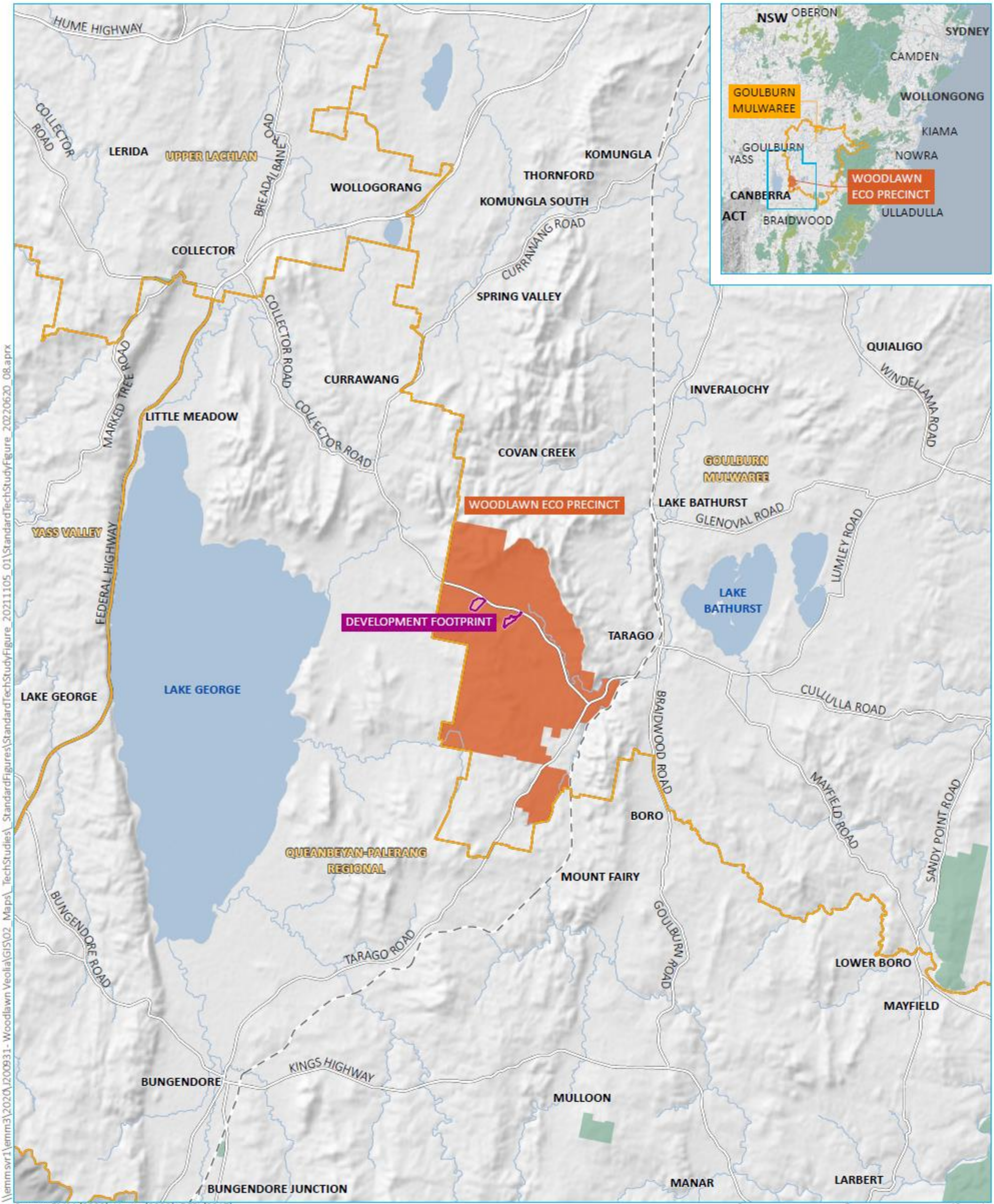
Veolia is proposing to develop and operate the Woodlawn Advanced Energy Recovery Centre (ARC), an energy recovery facility (ERF), at the existing Woodlawn Eco Precinct in Tarago, NSW, refer to **Figures 1.1 and 1.2** for the regional and local setting. The ARC will be designed to recover energy from waste that would otherwise be disposed to landfill.

The project involves construction and operation of the following key components comprising the ARC:

- development of the ARC, comprising an ERF for the thermal treatment of residual municipal solid waste (MSW) and commercial and industrial (C&I) waste (the residual waste feedstock) that will otherwise be disposed to landfill
- thermal treatment in the ARC of up to 380,000 tonnes per annum (tpa) of the residual waste feedstock
- installed capacity of up to 30 megawatts (MW) of electricity (generation of up to 240,000 megawatt hours (MWh) of electricity per annum)
- on-site management of residual by-products generated by the ARC
- ancillary development of site infrastructure to facilitate construction and operation of the project.

The project study area, shown in **Figures 1.2 and 1.3** includes the following:

- The ARC development footprint – this area includes the main ARC plant building and ancillary infrastructure, incinerator bottom ash (IBA) infrastructure and new access road and intersection. This area currently contains former mine plant infrastructure, water management infrastructure (plant collection dam) and other disturbed areas subject to ancillary waste management operations.
- Encapsulation cell development footprint - the area encompassed by the dedicated lined and engineered landfill cells for the encapsulation of stabilised air pollution control residues (APCr) from the flue gas treatment system. This area is disturbed and currently comprises water management infrastructure (Evaporation Dam 1).



Source: EMM (2022); Veolia (2022); DFSI (2017)

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KEY

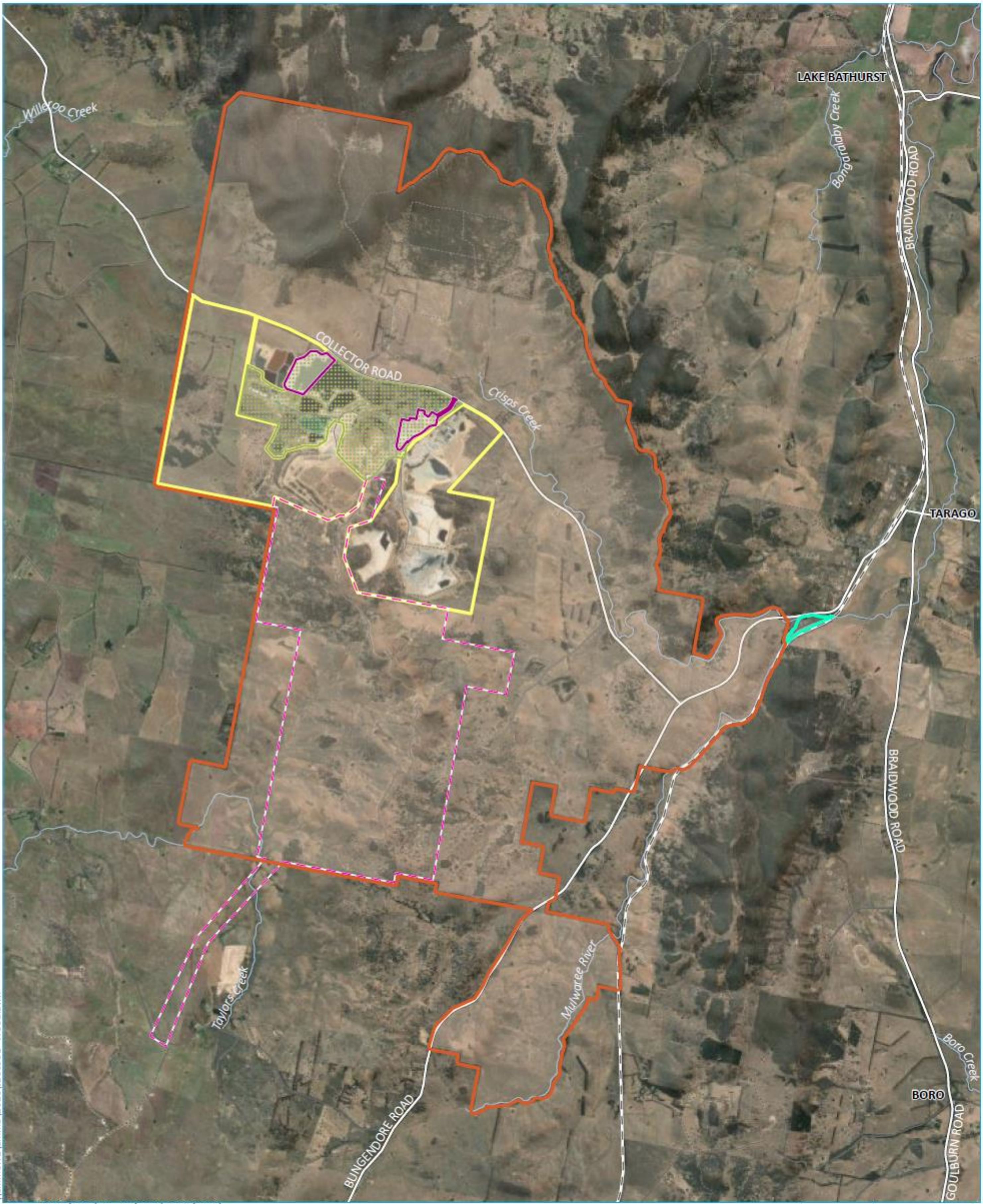
- Development footprint
- Woodlawn Eco Precinct
- Rail line
- Major road
- Watercourse
- Named waterbody
- NPWS reserve
- Local government area

Regional setting

Figure 1.1

Woodlawn Advanced Energy Recovery Centre
Environmental impact statement

EMM
creating opportunities



Source: EMM (2022); Veolia (2022); DFSI (2017)

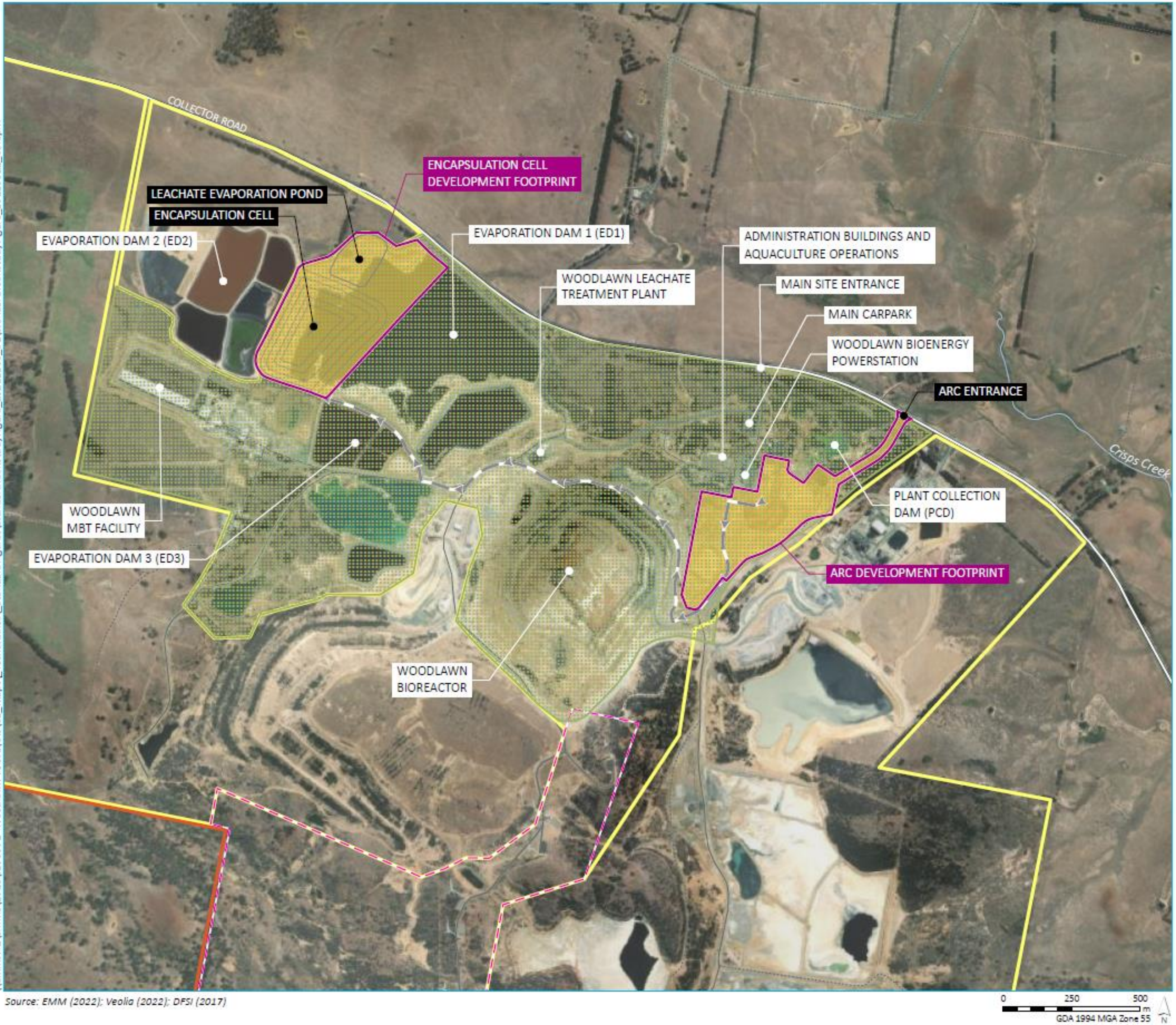
KEY
- Development footprint
- Veolia integrated waste management operations
- Woodlawn Eco Precinct
- Crisps Creek Intermodal Facility (IMF)
- Woodlawn Mine operations area
- Woodlawn Wind Farm
- Rail line
- Major road
- Minor road
- Vehicular track
- Watercourse

Local setting

Figure 1.2

Woodlawn Advanced Energy Recovery Centre
Environmental impact statement

EMM
creating opportunities



KEY
- Development footprint
- Veolia integrated waste management operations
- Woodlawn Eco Precinct
- Woodlawn Mine operations area
- Woodlawn Wind Farm
- APCr transport route
- Major road
- Minor road
- Vehicular track
- Watercourse

Source: EMM (2022); Veolia (2022); DFSI (2017)

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Project layout

Figure 1.3

Woodlawn Advanced Energy Recovery Centre
Environmental impact statement

EMM
creating opportunities

1.3 Objectives

The overall objective of this report is to undertake a human health risk assessment (HHRA) in relation to potential impacts to the community from the operation of the proposed ARC.

The focus of the HHRA relates to impacts on community health associated with changes in air quality and has not addressed any other impacts related to the proposed Project.

The HHRA has focused on impacts on community health for populations located outside of the Project area (which is the Veolia integrated waste management operations, refer to **Figure 1.3**). The HHRA has not addressed risks to workers involved in construction or operation of the ARC. Workers involved in construction and operation of the ARC would be managed under the *Work Health and Safety Act 2011* and *Work Health and Safety Regulation 2017* and all other relevant codes of practice as detailed by Work Safe NSW and Safe Work Australia.

1.4 Secretary's Environmental Assessment Requirements

More specifically, the HHRA has been prepared to address the requirements of the Secretary's Environmental Assessment Requirements (SEARs) issued on 2 July 2021, and specific requirements of NSW Health. These requirements are detailed in **Table 1.1** along with reference to where these aspects have been addressed in this report.

Table 1.1: SEARs and Agency requirements and relevant report sections

Aspect	Where addressed
SEARs	
Human Health Risk – a quantitative human health risk assessment in accordance with the 'Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards' (enHealth, 2012), including:	Whole report
▪ an assessment of the inhalation of criteria pollutants and exposure (from all pathways, i.e. inhalation, ingestion and dermal) to specific air toxics, including impacts from the transport of waste material	Sections 3 and 4
▪ consideration of the impacts on drinking water sources and rainwater tanks, including the impacts on water quality and human health	Section 4.7
▪ consideration of the potential health related impacts caused by the incineration of per- and polyfluoroalkyl substances (PFAS) which may be present within the proposed waste fuel, including an assessment of the potential for intake via drinking water and food consumption	Section 4.10
▪ an assessment of cumulative human health risk impacts associated with the facility and surrounding developments, including any approved (but not yet constructed) developments and the proposed Jerrara Power Energy from Waste Facility (SSD-22879238).	Section 4, noting that the Jerrara Power Energy from Waste Facility (SD-22879238) project has been withdrawn and has not been included in the cumulative assessment.
NSW EPA	
Assess all risks to the environment, human health and amenity associated with emissions of air pollutants, including odour from all stages of the proposal	Whole report, noting that odour aspects are addressed in the Air Quality Impact Assessment
A human health risk assessment must be undertaken in conjunction with the air quality and odour impact assessment.	Whole report, noting that odour aspects are addressed in the Air

Aspect	Where addressed
The human health risk assessment must be undertaken in accordance with *Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards* (enHealth) and must include:	Quality Impact Assessment
a) The inhalation of criteria pollutants and exposure from all pathways i.e., inhalation, ingestion and dermal to specific air toxics; and	Section 4
b) A demonstration of how the waste to energy facility would be operated in accordance with best practice measures to manage air emissions with consideration of the *Environment Protection Authority's NSW Energy from Waste Policy Statement*.	Whole report and Air Quality Impact Assessment
NSW Health – Murrumbidgee and Southern NSW Local Health Districts	
Human Health Risk Assessment ▪ Conduct in accordance with Environmental Health Risk Assessment Guidelines for Assessing Health Risks from Environmental Hazards and Australian Exposure Factor Guidelines (enHealth).	Section 1.5 and whole report
▪ Include appropriate justified and realistic modelled scenarios on sensitive receivers including local residential areas, school and child care centres, recreational users of Lake George and Lake Bathurst (and any other identified sensitive receivers).	Section 2
▪ Impacts on ground water, water sources, drinking water catchments and rain water tanks (where there is no connection available to a reticulated water supply, etc.)	Sections 4.7 and 4.8
▪ Cumulative impacts from other industry or facilities around, including those within the Woodlawn Eco Precinct, and the Woodlawn Zinc-Copper Project, Heron Resources Limited.	Section 4

1.5 Approach and scope of works

The HHRA has been undertaken in accordance with the following guidance (and associated references as relevant):

- enHealth, 2012. Environmental Health Risk Assessment: Guidelines for Assessing Human Health Risks from Environmental Hazards (enHealth 2012b), and associated Australian Exposure Factor Guidance (enHealth 2012a), consistent with guidelines to be used in the conduct of the HHRA as detailed in the SEARs.
- Guidance and guidelines available from the National Environment Protection Council in relation to ambient air quality (NEPC 2016, 2021) and contaminated land (NEPC 1999 amended 2013b).

Where relevant, the HHRA has also considered impacts to community health as outlined in the following guidance documents:

- enHealth, 2017. Health Impact Assessment Guidelines (enHealth 2017).
- Harris, P., Harris-Roxas, B., Harris, E. & Kemp, L., Health Impact Assessment: A Practical Guide, Centre for Health Equity Training, Research and Evaluation (CHETRE). Part of the UNSW Research Centre for Primary Health Care and Equity. University of New South Wales, Sydney, 2007 (Harris et al. 2007).

1.6 Definitions

For the conduct of the HHRA the following definitions are relevant and should be considered when reading this report.

Health:

The World Health Organisation defines health as "*a (dynamic) state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity*".

Hence the assessment of health should include both the traditional/medical definition that focuses on illness and disease as well as the more broad social definition that includes the general health and wellbeing of a population.

Health Hazard:

These are aspects of a Project, or specific activities that present a hazard or source of negative risk to health or well-being.

In relation to the HHRA these hazards may be associated with specific aspects of the proposed development/construction or operational activities, incidents or circumstances that have the potential to directly affect health. In addition, some activities may have a flow-on effect that results in some effect on health. Hence health hazards may be identified on the basis of the potential for both direct and indirect effects on health.

Health Outcomes:

These are the effects of the activity on health. These outcomes can be negative (such as injury, disease or disadvantage), or positive (such as good quality of life, physical and mental wellbeing, reduction in injury, diseases or disadvantage).

It is noted that where health effects are considered these are also associated with a time or duration with some effects being experienced for a short period of time (acute) and other for a long period of time (chronic). The terminology relevant to acute and chronic effects is most often applied to the assessment of negative/adverse effects as these are typically the focus of technical evaluations of various aspects of the project.

Likelihood:

This refers to how likely it is that an effect or health outcome will be experienced. It is often referred to as the probability of an impact occurring.

Risk:

This is the chance of something happening that will have an impact on objectives. In relation to the proposed project and the conduct of the HHRA, the concept of risk more specifically relates to the chance that some aspect of the project will result in a reduction or improvement in the health and/or well-being of the local community.

The assessment of risk has been undertaken on a quantitative basis. This is in line with the methods and levels of evidence currently available to assess risk.

1.7 Available information

In relation to the proposed project, and potential for impacts on air quality within the local community, this HHRA has been developed on the basis of information provided within the following report:

- EMM 2022, Air Quality Impact Assessment, Woodlawn Advanced Energy Recovery Centre. Report V5, dated October 2022.

Section 2. Community profile

2.1 Introduction

This section provides an overview of the community potentially impacted by the Project. It is noted that the focus of this assessment is the community surrounding the Project site (i.e. outside of the Veolia integrated waste management operations as shown in **Figure 1.3**).

2.2 Community location and receptors

The Project site is located in a rural area in Tarago, located 50 km south of Goulburn and 70 km north of Canberra. Key features surrounding the Project site include:

- a number of industrial areas adjacent to and surrounding the Project, which include Woodlawn Mine and associated emplacement areas and Woodlawn Windfarm
- a number of rural properties adjacent to and surrounding the site and larger Eco Precinct
- township of Tarago located approximately 6 km from the site
- townships of Collector located approximately 21 km to the northwest of the site and Bungendore located approximately 24 km to the south of the site
- town and recreational areas of Lake Bathurst located approximately 9 km to the northeast of the site and Lake George located approximately 8.5 km to the west of the site.

Figure 2.1 shows the location of the Eco Precinct and Project study area along with locations of rural residential homes, towns of Tarago, Lake Bathurst, Collector and Bungendore and recreational waterbodies of Lake Bathurst and Lake George.

In relation to rural uses in the areas surrounding the Project site, the following have been identified:

- Beef
- Lambs (fat lambs)
- Sheep for wool
- Horses
- Truffles
- Alpacas
- Crops including grapes, oats, barley and canola.

Figure 2.2 shows the location of the Eco Precinct which shows the location of areas close to the Project site, including some of the closest receptors (industrial, residential and Veolia receptors).

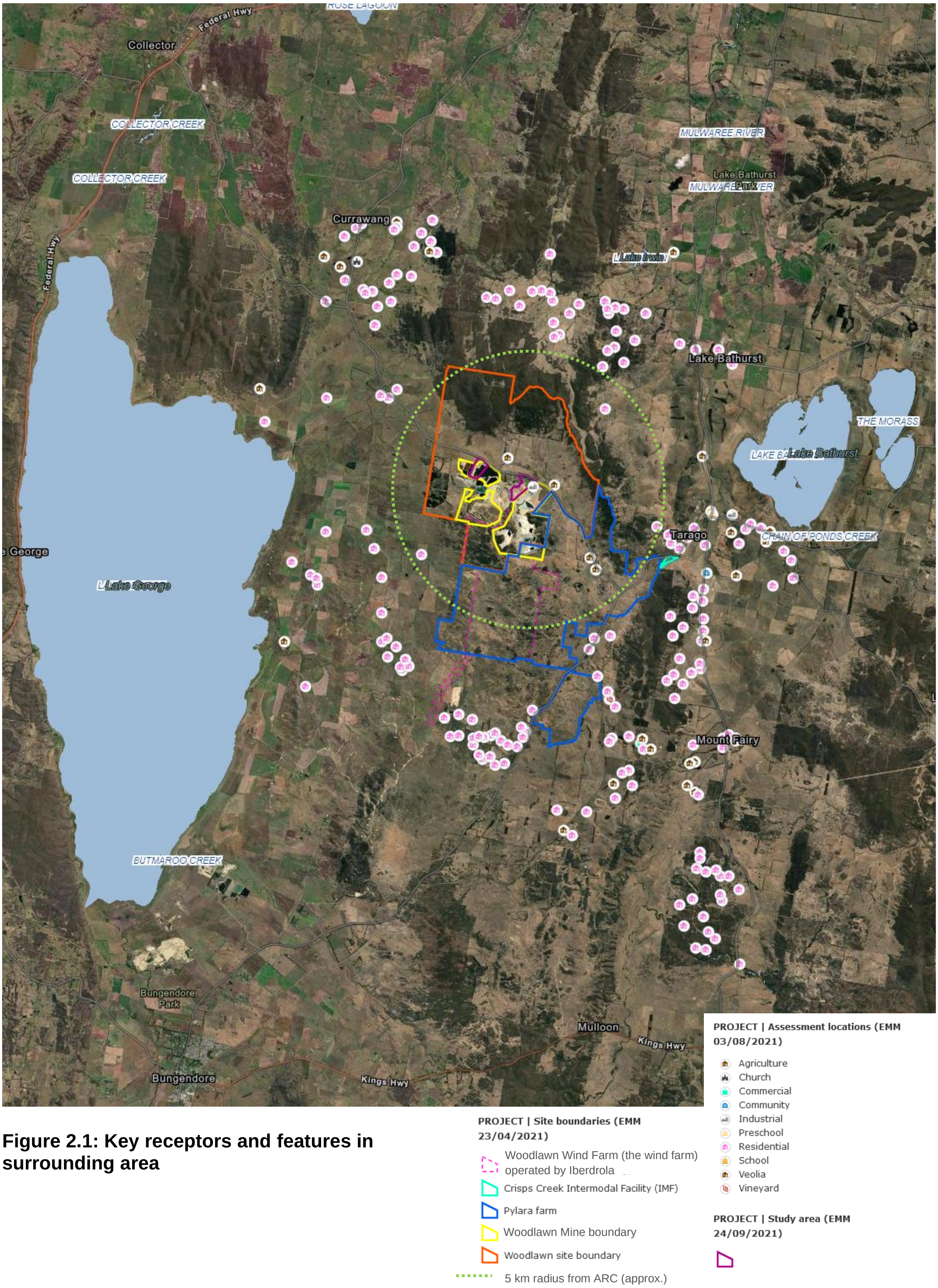
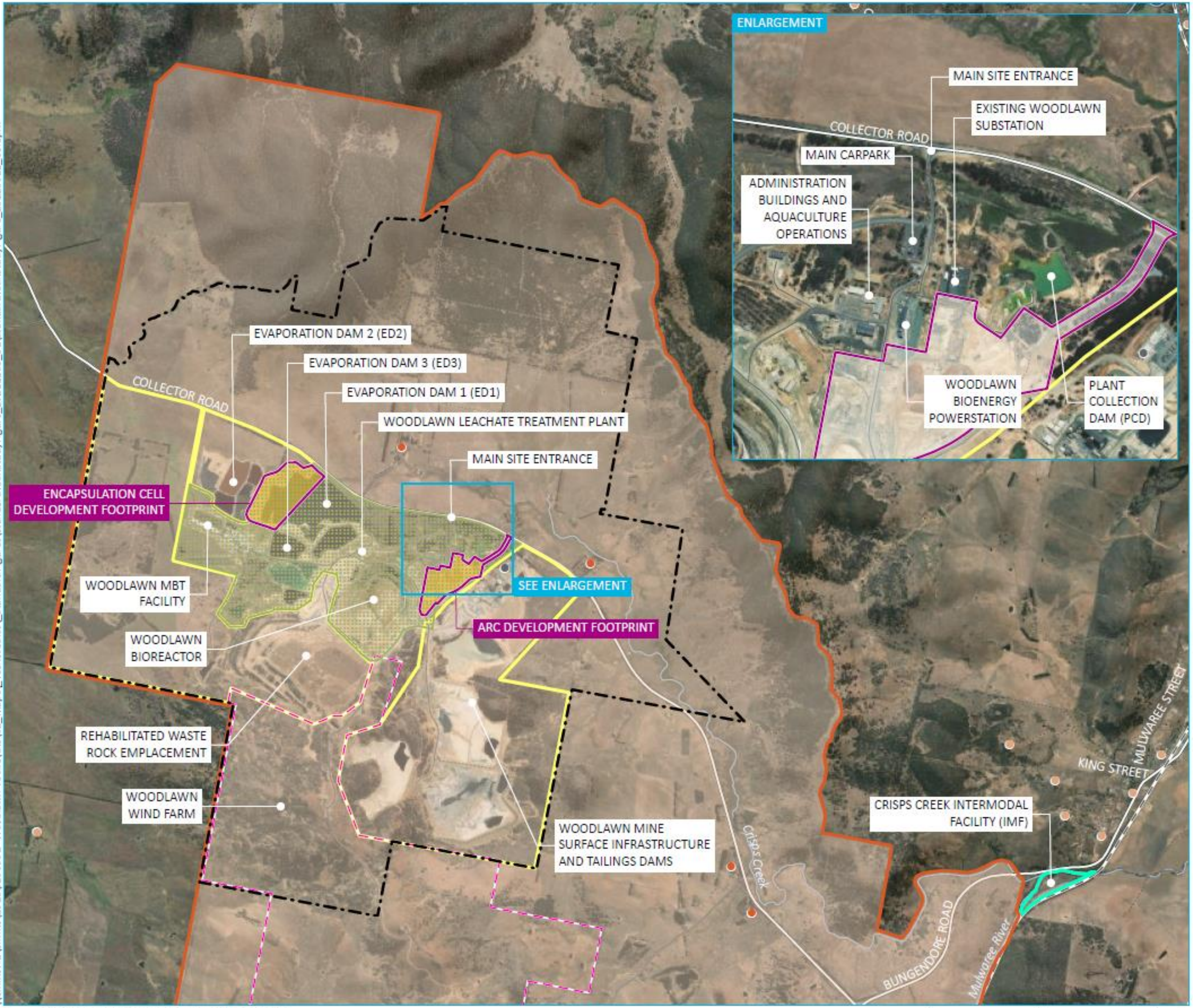


Figure 2.1: Key receptors and features in surrounding area



KEY
- Development footprint
- Veolia integrated waste management operations
- Woodlawn Eco Precinct
- Crisps Creek Intermodal Facility (IMF)
- Woodlawn Mine operations area
- Woodlawn Wind Farm
- Special (Crown & Private Lands) Lease 20
- Rail line
- Major road
- Minor road
- Vehicular track
- Watercourse

Assessment location
- Industrial
- Residential
- Veolia

Source: EMM (2022); Veolia (2022); DFSI (2017); DPE (2019)

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Eco precinct overview

Figure 2.2

Woodlawn Advanced Energy Recovery Centre
Environmental impact statement

EMM creating opportunities

The focus of the HHRA relates to the community surrounding the Project site. As a result, the assessment has considered all land uses surrounding the Project site, with specific focus on key receptor locations modelled in the Air Quality Impact Assessment (EMM 2022). The modelling has focused on a range of receptors as shown on **Figure 2.1**. These include existing land owned by Veolia and other commercial/industrial land/premises as well as a range of locations considered to be sensitive which include rural or agricultural properties, residential, school (including pre-school) and community locations (including church locations). **Table 2.1** presents a summary of the number of receptors evaluated in each of these categories and the minimum distance of these receptors from the ARC emissions stack for properties in each category.

Table 2.1: Summary of receptor locations (EMM 2022)

Receptor type/category	Number of properties evaluated	Closest distance to ARC stack (km)
Agriculture	22	6.8
Church	1	10.3
Commercial	1	10.4
Community	1	7.5
Industrial (Note 2)	2	0.4
Preschool	1	7.1
Residential (Note 1)	181	4.0
School	1	7.0
Veolia (Note 3)	4	1.2
Vineyard	1	8.4

Notes:

1 - It is noted that the closest residential receptor is located approximately 4 km from the ARC stack. All other residential receptors are located further from the stack (refer to **Figure 2.1** for locations)

2 - Industrial premises (with the closest being within Woodlawn Mine as shown on **Figure 2.2**)

3 – Veolia receptor locations are shown on **Figure 2.2.**

In addition to these individual receptor locations, EMM (2022) has also modelled potential impacts at the following locations:

- boundary receptors, located at 50 m intervals along the boundary of Veolia integrated waste management operations (refer to **Figures 1.3 and 2.2** for this area)
- additional boundary receptors located at 100 m intervals on the boundary of the Eco Precinct being all Veolia-owned land
- grid centred on the ARC stack as follows:
    - 10 km by 10 km at 500 m resolution
    - 20 km by 20 km at 1 km resolution
    - 30 km by 30 km at 2 km resolution
- sub-grid domain centres over Tarago village, which covers 2 km by 2 km at 250 m spacing
- individual location at 80 m height at the closest wind-turbine in the Woodlawn Windfarm (to address maintenance workers working at height to repair or maintain the turbines).

More broadly, these receptors and the larger grids that cover the broader area and Tarago village are located in the state suburbs (as per ABS definitions) of Tarago, Lake Bathurst and Currawang. These suburbs are located in the larger local government areas (LGA) of Goulburn Mulwaree and Queanbeyan-Palerang.

2.3 Demographics

Table 2.2 presents a summary of the population demographics for the suburbs and LGAs relevant to the community surrounding the Project site. These data are based on data available from the 2016 Census and 2016 Socio-Economic data from the Australian Bureau of Statistics (ABS). The data presented also addresses aspects relating to cultural and linguistic diversity (CALD) within the population. People born in some countries have higher rates of disease and health factors that may make them more vulnerable (NSW Health 2019). It is noted that migrant populations are often healthier than native-borne populations, with many having lower level of premature mortality and self-reported chronic conditions compared to those born in Australia (AIHW 2018).

Table 2.2 also provides some review of the demographics data to indicate where the population may be more or less vulnerable. The vulnerability of the population is considered to potentially reflect the ability of the population to adapt to environmental change and stressors. Communities with higher rates of unemployment, ranked more socioeconomically disadvantaged, with higher rates of young children or the elderly are considered to be potentially more vulnerable to the environmental stressors considered in this assessment.

Table 2.2: Summary of populations surrounding the proposed project site

Indicator	Suburb or Statistical Area					NSW	Australia
	Tarago	Lake Bathurst	Currawang	Goulburn Mulwaree LGA	Queanbeyan-Palerang LGA		
Total population	426	228	182	29,609	56,027	7,480,231	23,401,892
Population 0 - 4 years	7.0%	3.5%	5.5%	5.9%	6.5%	6.2%	6.3%
Population 5 - 19 years	16.2%	11.4%	19.8%	18.1%	19.4%	12.3%	18.5%
Population 20 - 64 years	58.5%	62.7%	59.3%	56.6%	62.0%	65.1%	59.6%
Population 65 years and over	17.1%	17.5%	15.9%	19.4%	12.2%	16.2%	15.7%
Median age	44	46	42	42	38	38	38
Household size	2.6	2.3	2.4	2.4	2.6	2.6	2.6
Unemployment	1.3% to 3.5% (for SA2 areas of Goulburn Region and Queanbeyan Region)			5.5%	2.7%	6.0% 6.3% (Sydney metro)	6.2%
Tertiary education	12.6%	14.4%	13.7%	13.7%	19.7%	22.4%	22%
SEIFA IRSD	1056	1030	1074	960	1053	--	--
SEIFA rank	4	4	5	3	5	--	--
Indigenous	1.6%	1.3%	1.6%	4.0%	3.1%	0.8%	2.8%
Born overseas	8.9%	17.1%	4.4%	9.9%	17.3%	34.9%	33.3%
Top 4 countries of birth	England Netherlands New Zealand Greece	England Philippines India Netherlands	NA	England New Zealand Philippines India	England India New Zealand Former Yugoslav Republic of Macedonia	China England India New Zealand	England New Zealand China India

Unemployment rates for June quarter 2021, relevant to LGA and Statistical Area 2 regions (SA2) as defined by the ABS, https://lmip.gov.au/default.aspx?LMIP/Downloads/SmallAreaLabourMarketsSALM/Estimates
SEIFA IRSD = index of socioeconomic disadvantage, rank relates to rank in Australia that ranges from 1 = most disadvantaged to 5 = least disadvantaged
Shading relates to comparison against NSW (potential): more vulnerable; less vulnerable
Country of birth – where in blue there is the potential for higher levels of diabetes or complications from diabetes (relevant for England and Philippines) (NSW Health 2019)

Based on the population data available and presented in **Table 2.2**, the community in the area surrounding the proposed Project are generally similar to the larger population in Goulburn Mulwaree LGA and NSW overall with the exception of the following:

- The populations in state suburbs surrounding the Project site are small (population numbers) which would result in more variable statistics for these areas compared with the LGAs.
- The population in the suburbs of Tarago, Lake Bathurst and Currawang has a lower rate of unemployment and are considered less socioeconomically disadvantaged. These aspects suggest the population may have some decreased level of vulnerability to Project related impacts.
- The population of Lake Bathurst has a lower proportion of young children and a higher proportion of people aged 65 years and older. These groups are generally considered to be more sensitive to impacts, however, the statistics for the area do not suggest the population would be (overall) more vulnerable.
- The LGAs that encompass these smaller populations indicate a higher proportion of people aged 65 years and older in Goulburn Mulwaree LGA, with the population in Queanbeyan Palerang LGA having a lower rate of unemployment and considered less socioeconomically disadvantaged. These data support that the population surrounding the Project would not be considered vulnerable to Project related impacts.

Overall, the demographics data do not indicate any aspects that suggest the population would have any increased vulnerability to Project related impacts in the communities surrounding the Project site.

2.4 Existing community health

The health of the community is influenced by a complex range of interactive factors including age, socio-economic status, social capital, behaviours, beliefs and lifestyle, life experiences, country of origin, genetic predisposition and access to health and social care. The health indicators available and reviewed in this report (**Table 2.3**) generally reflect a wide range of these factors.

The population in the area surrounding the Project site is relatively small and health data specifically relating to this population are not available. However, it is assumed that the health of the local community is consistent with that reported in the Southern NSW Area Local Health District (LHD) (that incorporates the LGAs and suburbs evaluated in this assessment).

Table 2.3 presents a summary of the general population health considered relevant to the area. The table presents available information on health-related behaviours (i.e. key factors related to lifestyle and behaviours known to be of importance to health) and indicators for the burden of disease within the community compared to NSW.

Table 2.3: Summary of health indicators/data

Health indicator/data[1]	Southern NSW LHD	NSW
Health behaviours (95% confidence interval)		
Adults - compliance with fruit consumption guidelines (2020)	39.7% (30.7% - 48.7%)	40.3% (38.6% – 42%)
Adults - compliance with vegetable consumption guidelines (2020)	3.0% (0.3% - 5.7%)	5.9% (5.2% – 6.7%)
Children - compliance with fruit consumption guidelines (2019-2020)	65.2% (52.1% - 78.3%)	64.2% (61.7% - 66.7%)
Children - compliance with vegetable consumption guidelines (2019-2020)	2.0% (0.0% - 4.9%)	5.2% (4.1% - 6.3%)
Adults - increased lifetime risk of alcohol related harm (2020)	40.2% (30.3% - 50.0%)	32.5% (30.8% - 34.2%)
Adults - body weight (overweight) (2020)	34.6% (25.8% - 43.4%)	34.3% (32.7% - 35.9%)
Adults - body weight (obese) (2020)	26.2% (18.7% - 33.7%)	22.5% (21.1% - 24.0%)
Adults – sufficient physical activity (2020)	64.3% (55.2% - 73.4%)	61.7% (60.0% - 63.4%)
Children – adequate physical activity (2019-2020)	28.6% (13.5% - 43.6%)	18.1% (15.7% - 20.4%)
Current smoker, adult (2020)	21.2% (12.2% - 30.2%	13.3% (12.1% - 14.5%)
Burden of disease (95% confidence interval) as rate per 100,000 unless indicated otherwise		
Morbidity - cardiovascular disease hospitalisations (all ages, 2019-2020)	1480.5 (1435.7 – 1526.4)	1583.8 (1475.9 – 1591.8)
Morbidity – respiratory disease hospitalisations (all ages, 2018-2019)	1654.4 (1601.3 – 1708.7)	1675.2 (1666.4 – 1684.0)
Mortality – all causes, all ages (2019)	556.1 (529.8 – 583.6)	513.8 (509.5 – 518.2)
Mortality – all causes (2017-2018)	Goulburn Mulwaree LGA = 590.1 (540.9 – 642.7) Queanbeyan-Palerang LGA = 497.6 (456.7 – 541.1)	520.9 (517.7 – 524.0)
Mortality – respiratory (all ages) (2016-2018)	57.3 (52.5 – 62.3)	49.6 (48.5 – 50.1)
Adults – prevalence of high blood pressure (2018)	33.3% (27.0% - 39.1%)	24.8% (23.7% - 25.9%)
Adult asthma – prevalence (2019)	21.1% (13.5% - 28.6%)	11.5% (10.5% – 12.5%)
Children (2 to15 years) – prevalence of current asthma (2017 – 2019)	13.2% (7.9% - 18.5%)	13.1% (11.8% - 14.4%)

* Rate per 100,000 population.

1 Data from NSW Health Statistics: http://www.healthstats.nsw.gov.au/ and https://beta.healthstats.nsw.gov.au/#/topics

Shading relates to comparison against NSW:

- statistic/data suggestive of a potential higher vulnerability within the population to health stressors.
- statistic/data suggestive of a potential lower vulnerability within the population to health stressors.

The key indicators of health for the population in areas surrounding the site indicate the following, when compared with the data for NSW:

- The population in Southern NSW LHD has a lower proportion of the population (adults and children) who consume the recommended intake of vegetables, the adults have a higher long-term consumption of alcohol, higher rate of smoking and a higher proportion of the population that is overweight. Both adults and children have higher rates of adequate physical exercise.

- The population for the LGA of Goulburn Mulwaree has a higher rate of mortality (all causes)[1]. The population in the Southern NSW LHD has a higher rate of mortality from respiratory disease, and higher rates of high blood pressure and asthma in adults. It is noted that, while the rate of asthma in adults is significantly higher than NSW, the rate of asthma in children is not different to NSW overall.

The above indicates that, based on existing health related behaviours and health statistics, the surrounding community may have some increased vulnerability to Project related impacts. It is noted that the statistics presented above relate to a large population. No data are available for the smaller population in the areas immediately surrounding the Project site.

[1] Rate of mortality is the number of deaths during the period of time indicated (in this case 2017-2018 and 2019) scaled to a defined population size (i.e. per 100,000 people) for specific causes (in this case all causes).

Section 3. Modelled air emissions from Project

3.1 Outline of emission sources relevant to Project

The key component of the project is the ARC building, an ERF for the thermal treatment of residual MSW and C&I waste feedstock, that will otherwise be disposed to landfill.

The Eco Precinct is served by the Crisps Creek Intermodal Facility (Crisps Creek IMF) near the village of Tarago. The Crisps Creek IMF is located approximately 8.5 km to the east of the Eco Precinct (by road). Operations are augmented by two waste transfer terminals located in Sydney; the Clyde Transfer Terminal, which commenced operation in 2004 with the Bioreactor and Crisps Creek IMF, and the Banksmeadow Transfer Terminal, which commenced operating in 2016.

Waste is transported from the Sydney transfer terminals in purpose-built shipping containers by rail on the Goulburn-Bombala Railway line to the Crisps Creek IMF. At the Crisps Creek IMF, the containers are loaded on to trucks for delivery to the Eco Precinct. Regional waste is also approved to be transported to the Eco Precinct by road. **Figure 3.1** outlines the existing and proposed waste volumes for the Eco Precinct. The Project does not involve any change to the existing approved waste transport modes or volumes. Hence this assessment has not further considered the transport of waste to the Eco Precinct.

The proposed ARC utilises proven, reliable and robust moving grate technology, with a dedicated flue gas treatment (FGT) system, which is the most commonly used in ERF technology worldwide. The ERF will be housed within a fully enclosed building. Waste would be received at the tipping hall which would be maintained under negative pressure with fast closing doors to minimise the potential for the release of odours to the environment.

The energy recovery process consists of the following stages:

- Stage 1: fuel reception and storage
- Stage 2: combustion and boiler
- Stage 3: energy recovery and electricity generation
- Stage 4: flue gas treatment
- Stage 5: residue handling and treatment.

A schematic process diagram of the ERF, depicting the key stages in the process listed above is provided in **Figure 3.2**.

The energy recovery process generally involves the waste feedstock released onto a grate, which moves through a drying and combustion process within a furnace (or combustion chamber). This occurs within a controlled air-flow environment, at temperatures of more than 850°C, with a residence time of at least two seconds. This high intensity combustion generates heat, which is used to produce steam in a purpose-built boiler. The steam drives a turbine to generate electricity for export to the power grid.

Emissions to air during construction are to be managed through the implementation of management measures (as detailed in the AQIA, EMM 2022). Hence these emissions have not been quantified or further assessed in the AQIA, or this assessment.

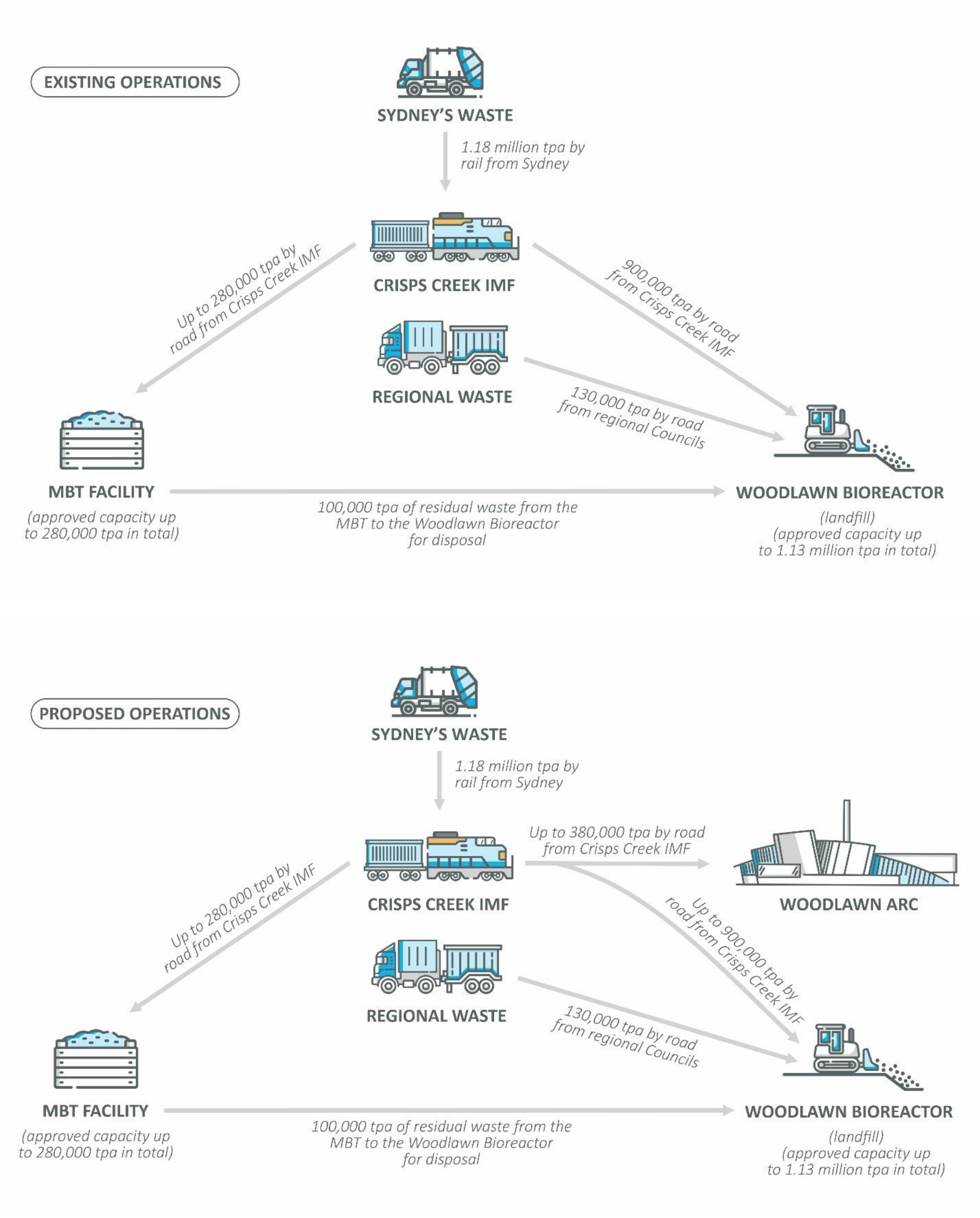
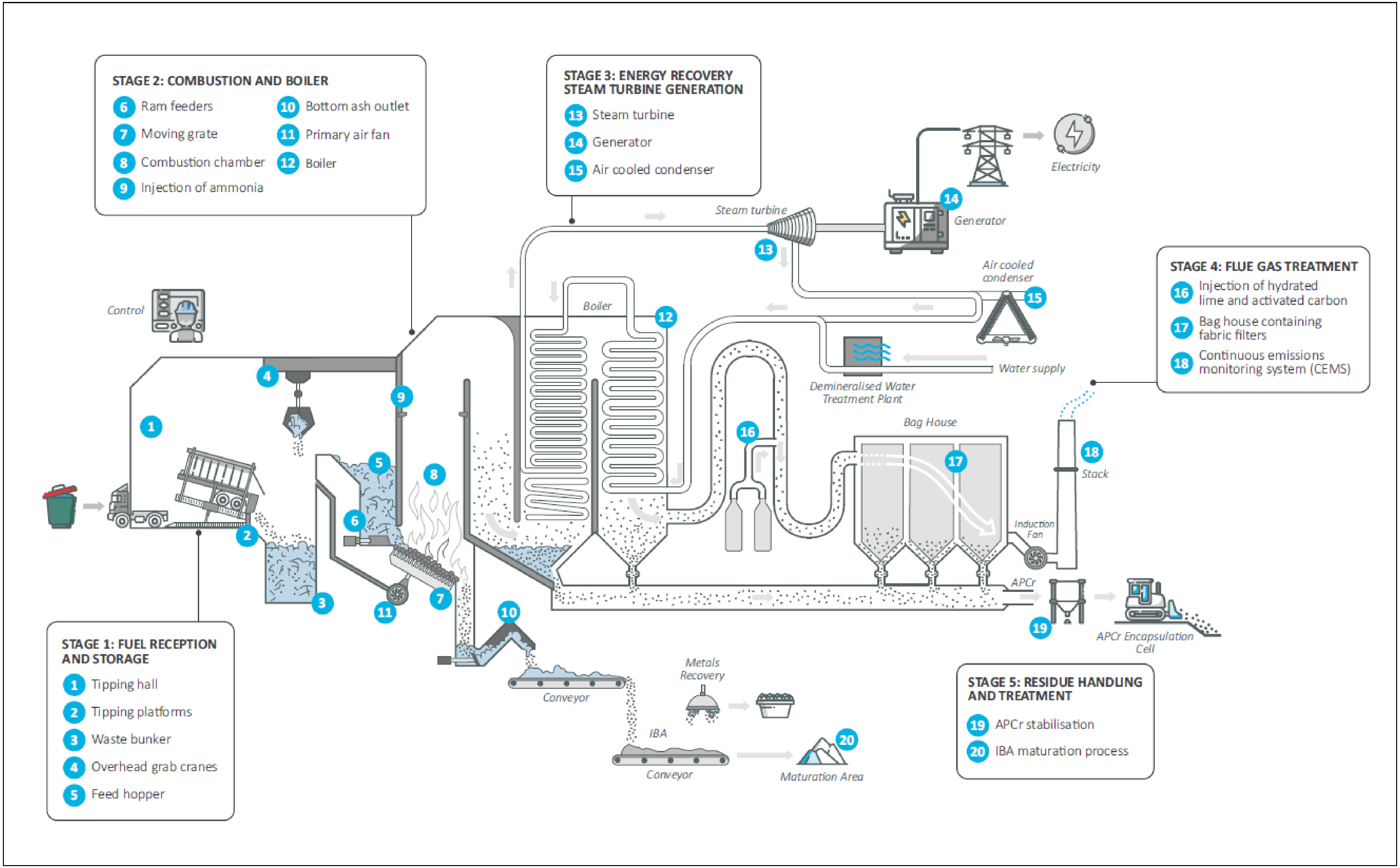


Figure 3.1: Existing (approved) and proposed waste volumes at the Eco Precinct



EMM creating opportunities

Schematic of the ARC process

Woodlawn Advanced Energy Recovery Centre
Environmental impact statement

Figure 3.2

The focus of the AQIA, and hence this assessment, relates to emissions to air from the Project when operational. When operational the following emission sources have been considered:

- Project:
  - ARC building stack emissions – release point of residual air pollutant emissions from the FGT system, where three emissions scenarios have been evaluated (refer to **Section 3.3** for further discussion on these scenarios and the scenarios further evaluated in this assessment)
  - truck movements – including the diversion of up to 380,000 tpa of incoming waste deliveries to the ARC tipping hall and away from the Bioreactor, the transportation of stabilised APCr from the ARC building to the APCr encapsulation cell, and the transfer of IBAA to the bioreactor or potentially off-site for future reuse
  - fugitive dust emissions from the handling and storage of material at the IBA area and APCr encapsulation cell
  - diesel fuel combustion by mobile plant and equipment and the auxiliary diesel burners and generator.
- Other emission sources (existing and approved) at or adjacent to the Eco Precinct:
  - fugitive dust emissions from approved Eco Precinct operations, based on approved waste throughput for the Bioreactor (1.13 Mtpa) and MBT (0.28 Mtpa)
  - fuel combustion emissions from the approved expanded Bioenergy power station and flare, based on the operation of up to 10 landfill gas engines (seven existing engines at Hub 1 and three additional future engines at Hub 2) accounting for increased landfill gas capture at the time of ARC operation in 2025
  - fugitive dust emissions from the Woodlawn Mine, based on approved underground ore production (0.35 Mtpa) and tailings recovery (1.15 Mtpa).

3.2 General concepts relevant to air modelling

To be able to determine the concentration of pollutants that may be in the air, off-site within the community, from a proposed project (i.e. one that has not yet been built), an air dispersion model has to be used. The model uses a range of information such as:

- the concentration (or emission rate) of pollutant in the stack before discharge
- information about the stack itself such as height and width at the top, the discharge velocity and temperature as well as the presence of any tall buildings close to the stack
- information about the meteorological conditions
- information about the terrain in the surrounding areas.

All this information is used to estimate how the pollutants are mixed and transported in the air and the concentration that may be present at ground level at different locations.

Figures 3.3 and 3.4 illustrate the processes which govern how the emissions get mixed into the atmosphere.

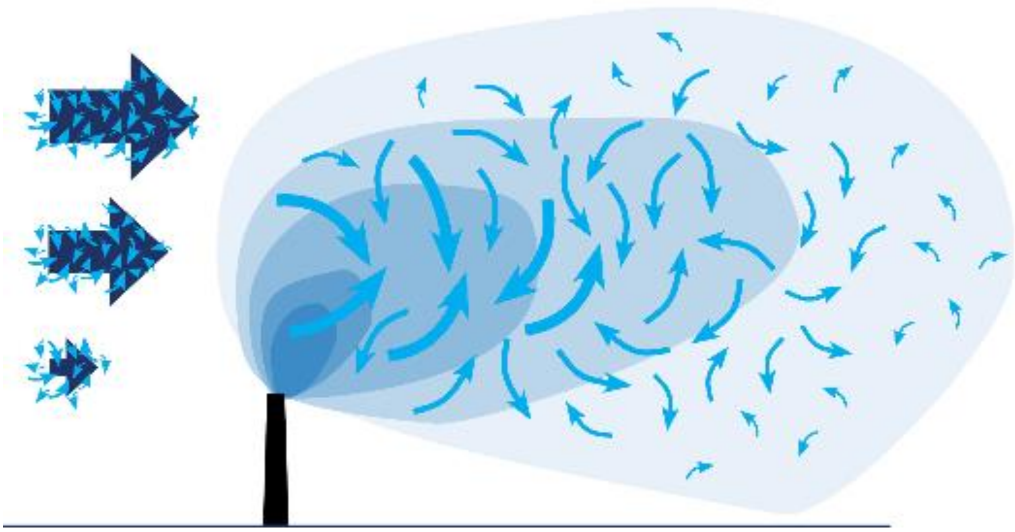


Figure 3.3: Turbulence in the air, how it mixes and dilutes pollutants emitted from a stack (NSW Chief Scientist 2018)

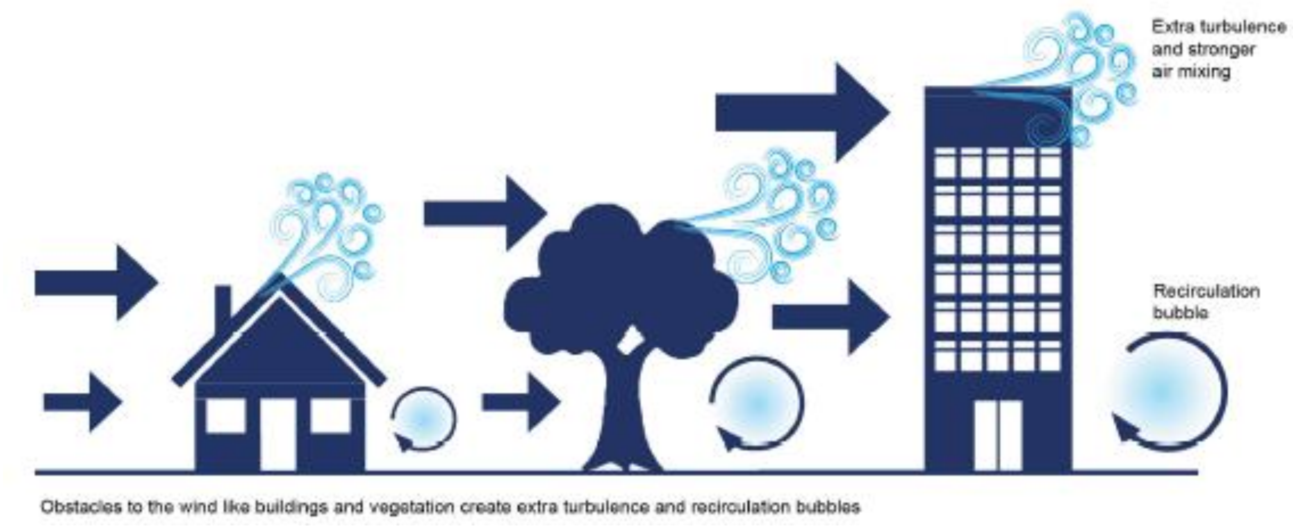


Figure 3.4: Turbulence in the air and how it is affected by buildings and vegetation (NSW Chief Scientist 2018)

Gases (and any fine particles such as PM_{10} and $PM_{2.5}$ that remain after flue gas treatment) are emitted at around 140°C and are pushed out of the stack using fans (i.e. at some speed) so these gases (and fine particles) rise or are pushed up significant distances above the top of the stack – because hot gases rise and because these gases are travelling at a faster speed than the air surrounding the stack. This can be seen in the figures above.

As the gases (and fine particles) cool and slow down they begin to interact with the wind above the stack (i.e. well above the 85 m stack height). This mixes the gases (and fine particles) into the atmosphere decreasing the actual concentration present in any one particular place.

Figure 3.3 shows that most of the pollutants remain up in the atmosphere away from where people would be exposed. However, small amounts do eventually reach ground level. The air dispersion modelling determines what proportion of the amount in the stack could reach ground level at different locations. Such modelling looks at worst case weather characteristics (that can actually occur – based on real meteorological data) to ensure that the amount that could reach ground level in areas where people live or work neighbouring the proposed facility are not underestimated. It is these ground level concentrations that are then used to assess potential for health impacts.

Data from the modelling can also be used to estimate the rate at which particles in the emissions could fall out of the atmosphere (due to gravity) or get washed out of the atmosphere (due to rain). It is this deposition rate that is then used to estimate how much of chemicals attached to particles could get into soil or water around the facility.

3.3 Overview of Project air modelling

To predict the concentration of emissions from the ARC, a study area was defined and shown in **Section 2.2** and predicted emissions from the ARC stack, along with all other emission sources relevant to the ARC and the Eco Precinct were modelled by EMM (2022) using the CALPUFF air dispersion model.

The CALPUFF air dispersion model is a regulatory air pollution model that was selected based on the need to evaluate complex terrain and heterogeneous land use (relevant to the area evaluated). This model uses air emission estimates for the ARC, plant design (for example, stack height and building sizes), local terrain and meteorological data to predict the ground level concentrations of emissions within the defined study area. Meteorological data from the monitoring station operated by Veolia located at the Eco Precinct, with additional data from the Bureau of Meteorology stations at Goulburn Airport and Canberra Airport were used in the modelling.

The modelling considered emissions to air from the ARC, as well as other emission sources that are existing or approved and located at or adjacent to the Eco Precinct (as listed in **Section 3.1**).

Background air quality is influenced by existing sources at or adjacent to the Eco Precinct (which have been directly evaluated) as well as:

- dust entrainment due to vehicle movements along unsealed roads and sealed roads with high silt loadings
- dust emissions from agricultural activities, in particular, livestock operations
- fuel combustion-related emissions from on-road and non-road engines
- wind generated dust from exposed areas within the surrounding region
- seasonal emissions from household wood burning for heating during winter
- hazard reduction activities and bushfires.

It is important to note that there are always a range of chemicals present in the air we breathe. The issue that is important for a newly proposed facility is whether the facility will change these levels significantly.

Limited background air data are available for the Eco Precinct and the neighbouring Woodlawn Mine. Hence these data have been supplemented by data from air quality monitoring stations at Goulburn, Bargo and ACT monitoring stations at Florey, Civic and Monash. These data have been used in the AQIA to establish background concentrations for a number of key air pollutants (namely particulates, NO_2, CO and SO_2).

For this project, the air modelling from the ARC was undertaken based on data from a reference facility as well as well as a worst-case where emissions to air always occurred at the maximum allowable under the NSW EfW Policy (NSW EPA 2021).

The reference facility evaluated is Veolia's United Kingdom (UK) facility in Staffordshire which utilises similar feedstock (with very similar breakdown of key aspects of residual MSW and C&I waste), moving grate technology and FGT and SNCR emissions control technology. Data for the year 2017 was adopted as most representative of typical operating conditions with data provided on pollutant concentrations in stack emissions as well as stack emission parameters such as flow rate, temperature, moisture content, oxygen content and barometric pressure. Both the concentration in the stack, as well as how the gas exits the stack are important for modelling emissions to air from any facility.

The modelling of air emissions evaluated three emissions scenarios, described as follows (refer to EMM 2022 for additional detail):

- **Scenario 1 – reference case emissions – expected emissions**:
    - Scenario 1 assumes the combination of average stack emission parameters and the average measured emission concentrations from the 2017 Staffordshire ERF emissions data.

  The results obtained for Scenario 1 should be viewed as the most relevant of potential air quality impacts for the actual operation of the Project, and hence are referred to as expected emissions.

- **Scenario 2 – reference case emissions – maximum emissions**:
    - Scenario 2 assumes the combination of maximum stack emission parameters and the maximum (100^{th} percentile) measured emission (stack) concentrations from the 2017 Staffordshire ERF emissions data
    - to account for interannual variability in maximum concentrations (i.e. the variability in emissions observed between each year from 2016 to 2020), the emission rates for Scenario 2 have been upscaled (i.e. increased by a factor) by pollutant-specific scaling factors to ensure the emission concentrations reflect the maximum reported at any time throughout the whole monitoring period (2016 to 2020)

  The results obtained for Scenario 2 represents a highly conservative upper bound estimation of potential air quality impacts from the Project. This scenario is sufficiently conservative to also address periods of plant shutdown and start-up (as these conditions were covered in the data from 2016-2020).

- **Scenario 3 – NSW EfW Policy regulatory case emissions**:
    - Scenario 3 assumes the combination of maximum stack emission parameters and the NSW EfW Policy emission concentration standards.

    The results obtained for Scenario 3 represents the highest potential impacts from the project if operating at the maximum allowable emission rates, at all times, under the NSW EfW Policy and is therefore another highly conservative scenario.

For the assessment of potential impacts to community health, the two worst-case emissions scenarios have been further evaluated in this assessment. These are as follows:

- **Scenario 2: Reference case emissions – maximum emissions**
- **Scenario 3: NSW EfW Policy regulatory case emissions.**

Full details on the air model are presented in the AQIA (EMM 2022). This model is used to provide predicted air concentrations over the study area and at all the individual receptor locations (as detailed in **Section 2.2** and **Figure 2.2**), with the results averaged over different time periods.

Section 4. Detailed assessment of potential health impacts from air emissions

4.1 General

This section presents a detailed assessment of potential risks to human health as a result of emissions to air from the Project. The assessment of risk has relied on air modelling presented in the AQIA (EMM 2022) and follows the principles outlined in the enHealth document Environmental Health Risk Assessment: Guidelines for Assessing Human Health Risks from Environmental Hazards (enHealth 2012b). This approach requires assessment of:

- how people may be exposed to the emissions to air over short-term (acute) and long-term (chronic) (i.e. exposure assessment)
- the hazards posed by (or toxicity of) the chemicals present in the emissions (i.e. hazard or toxicity assessment)
- calculation of potential risks to health or risk characterisation.

Figure 4.1 presents an overview of the assessment approach detailed in the following sections.

4.2 Exposure assessment – conceptual site model

Understanding how a community member may come into contact with pollutants released in air emissions from the proposed energy recovery facility is a vital step in assessing potential health risk from these emissions. A conceptual site model provides a holistic view of these exposures, outlining the ways a community may come in contact with these pollutants.

There are three main ways a community member may be exposed to a chemical substance emitted from the plant:

- inhalation of gases, vapour or fine particulate matter in air
- direct contact, which may include ingestion and/or dermal absorption of chemicals present in dust that may deposit onto surfaces or accumulate in water collected in rainwater tanks or water in recreational areas
- ingestion of persistent and bioaccumulative chemicals that may be deposited to soil and then taken up into homegrown produce that may be consumed.

For some of the emissions from the Project, inhalation is considered the only route of exposure. This is due to the substance's chemical properties, which make the other pathways inconsequential. This includes gases such as nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), hydrogen chloride (HCl), ammonia (NH_3), hydrogen fluoride (HF) and VOCs (assessed as benzene) as well as fine particulate matter as particulates less than 2.5 micrometres ($PM_{2.5}$) that are so small they remain suspended in air (i.e. inhalation only exposure pathway).

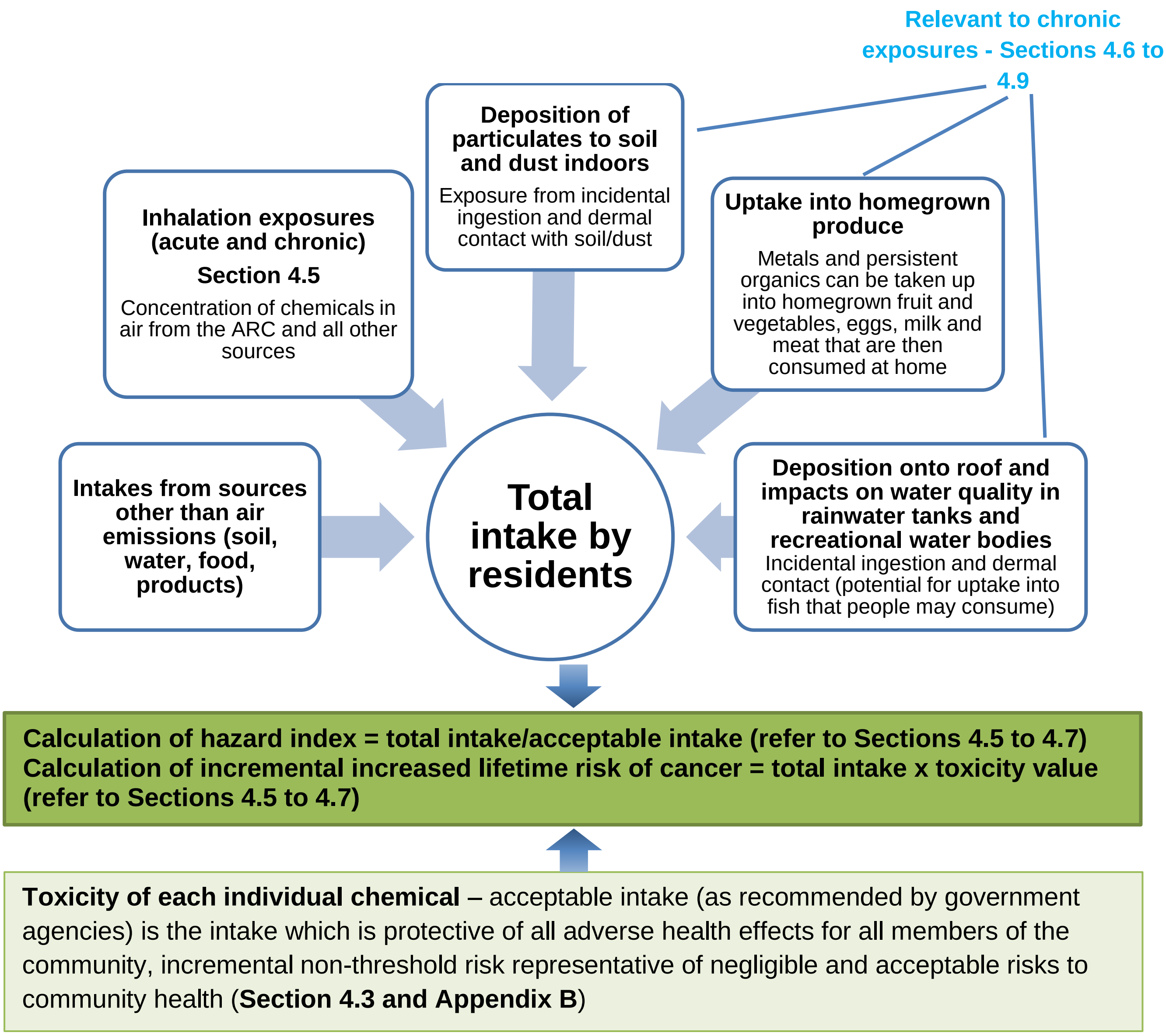


Figure 4.1: Overview of health risk assessment

Other chemicals in the emissions may be inhaled, but they may also be deposited on the ground/surfaces with the deposition of dust. These emissions can then be ingested either directly through accidental/incidental consumption of soil or indirectly through food/produce grown or raised in the soil (fruit, vegetables, eggs, meat or milk), or in drinking water where dust is deposited onto a roof where it may be washed into and affect water quality in rainwater tanks. Dust may also deposit to larger water bodies used for recreational purposes. Skin contact with the soil and water in rainwater tanks and recreational water is also possible. For some recreational locations, uptake into fish that people may eat could be possible. Therefore, it is important with these emissions that all exposure pathways are considered. In this instance, metals, PAHs, dioxins/furans and dioxin-like PCBs that are bound to the heavier particulate matter that may fall out and deposit onto the ground could be considered for these exposure pathways.

Table 4.1 lists the pollutants or chemicals evaluated in the emissions to air from the Project (from all emission sources evaluated) and the exposure pathway/s of potential concern. **Figure 4.2** provides a diagrammatical representation of the community exposures to emissions from the Project (conceptual site model).

Table 4.1: Substances and routes of exposure

<table>
<tr><th>Substance</th><th>Route of exposure</th></tr>
<tr><td>Nitrogen dioxide</td><td rowspan="7">Inhalation only as these are gases.</td></tr>
<tr><td>Sulfur dioxide</td></tr>
<tr><td>Hydrogen chloride</td></tr>
<tr><td>Hydrogen fluoride[1]</td></tr>
<tr><td>Carbon monoxide</td></tr>
<tr><td>Ammonia</td></tr>
<tr><td>Volatile organic compounds (VOCs) as benzene</td></tr>
<tr><td>PM_{10}</td><td rowspan="2">Inhalation relevant for particulates based on particle size as these particulates are very small and will remain suspended in air. It is noted that other exposure pathways have also been assessed for the individual chemical substances bound to these particles that may be deposited to the ground. These other pathways relate to the individual chemical substances, rather than the physical size of the particulates, however, they do relate to the more coarse fractions of dust in PM_{10} (rather than $PM_{2.5}$) as some PM_{10} will deposit to the ground.</td></tr>
<tr><td>$PM_{2.5}$</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Antimony</td><td rowspan="18">Inhalation of these pollutants adhered to fine particulates.
Ingestion and dermal contact with these pollutants deposited to soil, deposited to a roof where they wash into and impact on water quality in rainwater tanks, or deposited to recreational areas such as Lake George and Lake Bathurst. It is recognised that the surrounding rural and residential areas include rainwater tanks that are used for drinking water/potable water.
Ingestion of produce grown in soil potentially impacted by these pollutants. For this assessment, the surrounding rural residential areas may include homegrown fruit and vegetables, eggs, home consumed beef and lamb as well as crops such as oats, barley and canola as well as truffles and grapes. Metals, dioxins/furans, dioxin-like PCBs and PAHs can be taken up/bioaccumulated into plants and animal products that may be consumed.</td></tr>
<tr><td>Arsenic</td></tr>
<tr><td>Beryllium</td></tr>
<tr><td>Cadmium</td></tr>
<tr><td>Chromium</td></tr>
<tr><td>Copper</td></tr>
<tr><td>Cobalt</td></tr>
<tr><td>Lead</td></tr>
<tr><td>Manganese</td></tr>
<tr><td>Mercury</td></tr>
<tr><td>Nickel</td></tr>
<tr><td>Thallium</td></tr>
<tr><td>Vanadium</td></tr>
<tr><td>Zinc</td></tr>
<tr><td>Dioxins / furans</td></tr>
<tr><td>Dioxin-like polychlorinated biphenyls (PCBs)</td></tr>
<tr><td>Polycyclic aromatic hydrocarbons (PAHs)</td></tr>
</table>

For some of the pollutants evaluated, a conservative approach has been adopted for an individual pollutant or group of chemicals where the composition is less well known. The following conservative assumptions have been adopted in this assessment:

- Dioxins and furans have been assessed assuming the group is characterised by the toxicity of the most potent compound, 2,3,7,8-TCDD, assuming that the emissions limits relate to a WHO toxicity equivalent concentration (as WHO-TEQ from WHO in 2005).
- Dioxin-like PCBs have been assessed assuming that the emissions limits relate to a WHO toxicity equivalent concentration (as WHO-TEQ from WHO in 2005).
- PAHs have been assessed on the basis that 100% of the total PAH concentration comprises the more toxic compound benzo(a)pyrene (BaP). This is conservative as PAHs comprise hundreds of individual chemicals, of which only some are similar to BaP in terms of toxicity and carcinogenicity. This subgroup PAHs is typically evaluated based on toxicity equivalents (i.e. not all are as toxic as BaP). Assuming 100% of the PAHs comprises BaP provides a very conservative approach to assessing potential health risks associated with this group of chemicals.
- Chromium exposures have been assessed assuming all chromium present is present as chromium VI, the most toxic form of chromium.
- Inorganic mercury exposures have been assessed assuming that it is present in air as elemental mercury (the more toxic form), and when deposited to the ground forms inorganic mercury.
- The more general chemical group of volatile organic compounds (VOCs) includes a large number of individual volatile chemicals with varying toxicities. For this group, it has been conservatively assumed that this group is represented by benzene, one of the more toxic (and likely) components of VOCs expected to be present.

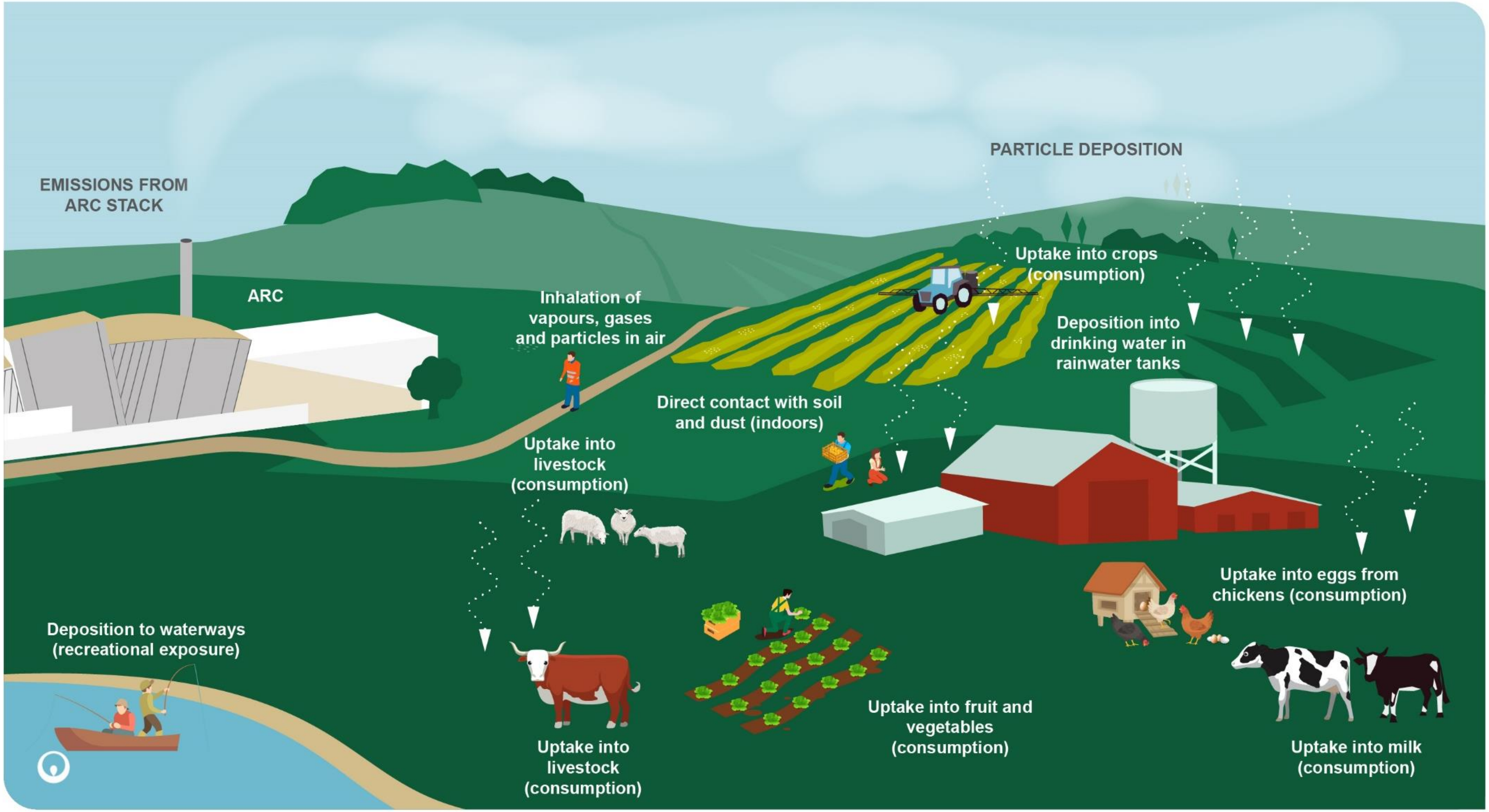


Figure 4.2: Conceptual site model (illustrative only, not to scale)

4.3 Hazard assessment

This assessment has addressed potential exposures to chemicals present in emissions to air via the stack from the ARC. The chemicals evaluated, as listed in **Table 4.1**, include gases and particulates as well as metals and organics that are bound to the particulates. This assessment has addressed acute inhalation exposures, along with chronic inhalation and multi-pathway exposures. To quantify the potential for the chemicals of concern in relation to health risks, the hazards associated with these chemicals have been quantified for acute and chronic inhalation, and chronic oral and dermal exposures, using current and robust toxicity reference values (TRVs).

Appendix B presents further discussion and detail relating to the TRVs adopted for the quantification of hazards for the chemicals evaluated in this assessment. Some additional discussion on hazards and the TRVs or health-based guidelines adopted is also presented in **Section 4.5**, with information specific to assessing particulate size, nitrogen dioxide, sulfur dioxide and carbon monoxide presented in relevant subsections.

4.4 Use of air modelling data in HHRA

This assessment has evaluated exposures and risks relevant to the ARC for the two worst-case emissions scenarios:

- Scenario 2: Reference case emissions – maximum emissions
- Scenario 3: NSW EfW Policy regulatory case emissions.

These scenarios provide a conservative assessment of upper bound emissions from the ARC, noting that the reference case scenario includes periods of time where plant shutdown and start-up may occur.

Both these scenarios have also included emissions to air from existing or approved sources on or adjacent to the ARC. These are referred to as the other emission sources.

Ground level concentrations for gases and particulate bound metals and organics (as $PM_{2.5}$), and deposition rates for particle bound metals and organics (bound to total suspended particles (TSP)) have been predicted from the air quality modelling based on meteorological data for 2018 (a suitably representative year) and provided for use in this assessment.

The focus of this assessment relates to the evaluation of health impacts that may occur as a result of acute or chronic exposures to emissions from the facility. This requires the use of 1-hour average (for the assessment of acute exposures to most pollutants except particulates), 24-hour average data (for short-term exposures to particulates) and annual average (for the assessment of chronic exposures) data. All data required for use in this assessment have been provided by EMM (2022) and are from the same model as presented in the AQIA. There have been no adjustments or post processing of the air modelling outputs for use in this assessment.

The modelling undertaken has provided the following for use in this assessment:

- estimated ground level concentrations for gases and vapours as well as chemicals bound to particulates, assuming the particulates are present as $PM_{2.5}$ (which is of most relevance to the assessment of health effects)

- estimated deposition rates for chemicals bound to particulates, based on the deposition of total suspended particulates (TSP) which include the larger sized particulates and PM_{10} and $PM_{2.5}$.

The modelling provides data relevant to emissions from the ARC alone, as well as the ARC plus other emission sources. The HHRA has evaluated cumulative emissions from the ARC plus other sources relevant to the area. Where relevant, background air concentrations have also been included.

Risk calculations have been presented for the following locations within the community:

- **Maximum impacted location** which includes all modelled locations on the boundary and off-site of the Project area (namely the Veolia integrated waste management operations), regardless of location and use – this is a location on or close to the Project boundary, where inhalation exposures by workers and visitors may occur on occasion. Inhalation exposures have been assumed to occur for 8 hours per day, 5 days per week for 30 years at this location to provide a conservative maximum.
- **Maximum impacted commercial/industrial receptor –** this is the maximum impacted receptor that on land located off the Project area and zoned as commercial/industrial. Exposures are inhalation exposures only and are assumed to occur 8 hours per day, 5 days per week for 30 years.
- **Maximum impacted sensitive receptor** – this is the maximum impacted receptor from the individual sensitive (including schools) or rural residential receptors shown on **Figure 2.2**, as well as the grid receptors relevant to Tarago village. Exposures (inhalation and multi-pathway) are assumed to occur for 24 hours per day, 7 days per week for 70 years at this location.

In addition to the above receptor locations, potential exposures by workers at height maintaining wind-turbines at the adjacent windfarm have been evaluated separately. These exposures relate to inhalation exposures only, which are expected to be infrequent and of short duration (i.e. number of hours). For these workers the maximum predicted impact over a 1-hour average has been assumed to occur at the same time a worker may be present.

4.5 Inhalation exposures

4.5.1 General

For all the pollutants released to air from the proposed facility, whether present as a gas or as particulates, there is the potential for the community to be exposed via inhalation. Assessment of potential health impacts relevant to inhalation exposures for these pollutants is discussed further below.

4.5.2 Particulates (size)

The assessment of potential health impacts associated with exposure to particulate matter, based on the size of the particulate matter, rather than composition, has been undertaken and presented within the AQIA (EMM 2022). This assessment has focused on fine particulates, namely $PM_{2.5}$, which are small enough to reach deep into the lungs and have been linked with, and shown to be causal, for a wide range of health effects (USEPA 2012; WHO 2013a). These health effects were considered in the derivation of the NEPM air guideline for $PM_{2.5}$ (NEPC 2016, 2021). The NSW Government is a signatory to the NEPM, with the $PM_{2.5}$ NEPM standards adopted as impact assessment criteria for NSW (NSW EPA 2017).

The air criteria relate to total exposures to $PM_{2.5}$, that is background or existing levels (which includes existing sources) as well as the additional impact from the proposed facility. Background levels of $PM_{2.5}$ relevant to the local area have been included in the modelling (as time varying concentrations).

Table 4.2 provides a summary of the contribution of the project to the total $PM_{2.5}$ concentrations for both Scenario 2 and Scenario 3, and the air criteria. The table also include impacts form existing sources, for comparison with impacts predicted from the ARC plus existing sources. This table shows that cumulative impacts, from the ARC plus existing sources (Eco Precinct and mine) are slightly lower than the existing impacts. This is due to Project-related reductions in unpaved haul road truck movements. The contribution to total PM2.5 concentrations from the operation of the ARC alone is very small and would not be expected to result in any significant change in existing $PM_{2.5}$ concentrations in the community.

It is noted that background concentrations of $PM_{2.5}$ (which include impacts from existing sources as well as other regional sources) are already elevated above the NEPM guideline. Elevated background levels of $PM_{2.5}$ are dominated by emissions from other regional sources that include domestic wood burning, occasional controlled burns and bushfires. The review conducted by EMM (2022) identified that emissions from the facility are unlikely to change the number of exceedances of the NEPM guideline.

Table 4.2: $PM_{2.5}$ impacts from the ARC Project – maximum impacts

Parameter	Scenario 2 - Reference case maximum emissions		Scenario 3 – NSW EfW regulatory emissions	
	$PM_{2.5}$ – as 24-hour average (µg/m^3)	$PM_{2.5}$ – as annual average (µg/m^3)	$PM_{2.5}$ – as 24-hour average (µg/m^3)	$PM_{2.5}$ – as annual average (µg/m^3)
Air guideline – NEPM	25	8	25	8
Air guideline – NEPM goals for 2025	20	7	20	7
Existing sources (Eco Precinct and mine)				
Maximum off-site (maximum for grid that relates to Project boundary and off-site)	33	3.7	33	3.7
Commercial/industrial areas - maximum	14	2.1	14	2.1
Residential, rural, school, preschool, church and community receptors - maximum	0.92	0.083	0.92	0.083
Cumulative impacts from ARC (max) + existing sources (Eco Precinct and mine)				
Maximum off-site (maximum for grid that relates to Project boundary and off-site)	27	3.3	28	3.3
Commercial/industrial areas - maximum	13	2.0	13	2.1
Residential, rural, school, preschool, church and community receptors - maximum	0.76	0.076	0.79	0.12
ARC + existing sources + background				
Maximum off-site sensitive receptor	23.1	7.1	23.2	7.2

In addition to the analysis presented above, it is possible to also estimate the incremental individual risk associated with the change in $PM_{2.5}$ from the facility. This calculation has been undertaken on the basis of the most significant health indicator, namely mortality, for which changes in $PM_{2.5}$ have been identified to have a causal relationship. The health indicator also captures a wide range of other health effects associated with $PM_{2.5}$. The calculation has considered the baseline mortality rate Goulburn Mulwaree LGA (all ages and all causes – refer to **Table 2.3**), along with the exposure-response relationship relevant to assessing all-cause mortality. Further details and calculations are presented in **Appendix A**. These calculations assume that someone is present at the location of maximum increase in $PM_{2.5}$ from the ARC for 24 hours a day, every day of the year.

The worst-case/maximum incremental risks are calculated as follows:

- Scenario 2 - reference case maximum emissions: For an annual average increase of $PM_{2.5}$ of 0.002 µg/m^3, the maximum incremental increase in $PM_{2.5}$ from the ARC in the off-site community (residential, rural, school, preschool, church and other community receptors) results in an incremental risk of 7 x 10^{-8}. This risk level is considered to be negligible, as per guidance from enHealth and NEPC (enHealth 2012b; NEPC 2011).
- Scenario 3 – NSW EfW regulatory emissions: For an annual average increase of $PM_{2.5}$ of 0.04 µg/m^3, the maximum incremental increase in $PM_{2.5}$ from the ARC from all receptors in the surrounding community results in an incremental risk of 1 x 10^{-6}. This risk level is considered to be negligible, as per guidance from enHealth and NEPC (enHealth 2012b; NEPC 2011).

On the basis of the above, changes in $PM_{2.5}$ derived from the ARC are considered to have a negligible impact on the health of the off-site community.

4.5.3 Sulfur dioxide

Sulfur oxides are formed during combustion when chemicals present in fuels (such as coal, gas, petrol etc) containing sulfur react with oxygen to form sulfur oxides. Burning of coal in power stations in Europe resulted in acid rain affecting forests. The acid rain was primarily a result of the formation of sulfur oxides as the coal was burnt. Sulfur oxides are also released from volcanos. Wildfires and other types of fires are also sources to the atmosphere of these chemicals (USEPA 2018).

Sulfur dioxide (SO_2) is the main sulfur oxide that can have impacts on people. Exposure to elevated levels can result in irritation of the respiratory system and can make breathing difficult. The most affected by exposure to these chemicals are people with asthma (USEPA 2018).

Guidelines are available from NSW EPA (NSW EPA 2017) and NEPC (NEPC 2016) which indicate concentrations of SO_2 considered to be acceptable by national health authorities. These are the guidelines adopted by EMM (2022).

In May 2021, the national guidelines for SO_2 in the air quality NEPM were changed (NEPC 2021).

The review conducted to support the 2021 NEPM (NEPC 2019) considered the large amount of research published since the previous review and evaluation (NEPC 2010). The findings of recent studies have strengthened the evidence that the main health effects associated with exposure to sulfur dioxide are short-term effects on the respiratory system, with children, people over 65 years of age and people with existing health conditions (respiratory, cardiovascular and asthma) the most susceptible groups of the effects of sulfur dioxide. Asthma remains the most sensitive health effect. Evidence for long-term health effects is weak, noting the available data is limited. Hence the NEPM has focused on establishing health protective guidelines of short-term exposures based on a 1-hour average and 24-hour average (with long-term health based guidelines removed). The NEPM review also benchmarked the air guidelines in Australia against international guidelines, where it was clear lower guidelines for sulfur dioxide have been adopted in most other international jurisdictions.

As a result of the more recent review, the air quality guidelines for sulfur dioxide in the current NEPM for ambient air quality (NEPC 2021) are significantly lower than in the previous NEPM (NEPC 2016). These lower air guidelines have also been considered in this assessment.

These guidelines are based on protection from adverse health effects following both short term (acute) and longer term (chronic) exposure for all members of the population including sensitive populations like asthmatics, children and the elderly.

Tables 4.3 and 4.4 present a comparison of modelled SO_2 levels and the relevant air guidelines, for Scenario 2 reference case (**Table 4.3**) and Scenario 3 regulatory case (**Table 4.4**).

Table 4.3: SO_2 impacts from the ARC Project - maximum impacts for Scenario 2 – reference case maximum emissions

Parameter	Scenario 2 - Reference case maximum emissions - SO_2 (µg/m^3)		
	1-hour average	**24-hour average**	**Annual average**
Guideline (NEPM 2016)	570 (200 ppb)	228	60
Guideline (NEPM 2021)	262 (100 ppb) 196 (75 ppb in 2025)	52 (20 ppb)	Guideline removed
Existing sources (Eco Precinct and mine)			
Maximum off-site (maximum for grid that relates to Project boundary and off-site)	439	49	3.6
Commercial/industrial areas - maximum	179	27	4.9
Residential, rural, school, preschool, church and community receptors - maximum	33	2.0	0.16
Contribution from ARC + existing sources			
Maximum off-site (maximum for grid that relates to Project boundary and off-site)	439	49	4.3
Commercial/industrial areas - maximum	179	29	5.7
Residential, rural, school, preschool, church and community receptors - maximum	46	4.6	0.47
At height – workers repairing wind turbines	185	24	NA (exposure period not relevant)
ARC + existing sources + background			
Maximum off-site sensitive receptor	75	8.9	1.3

Table 4.4: SO_2 impacts from the ARC Project - maximum impacts for Scenario 3 – NSW EfW regulatory emissions

Parameter	Scenario 3 – NSW EfW regulatory emissions - SO_2 (µg/m^3)		
	1-hour average	24-hour average	Annual average
Guideline (NEPM 2016)	570 (200 ppb)	228	60
Guideline (NEPM 2021)	262 (100 ppb) 196 (75 ppb in 2025)	52 (20 ppb)	Guideline removed
Existing sources (Eco Precinct and mine)			
Maximum off-site (maximum for grid that relates to Project boundary and off-site)	439	49	3.6
Commercial/industrial areas - maximum	179	27	4.9
Residential, rural, school, preschool, church and community receptors - maximum	33	2.0	0.16
Contribution from ARC + existing sources			
Maximum off-site (maximum for grid that relates to Project boundary and off-site)	439	49	4.0
Commercial/industrial areas - maximum	179	29	5.4
Residential, rural, school, preschool, church and community receptors - maximum	33	3.4	0.36
At height – workers repairing wind turbines	127	16	NA (exposure period not relevant)
ARC + existing sources + background			
Maximum off-site sensitive receptor	62	8.4	1.2

Tables 4.3 and 4.4 show the following:

- The contribution of emissions to air from the operation of the ARC does not result in any significant change in air quality in the off-site community.
- There is no significant change in the maximum concentration (maximum anywhere) of SO_2 as a result of the operation of the ARC for Scenario 2 or 3. It is noted that the maximum 1-hour average SO_2 concentration is below the 2016 guideline, but exceeds the 2021 guideline, regardless of the operation of the ARC.
- All predicted concentrations in industrial areas, or in the community, relevant to the Scenarios 2 or 3, are below the NEPM criteria that are protective of short-term exposures (1-hour average) and chronic exposures (annual average).
- For workers who may undertake maintenance works on wind turbines located close to the ARC (where works would be undertaken at 80 m height), the maximum predicted concentrations of SO_2 relevant to short-term exposures (based on 1-hour average and 24-hour average concentrations) are below the lowest health-based guideline.

On the basis of the above, there are no risk issues of concern for community health in relation to SO_2 emissions from the ARC Project.

4.5.4 Nitrogen dioxide

Nitrogen oxides (NOx) refer to a collection of highly reactive gases containing nitrogen and oxygen, most of which are colourless and odourless. Nitrogen oxide gases form when fuel is burnt including when residual waste is used as fuel. Motor vehicles, along with industrial, commercial and residential (e.g., gas heating or cooking) combustion sources, are primary producers of nitrogen oxides.

In greater NSW, on-road vehicles accounted for about 15% of emissions of nitrogen oxides and industrial facilities accounted for 53%. In Sydney, a greater contribution is derived from on-road vehicles (approximately 53%, predominantly from diesel engines) (Ewald et al. 2020; NSW EPA 2019).

In terms of health effects, nitrogen dioxide is the only oxide of nitrogen that may be of concern (WHO 2000d). Nitrogen dioxide is a colourless and tasteless gas with a sharp odour. Nitrogen dioxide can cause inflammation of the respiratory system and increase susceptibility to respiratory infection. Exposure to elevated levels of nitrogen dioxide has also been associated with increased mortality, particularly related to respiratory disease, and with increased hospital admissions for asthma and heart disease patients (WHO 2013b). Asthmatics, the elderly and people with existing cardiovascular and respiratory disease are particularly susceptible to the effects of elevated nitrogen dioxide (Morgan, Broom & Jalaludin 2013; NEPC 2010). The health effects associated with exposure to nitrogen dioxide depend on the duration of exposure as well as the concentration.

Guidelines are available from NSW EPA (NSW EPA 2017) and NEPC (NEPC 2016, 2021) which indicate concentrations of nitrogen dioxide considered to be acceptable by national health authorities. The guidelines from NEPC (2016) have been adopted by EMM (2022).

In May 2021, the national guidelines for nitrogen dioxide in the air quality NEPM were changed (NEPC 2021). This update resulted in lower air guidelines for NO_2 based on consideration of the current health evidence and more stringent guidelines in other leading countries. These lower air guidelines have also been considered in this assessment.

These guidelines are based on protection from adverse health effects following both short term (acute) and longer term (chronic) exposure for all members of the population including sensitive populations like asthmatics, children and the elderly.

Table 4.5 presents a comparison of the maximum modelled NO_2 concentrations for Scenario 2 reference case maximum emissions and Scenario 3 regulatory case and the relevant air guidelines.

Table 4.5: NO_2 impacts from the ARC Project - maximum impacts

Parameter	Scenario 2 - Reference case maximum emissions (µg/m^3)		Scenario 3 – NSW EfW regulatory emissions (µg/m^3)	
	1-hour average	Annual average	1-hour average	Annual average
Guideline (NEPM 2016)	246 (0.12 ppm)	62 (0.03 ppm)	246 (0.12 ppm)	62 (0.03 ppm)
Guideline (NEPM 2021)	150 (0.08 ppm)	28 (0.015 ppm)	150 (0.08 ppm)	28 (0.015 ppm)
Existing sources + background				
Maximum off-site (maximum for grid that relates to Project boundary and off-site)	175	22	174	22
Commercial/industrial areas - maximum	108	20	98	20
Residential, rural, school, preschool, church and community receptors - maximum	68	9.1	44	9.1
At height – workers repairing wind turbines	79	NA (exposure period not relevant)	79	NA (exposure period not relevant)
Contribution from the ARC				
Maximum off-site (maximum for grid that relates to Project boundary and off-site)	173	14	174	14
Commercial/industrial areas - maximum	98	12	98	12
Residential, rural, school, preschool, church and community receptors - maximum	44	1.0	44	0.95
At height – workers repairing wind turbines	88	NA (exposure period not relevant)	87	NA (exposure period not relevant)
Cumulative: ARC + existing sources + background				
Maximum off-site sensitive receptor	70	9.4	70	9.3

Table 4.5 shows the following:

- The contribution of emissions to air from the operation of the ARC does not result in any significant change in air quality in the off-site community.
- There is no change in the maximum concentration (maximum anywhere off-site) of NO_2 as a result of the operation of the ARC for Scenarios 2 or 3. It is noted that the maximum 1-hour average NO_2 concentration is below the 2016 guideline, but exceeds the 2021 guideline, regardless of the operation of the ARC.
- All predicted concentrations in industrial areas, or in the community, relevant to Scenarios 2 or 3, are below the NEPM criteria that are protective of short-term exposures (1-hour average) and chronic exposures (annual average).
- For workers who may undertake maintenance works on wind turbines located close to the ARC (where works would be undertaken at 80 m height), the maximum predicted concentrations of NO_2 relevant to short-term exposures (based on 1-hour average concentrations) are below the lowest health-based guideline.

On the basis of the above, there are no risk issues of concern for community health in relation to NO_2 emissions from the ARC Project.

4.5.5 Carbon monoxide

Motor vehicles are the dominant source of carbon monoxide in air (DECCW 2009). Carbon monoxide is produced during combustion when there is a limited supply of oxygen. This facility is designed to optimise the oxygen available in the combustion zone so the production of carbon monoxide should be very low.

The sorts of effects that can be expected due to exposure to CO are those linked with carboxyhaemoglobin (COHb) in blood – i.e., where CO replaces oxygen in the blood preventing oxygen from being transported around the body. In addition, association between exposure to carbon monoxide and cardiovascular hospital admissions and mortality, especially in the elderly for cardiac failure, myocardial infarction and ischemic heart disease; and some birth outcomes (such as low birth weights) have been identified (NEPC 2010).

Guidelines are available from the NSW EPA (NSW EPA 2017) and NEPC (NEPC 2016, 2021) which indicate concentrations of carbon monoxide considered to be acceptable by national health authorities. The guidelines from NEPC (2016) have been adopted by EMM (2022). These guidelines (for an 8-hour average) remain unchanged in the NEPC update in 2021.

Table 4.6 presents a comparison of the maximum modelled CO concentrations for Scenarios 2 and 3 and the air guidelines.

Table 4.6: CO impacts from the ARC Project - maximum impacts

Parameter	Scenario 2 - Reference case maximum emissions (µg/m^3)		Scenario 3 – NSW EfW regulatory emissions (µg/m^3)	
	1-hour average	8-hour average	1-hour average	8-hour average
Guideline (NEPM 2016 and 2021)	NA	10,000	NA	10,000
Guideline (NSW EPA 2017a)	30,000	10,000	30,000	10,000
Existing sources + background				
Maximum off-site (maximum for grid that relates to Project boundary and off-site)	3283	522	3283	522
Commercial/industrial areas - maximum	1266	253	1266	253
Residential, rural, school, preschool, church and community receptors - maximum	242	42	242	42
At height – workers repairing wind turbines	332	101	332	101
Contribution from ARC + existing sources				
Maximum off-site (maximum for grid that relates to Project boundary and off-site)	3283	522	3283	522
Commercial/industrial areas - maximum	1266	254	1266	254
Residential, rural, school, preschool, church and community receptors - maximum	242	42	242	42
At height – workers repairing wind turbines	332	101	332	101
ARC + existing sources + background				
Maximum off-site sensitive receptor	3017	64	3017	64

Table 4.6 shows that emissions of CO from the ARC make no change to the existing air quality in the community for both Scenario 2 and Scenario 3. All concentrations of CO are well below the relevant health protective criteria.

On this basis, there are no risk issues of concern for community health in relation to CO emissions from the ARC Project.

4.5.6 All other pollutants

For all other pollutants, inhalation exposures have considered both short-term/acute exposures as well as chronic exposures.

Acute exposures

The assessment of acute exposures is based on comparing the maximum predicted 1-hour average exposure concentration with health-based criteria relevant to acute or short-term exposure, also based on a 1-hour average exposure time. The ratio of the maximum predicted concentration to the acute guideline is termed a hazard index (HI) and is calculated as follows:

$$HI = \frac{\text{Exposure concentration (maximum modelled 1-hour average)}}{\text{(Acute TRV)}}$$

$$\text{Total HI} = \sum \text{HI (individual pollutants)}$$

Where:
Exposure concentration = maximum modelled concentration (as the 99.9th percentile concentration consistent with NSW EPA guidance (NSW EPA 2017)[2]) of pollutant in air for the ARC + existing sources as a gas/vapour or present as $PM_{2.5}$ (mg/m^3)
Acute TRV = health based toxicity reference value (TRV) or guideline that is protective of short-duration exposures for all members of the community including sensitive individuals, as per **Appendix B** (mg/m^3)

Consistent with guidance provided by enHealth (enHealth 2012b), risks associated with acute exposures are considered to be acceptable where the individual and total HI's are less than or equal to 1.

The acute health-based guidelines, or acute toxicity reference values (TRVs), adopted in this assessment have been selected on the basis of the approach detailed in **Appendix B**. It is noted that for the assessment of exposure to dioxins and furans, dioxin-like PCBs and PAHs as well as some metals, there are no relevant health-based guidelines available as the key issues associated

[2] The 99.9th percentile 1-hour average is used from an air model as the absolute maximum (or 100th percentile) is expected to reflect implausible model artifacts (i.e. inherently excessive overpredictions or erroneous outputs from faulty weather data). The 99.9th percentile concentrations are considered reasonable, reliable worst-case modelling outputs that others can reproduce. The use of the 99.9th percentile 1-hour average is consistent with NSW EPA (2017) guidance for air modelling. It is relevant to assess potential worst-case acute inhalation exposures on the basis of modelled data that is considered reasonable and reliable.

with these chemicals relate to chronic exposures or long-term body burdens. The acute assessment has, therefore, focused on the chemicals where acute health effects are relevant.

Tables 4.7 and 4.8 present a summary of the relevant health-based guideline, the predicted maximum 1-hour average concentrations (for the ARC + existing sources) for the maximum impacted location and the maximum impacted sensitive receptor, and the calculated HI for each chemical for Scenario 2 reference case maximum emissions (**Table 4.7**) and Scenario 3 NSW EfW regulatory emissions (**Table 4.8**). Exposures at all other locations, including the other sensitive receptors will be lower than presented in **Tables 4.7 and 4.8**.

Table 4.7: Review of acute exposures and risks (ARC + existing sources) – Scenario 2: Reference case maximum emissions

		Air Concentration - Maximum 1 hour average* (mg/m^3)				Calculated HI			
Pollutant	**Acute air guideline - health (mg/m^3)**	**Maximum anywhere**	**Maximum - commercial/ industrial receptors**	**Maximum - residential, rural, school receptors**	**Maximum – Workers in wind turbine****	**Maximum anywhere**	**Maximum - commercial/ industrial receptors**	**Maximum - residential, rural, school receptors**	**Maximum – Workers in wind turbine****
Hydrogen chloride (HCl)	0.66 ^{T}	0.012	0.0049	0.0015	0.023	0.018	0.0074	0.0023	0.035
Hydrogen fluoride (HF)	0.06 ^{T}	0.000031	0.0000128	0.0000040	0.000061	0.00052	0.00021	0.000067	0.0010
Ammonia	0.59 ^{T}	0.021	0.0085	0.0026	0.040	0.035	0.014	0.0045	0.068
VOCs - as benzene	0.58 ^{T}	0.0045	0.0019	0.00058	0.0089	0.0078	0.0032	0.0010	0.015
Antimony	0.001 ^{A}	0.000010	0.00000099	0.00000029	--	0.010	0.00099	0.00029	--
Arsenic	0.0099 ^{T}	0.0000090	0.0000036	0.00000040	--	0.00091	0.00036	0.000041	--
Cadmium	0.018 ^{T}	0.0000026	0.00000084	0.00000014	--	0.00014	0.000047	0.0000075	--
Chromium (Cr VI assumed)	0.0013 ^{T}	0.0000084	0.0000034	0.00000071	--	0.0065	0.0026	0.00055	--
Copper	0.1 ^{O}	0.0000016	0.00000086	0.00000018	--	0.000016	0.0000086	0.0000018	--
Manganese	0.0091 ^{T}	0.000014	0.0000049	0.00000099	--	0.0016	0.00053	0.00011	--
Mercury	0.0006 ^{O}	0.0000012	0.00000052	0.00000016	--	0.0021	0.00087	0.00027	--
Nickel	0.0011 ^{T}	0.000019	0.0000098	0.0000019	--	0.017	0.0089	0.0017	--
Vanadium	0.03 ^{O}	0.0000069	0.0000035	0.00000066	--	0.00023	0.00012	0.000022	--
					Total HI	**0.10**	**0.032**	**0.0085**	**0.084**
					Acceptable HI	≤ 1			

* Maximum 1-hour average concentration is the 99.9th percentile concentration modelled for this scenario, consistent with NSW EPA guidance (NSW EPA 2017)
** Assessment of worker exposures at 80 m height where repair work may be undertaken on wind turbines has focused on short-term exposure to gaseous emissions (rather than particulate emissions)

References for health-based acute air guidelines (1-hour average):

T = Guideline available from the Texas Commission on Environmental Quality (TCEQ), https://www.tceq.texas.gov/toxicology/dsd/final.html

O = Guideline available from California Office of Environmental Health Hazard Assessment (OEHHA) https://oehha.ca.gov/air/general-info/oehha-acute-8-hour-and-chronic-reference-exposure-level-rel-summary

A = Guideline available from the Agency for Toxic Substances and Disease Registry (ATSDR), as an acute air guideline (relevant to exposures from 1 hour to 14 days) https://www.atsdr.cdc.gov/mrls/index.html

Table 4.8: Review of acute exposures and risks (ARC + existing sources) – Scenario 3: NSW EfW regulatory emissions

		Air Concentration - Maximum 1 hour average* (mg/m^3)				Calculated HI			
Pollutant	**Acute air guideline - health (mg/m^3)**	**Maximum anywhere**	**Maximum - commercial/ industrial receptors**	**Maximum - residential, rural, school receptors**	**Maximum – Workers in wind turbine****	**Maximum anywhere**	**Maximum - commercial/ industrial receptors**	**Maximum - residential, rural, school receptors**	**Maximum – Workers in wind turbine****
Hydrogen chloride (HCl)	0.66 T	0.021	0.0085	0.0027	0.041	0.032	0.013	0.0040	0.062
Hydrogen fluoride (HF)	0.06 T	0.0017	0.00068	0.00021	0.0033	0.028	0.011	0.0036	0.054
Ammonia	0.59 T	0.0021	0.00085	0.00027	0.0041	0.0035	0.0014	0.00045	0.0069
VOCs - as benzene	0.58 T	0.0033	0.00135	0.00042	0.0064	0.0056	0.0023	0.00072	0.011
Antimony	0.001 A	0.000043	0.000018	0.0000055	--	0.043	0.018	0.0055	--
Arsenic	0.0099 T	0.000013	0.0000063	0.0000017	--	0.0013	0.00064	0.00017	--
Cadmium	0.018 T	0.000014	0.0000059	0.0000018	--	0.00078	0.00033	0.00010	--
Chromium (Cr VI assumed)	0.0013 T	0.000082	0.000034	0.000011	--	0.063	0.026	0.0082	--
Copper	0.1 O	0.000012	0.0000047	0.0000015	--	0.00012	0.000047	0.000015	--
Manganese	0.0091 T	0.000096	0.000039	0.000012	--	0.010	0.0043	0.0014	--
Mercury	0.0006 O	0.000028	0.000011	0.0000036	--	0.046	0.019	0.0059	--
Nickel	0.0011 T	0.00010	0.000041	0.000013	--	0.093	0.037	0.012	--
Vanadium	0.03 O	0.000027	0.000010	0.0000034	--	0.00089	0.00035	0.00011	--
					Total HI	**0.33**	**0.11**	**0.034**	**0.018**
					Acceptable HI	≤ 1			

* Maximum 1-hour average concentration is the 99.9th percentile concentration modelled for this scenario, consistent with NSW EPA guidance (NSW EPA 2017)
** Assessment of worker exposures at 80 m height where repair work may be undertaken on wind turbines has focused on short-term exposure to gaseous emissions (rather than particulate emissions)

References for health-based acute air guidelines (1-hour average):

T = Guideline available from the Texas Commission on Environmental Quality (TCEQ), https://www.tceq.texas.gov/toxicology/dsd/final.html

O = Guideline available from California Office of Environmental Health Hazard Assessment (OEHHA) https://oehha.ca.gov/air/general-info/oehha-acute-8-hour-and-chronic-reference-exposure-level-rel-summary

A = Guideline available from the Agency for Toxic Substances and Disease Registry (ATSDR), as an acute air guideline (relevant to exposures from 1 hour to 14 days) https://www.atsdr.cdc.gov/mrls/index.html

Review of **Tables 4.7 and 4.8** indicates all maximum predicted concentrations of chemicals in air (ARC + existing sources) for both Scenario 2 (reference case maximum emissions) and Scenario 3 (NSW EfW regulatory emissions) are below the health-based criteria protective of acute effects.

On the basis of the above assessment, there are no acute risk issues of concern in relation to inhalation exposures to emissions from the ARC Project.

Chronic exposures

For the assessment of chronic exposures, nearly all the chemicals evaluated have a threshold guideline value that enables the predicted annual average concentration to be compared with a health based, or acceptable, guideline. For the assessment of chronic effects, the assessment has also considered potential intakes of these chemical substances from other sources, i.e. background intakes. As a result, the individual HI is calculated as follows (enHealth 2012b):

$$\text{HI} = \frac{\text{Exposure concentration}}{\text{TRV x (100\% - Background)}}$$

$$\text{Total HI} = \sum \text{HI (individual pollutants)}$$

Where:

Exposure concentration = concentration in air relevant to the exposure period – annual average, modelled air concentration from the ARC + existing sources for gas/vapour and others present on dust as $PM_{2.5}$ (mg/m^3)

TRV = health-based toxicity reference value based on a threshold that is protective of all health effects for all members of the community (mg/m^3) (refer to **Appendix B**)

Background = proportion of the TRV that may be derived from other ambient or background sources/exposures such as water, soil or consumer products (%) (refer to **Appendix B**)

Risks associated with chronic exposures are considered to be negligible (or acceptable) where the individual and total HI's are less than or equal to 1.

For the assessment of exposures to benzene and PAHs, the calculation of an incremental lifetime cancer risk is required as these chemicals/chemical groups are genotoxic carcinogen. This is a different calculation that only considers the incremental risk associated with exposures to benzene or benzo[a]pyrene equivalents derived from the facility (i.e., no consideration of background). The calculation of risk is as follows:

$$\text{Incremental lifetime risk} = \text{Exposure concentration x inhalation unit risk}$$

$$\text{Total non-threshold risk} = \sum \text{incremental lifetime risks (individual pollutants)}$$

Where:

Inhalation unit risk = health-based value relevant to calculating the risk associated with an inhalation exposure (relevant to exposures within the community) (refer to **Appendix B**) $(mg/m^3)^{-1}$

For the assessment of incremental lifetime cancer risks, risks that are less than 1×10^{-6} are considered to be negligible or representative of an essentially zero risk (enHealth 2012b), while risks less than or equal to 1×10^{-5} are considered to be acceptable (NEPC 1999 amended 2013b).

When quantifying inhalation exposures, the following has been assumed:

- The maximum concentration reported occurs on the site boundary (or close to the boundary of the Veolia integrated waste management operations) which is an industrial area, where inhalation exposures are assumed to occur at this maximum impacted location for 8 hours per day, 240 days of the year for 30 years.
- The maximum concentration reported in commercial/industrial receptor locations has been assessed on the basis of inhalation exposures assumed to occur at this maximum impacted location for 8 hours per day, 240 days of the year for 30 years.
- The maximum concentrations at sensitive receptors, namely residential, rural residential, schools and churches, are all assumed to be a residential location where a resident spends 24 hours per day at home, every day of the year for 70 years. A conservative estimate of the time a resident spends living on one property has been adopted (70 years) to ensure the assessment includes all residents who may grow up and then work on a family owned and run agricultural property. A period of 70 years is longer than the duration of operation for the ARC, but reflects long term exposures to pollutants that may have accumulated during the operation of the ARC and remain present in soil for long periods of time.

Appendix B presents the relevant health-based values adopted in these calculations, along with assumptions adopted for the assessment of background intakes and the quantification of inhalation exposures for the calculation of the HI and incremental lifetime risk. **Appendices D and E** presents the calculations undertaken to evaluate inhalation exposures for Scenarios 2 and 3 respectively.

Tables 4.9 and 4.10 present the calculated individual HI and the incremental lifetime cancer risk relevant to the assessment of chronic inhalation exposures for workers and residents based on maximum concentrations relevant to these receptors (relevant to modelled emissions from the ARC and existing sources) for Scenario 2 (reference case maximum emissions) and Scenario 3 (NSW EfW regulatory emission) respectively.

Table 4.9: Calculated chronic inhalation risks (ARC + existing sources) – Scenario 2: Reference case maximum emissions

Pollutant	Calculated non-threshold risk			Calculated HI		
	Maximum anywhere (boundary and off-site)	**Maximum - commercial/ industrial receptors**	**Maximum - residential, rural, school receptors**	**Maximum anywhere (boundary and off-site)**	**Maximum - commercial/ industrial receptors**	**Maximum - residential, rural, school receptors**
Hydrogen chloride (HCl)	--	--	--	0.0029	0.0028	0.0024
Hydrogen fluoride (HF)	--	--	--	0.0000070	0.0000066	0.0000058
Ammonia	--	--	--	0.00042	0.00040	0.00035
VOCs - as benzene	7.6×10^{-8}	7.2×10^{-8}	1.5×10^{-7}	0.0011	0.0010	0.00090
Antimony	--	--	--	0.00095	0.000066	0.000056
Arsenic	--	--	--	0.0013	0.00059	0.00014
Beryllium	--	--	--	0.0011	0.00084	0.00014
Cadmium	--	--	--	0.011	0.0017	0.0012
Chromium (Cr VI assumed)	--	--	--	0.00063	0.00038	0.00024
Copper	--	--	--	0.000000089	0.000000072	0.000000022
Cobalt	--	--	--	0.012	0.0057	0.0014
Lead	--	--	--	0.0041	0.0011	0.00025
Manganese	--	--	--	0.00098	0.00051	0.00025
Mercury	--	--	--	0.000040	0.000038	0.000033
Nickel	--	--	--	0.013	0.010	0.0027
Thallium	--	--	--	0.0000012	0.0000012	0.0000010
Vanadium	--	--	--	0.000011	0.0000088	0.0000020
Zinc	--	--	--	0.0000084	0.0000038	0.0000013
PAHs (as BaP)	1.0×10^{-9}	9.5×10^{-10}	1.9×10^{-9}	--	--	--
Dioxins and furans (WHO-TEQ)	--	--	--	0.000044	0.000041	0.000036
Dioxin-like PCBs (WHO-TEQ)	--	--	--	0.0000094	0.0000090	0.0000078
Total Risk/HI	**8×10^{-8}**	**7×10^{-8}**	**1×10^{-7}**	**0.050**	**0.026**	**0.010**
Acceptable Risk/HI		**$\leq 1 \times 10^{-5}$**			**≤ 1**	
Negligible risk		**$\leq 1 \times 10^{-6}$**			**≤ 1**	

Table 4.10: Calculated chronic inhalation risks (ARC + existing sources) – Scenario 3: NSW EfW regulatory emissions

	Calculated non-threshold risk			Calculated HI		
Pollutant	**Maximum anywhere (boundary and off-site)**	**Maximum - commercial/ industrial receptors**	**Maximum - residential, rural, school receptors**	**Maximum anywhere (boundary and off-site)**	**Maximum - commercial/ industrial receptors**	**Maximum - residential, rural, school receptors**
Hydrogen chloride (HCl)	--	--	--	0.0052	0.0049	0.0043
Hydrogen fluoride (HF)	--	--	--	0.00037	0.00035	0.00031
Ammonia	--	--	--	0.000042	0.000040	0.000035
VOCs - as benzene	5.5×10^{-8}	5.2×10^{-8}	6.5×10^{-7}	0.00079	0.00075	0.0040
Antimony	--	--	--	0.0014	0.0013	0.0011
Arsenic	--	--	--	0.0014	0.0011	0.00095
Beryllium	--	--	--	0.0012	0.0010	0.00035
Cadmium	--	--	--	0.023	0.022	0.019
Chromium (Cr VI assumed)	--	--	--	0.0053	0.0051	0.0044
Copper	--	--	--	0.00000037	0.00000035	0.00000030
Cobalt	--	--	--	0.013	0.0088	0.0073
Lead	--	--	--	0.0042	0.0015	0.0011
Manganese	--	--	--	0.0050	0.0048	0.0041
Mercury	--	--	--	0.00089	0.00085	0.00074
Nickel	--	--	--	0.038	0.037	0.031
Thallium	--	--	--	0.000027	0.000026	0.000022
Vanadium	--	--	--	0.000022	0.000022	0.000018
Zinc	--	--	--	0.000016	0.000015	0.000013
PAHs (as BaP)	--	--	--	--	--	--
Dioxins and furans (WHO-TEQ)	--	--	--	0.000073	0.000069	0.000060
Dioxin-like PCBs (WHO-TEQ)	--	--	--	--	--	--
Total Risk/HI	**5×10^{-8}**	**5×10^{-8}**	**6×10^{-7}**	**0.10**	**0.090**	**0.079**
Acceptable Risk/HI		**$\leq 1 \times 10^{-5}$**			**≤ 1**	
Negligible risk		**$\leq 1 \times 10^{-6}$**			**≤ 1**	

Review of **Tables 4.9 and 4.10** indicates the following:

- All calculated non-threshold risks associated with incremental lifetime risks associated with exposure to benzene and/or PAHs are well below the adopted criteria representative of acceptable risk ($1x10^{-5}$) and negligible risk ($1x10^{-6}$), for both Scenario 2 and Scenario 3.
- The calculated HI for all chemicals individually and as a sum are less than 1 which is representative of negligible/acceptable exposures, for both Scenario 2 and Scenario 3.

On this basis, there are no chronic risk issues of concern in relation to inhalation exposures in the community surrounding the ARC.

It is noted that the calculation presented relates to exposure to emissions from the ARC plus other existing sources (Eco Precinct and mine) as well as consideration of background exposure to these chemicals in ambient air (from other sources, where relevant).

It is noted that the margin of safety (MOS) relevant to inhalation exposures for sensitive receptors range is 100 for Scenario 2 the reference case maximum emissions (which is considered more representative of worst-case long-term emissions to air from the ARC) for the total HI and non-threshold risk[3], with the MOS higher than this for many individual pollutants. This means there is at least a 100-fold factor between the maximum predicted exposures in the community (rural, residential, school, church and other sensitive areas) due to this facility and exposures that government health authorities agree are acceptable. This is more than sufficient to address any likely changes in guidelines that may be applicable to these pollutants over time.

4.6 Multiple pathway exposures

4.6.1 General

Where pollutants may be bound to particulates, are persistent in the environment and have the potential to bioaccumulate in plants or animals, it is relevant to also assess potential exposures that may occur as a result of particulates (as TSP) depositing to the environment where a range of other exposures may then occur. These include:

- Deposition to water (refer to **Section 4.7**):
  - rainwater tanks, where water may be used as potable/drinking water where ingestion and dermal contact is relevant
  - larger water bodies such as Lake Bathurst and Lake George that may be used for recreational purposes where ingestion and dermal contact is relevant as well as ingestion of fish.
- Deposition to soil:

[3] The MOS is calculated as the ratio of the target/acceptable HI: calculated total HI or target/acceptable risk:calculated total risk. Hence for the assessment of exposures at the maximum impacted sensitive receptor the MOS is calculated to be 2.7E-08/1E-05 = 370 (rounding to 2 significant figures) for the calculated non-threshold risk. For the assessment of exposures at the maximum impacted sensitive receptor the MOS for the HI is calculated as 1/0.055 = 18 (rounded to 2 significant figures).

- incidental ingestion and dermal contact with soil (and dust indoors that is derived from outdoor soil or deposited particulates)
- ingestion of homegrown fruit and vegetables where chemicals may deposit onto the plants and onto the soil where the plants are grown resulting in such chemicals being taken up into these plants
- ingestion of eggs where chemicals may deposit onto pasture and be present in soil (which is the same soil present where backyard chickens are kept and ingested during feeding), and the chemicals are taken up into the eggs
- ingestion of other produce at a rural residential property, that may include milk (from dairy cows), beef from cattle and lamb.

It is also noted that some rural properties also grow crops such as wheat, barley, canola, truffles or grapes. There is the potential for metals and organics to be taken up into these products, and these products may be sold into the market. The uptake of these metals and organics into produce that may be sold, has been further evaluated in **Section 4.9**.

The above exposures are chronic or long-term exposures.

4.6.2 Assessment approach

In relation to these exposures, such exposures will only occur on rural residential or residential properties where people live and where rainwater tanks are used, and/or homegrown produce is grown and consumed. This assessment has assessed multi-pathway exposures for the maximum predicted impacts in all sensitive receptor locations, specifically rural and residential areas. Exposures in all other residential areas will be lower than the maximum presented in this assessment.

The calculation of risks posed by multiple pathway exposures only relates to pollutants that are bound to the particulates. The air modelling has provided deposition rates for metals and organics on dust as TSP (i.e., including the coarser fractions that deposit to the ground as well as the fine fractions) relevant to each pollutant, relevant to emissions to air from the ARC + existing sources. These have been used in this assessment.

Appendix C includes the equations and assumptions adopted for the assessment of potential exposures via these exposure pathways, with the calculation of risk for each of these exposure pathways presented in **Appendices D and E** for Scenario 2 (reference case maximum emissions) and Scenario 3 (NSW EfW regulatory emissions) respectively.

It is noted that assessment of potential risks related to exposure to water in rainwater tanks and recreational water is presented separately in **Sections 4.7 and 4.8**. In addition, assessment of risks relevant to the growing of crops or uptake into meat, milk or eggs are presented separately in **Section 4.9**.

4.6.3 Calculated risks

Tables 4.11 and 4.12 present the calculated risks associated with the multiple pathway exposures relevant to both adults and children for Scenario 2 (reference case maximum emissions) and Scenario 3 (NSW EfW regulatory emissions). These risks have been calculated on the basis of the maximum predicted deposition rate for all of the sensitive receptors in the surrounding community. Calculated risks for all other receptors would be lower than presented in this table.

The table presents the total non-threshold risk and HI for each exposure pathway, calculated as the sum over all the pollutants evaluated. The table also includes the calculated non-threshold risk and HI associated with inhalation exposures (as per **Tables 4.9 and 4.10**), as these exposures are additive to the other exposure pathways for residential properties.

Depending on the use of a property, the mix or combination of exposures that may occur are likely to vary. For this assessment, a number of scenarios have been considered where a range of different exposures or combination of exposures may occur. The sum of risks associated with these multiple exposures is presented in **Tables 4.11 and 4.12**.

Table 4.11: Summary of risks for multiple pathway exposures – Scenario 2: Reference case maximum emissions (maximum sensitive receptor, ARC + existing emissions)

Exposure pathway	Calculated non-threshold risk		Calculated HI	
	Young children	Adults	Young children	Adults
Individual exposure pathways				
Inhalation (I)	1.5×10^{-7}	1.5×10^{-7}	0.010	0.010
Soil ingestion (SI)	5.0×10^{-12}	5.7×10^{-12}	0.039	0.0042
Soil dermal contact (SD)	4.0×10^{-12}	2.1×10^{-11}	0.00035	0.00017
Ingestion of homegrown fruit and vegetables (F&V)	1.5×10^{-11}	4.3×10^{-11}	0.0047	0.0017
Ingestion of homegrown eggs (E)	2.0×10^{-15}	1.1×10^{-14}	0.00017	0.000087
Ingestion of home produced milk (M)	1.9×10^{-10}	5.2×10^{-10}	0.038	0.0097
Ingestion of home produced beef (B)	1.5×10^{-11}	6.5×10^{-11}	0.0067	0.0027
Ingestion of home produced lamb (L)	8.2×10^{-12}	4.4×10^{-11}	0.0036	0.0018
Multiple pathways (i.e. combined exposure pathways)				
I + SI + SD	1.5×10^{-8}	1.5×10^{-7}	0.050	0.014
I + SI + SD + F&V	1.5×10^{-8}	1.5×10^{-7}	0.054	0.016
I + SI + SD + E	1.5×10^{-8}	1.5×10^{-7}	0.050	0.015
I + SI + SD + F&V + E	1.5×10^{-8}	1.5×10^{-7}	0.054	0.016
I + SI + SD + M	1.5×10^{-8}	1.5×10^{-7}	0.088	0.024
I + SI + SD + B	1.5×10^{-8}	1.5×10^{-7}	0.056	0.017
I + SI + SD + L	1.5×10^{-8}	1.5×10^{-7}	0.053	0.016
I + SI + SD + F&V + E + M	1.5×10^{-8}	1.5×10^{-7}	0.093	0.026
I + SI + SD + F&V + E + B	1.5×10^{-8}	1.5×10^{-7}	0.061	0.019
I + SI + SD + F&V + E + L	1.5×10^{-8}	1.5×10^{-7}	0.058	0.018
I + SI + SD + F&V + E + M + B + L	1.5×10^{-8}	1.5×10^{-7}	0.10	0.030
Acceptable risk	**$\leq 1 \times 10^{-5}$**	**$\leq 1 \times 10^{-5}$**	**≤1**	**≤1**
Negligible risk	**$\leq 1 \times 10^{-6}$**	**$\leq 1 \times 10^{-6}$**	**≤1**	**≤1**

* Refer to **Appendix** for detailed risk calculations for each exposure pathway

Table 4.12: Summary of risks for multiple pathway exposures – Scenario 3: NSW EfW Regulatory emissions (maximum sensitive receptor, ARC + existing emissions)

Exposure pathway	Calculated non-threshold risk		Calculated HI	
	Young children	Adults	Young children	Adults
Individual exposure pathways				
Inhalation (I)	6.5×10^{-7}	6.5×10^{-7}	0.079	0.079
Soil ingestion (SI)	--	--	0.055	0.0059
Soil dermal contact (SD)	--	--	0.00048	0.00024
Ingestion of homegrown fruit and vegetables (F&V)	--	--	0.0087	0.0035
Ingestion of homegrown eggs (E)	--	--	0.00034	0.00017
Ingestion of home produced milk (M)	--	--	0.049	0.012
Ingestion of home produced beef (B)	--	--	0.0093	0.0037
Ingestion of home produced lamb (L)	--	--	0.0050	0.0025
Multiple pathways (i.e. combined exposure pathways)				
I + SI + SD	6.5×10^{-7}	6.5×10^{-7}	0.13	0.085
I + SI + SD + F&V	6.5×10^{-7}	6.5×10^{-7}	0.14	0.089
I + SI + SD + E	6.5×10^{-7}	6.5×10^{-7}	0.13	0.085
I + SI + SD + F&V + E	6.5×10^{-7}	6.5×10^{-7}	0.14	0.089
I + SI + SD + M	6.5×10^{-7}	6.5×10^{-7}	0.18	0.098
I + SI + SD + B	6.5×10^{-7}	6.5×10^{-7}	0.14	0.089
I + SI + SD + L	6.5×10^{-7}	6.5×10^{-7}	0.14	0.088
I + SI + SD + F&V + E + M	6.5×10^{-7}	6.5×10^{-7}	0.19	0.10
I + SI + SD + F&V + E + B	6.5×10^{-7}	6.5×10^{-7}	0.15	0.092
I + SI + SD + F&V + E + L	6.5×10^{-7}	6.5×10^{-7}	0.15	0.091
I + SI + SD + F&V + E + M + B + L	6.5×10^{-7}	6.5×10^{-7}	0.21	0.11
Acceptable risk	**$\leq 1 \times 10^{-5}$**	**$\leq 1 \times 10^{-5}$**	**≤1**	**≤1**
Negligible risk	**$\leq 1 \times 10^{-6}$**	**$\leq 1 \times 10^{-6}$**	**≤1**	**≤1**

-- Pathway not quantified for non-threshold risk as the regulatory scenario does not include emission limits for PAHs (the only chemical assessed on a non-threshold basis for pathways associated with deposition and accumulation in soil or produce)

* Refer to **Appendix E** for detailed risk calculations for each exposure pathway

Review of **Tables 4.11 and 4.12** indicates that all calculated risks associated with each individual exposure pathway as well as a combination of multiple exposure pathways, remain below the target risk levels considered representative of negligible/acceptable risks, for both Scenario 2 and Scenario 3.

The MOS relevant to the calculated multi-pathway risks for Scenario 2 reference case maximum emissions (the scenario most relevant to the assessment of worst-case long term exposures) ranges from 10 (for the maximum HI) to 67 (for the non-threshold risk) for the most conservative scenario where a rural resident is home 365 days the every year and produces and consumes fruit and vegetables, eggs, milk, beef and lamb from the same property at the maximum impacted receptor location continually for 70 years (and the facility operates for this period of time).

On the basis of the assessment undertaken, there are no chronic risk issues of concern in relation to multiple pathway exposures that may be relevant to the off-site community.

4.7 Residential drinking water exposures

Where there may be deposition of persistent chemicals in areas where rainwater tanks are used for collecting and storing water used for drinking/potable water, there is the potential for these chemicals to accumulate and impact on water quality. Particles can deposit onto a roof and then be washed off the roof into a rainwater tank when it rains. For many of the residential and rural properties surrounding the Project drinking water is sourced from rainwater tanks and/or groundwater. Hence it is important to evaluate potential impacts of the ARC Project on the quality of water in rainwater tanks.

The deposition of chemicals to a roof, and accumulation in rainwater has been estimated for the maximum impacted receptor location (based on deposition derived from the ARC and existing sources), assuming the average rainfall for Lake Bathurst (from the Bureau of Meteorology), a roof that is consistent with a 4 bedroom Australian home and no use of a first flush device. Using this approach, concentrations of chemicals in the water as suspended sediment and as dissolved chemicals have been calculated assuming 100% of the dust that deposits on the roof washed into the tank. Rainwater tanks are designed such that suspended sediment deposits or settles and is not consumed. For the purpose of this assessment, dissolved phase concentrations are assumed to be representative of concentrations that would be consumed on a daily basis.

Predicted concentrations in rainwater tanks have then been compared with drinking water guidelines, which are protective of all exposures relevant to potable water use including ingestion, dermal contact, bathing and irrigation of produce that may be consumed. These guidelines are also protective of the health of pets who may consume water from rainwater tanks.

Tables 4.13 and 4.14 present the maximum predicted concentrations in rainwater tanks for Scenario 2 (reference case maximum emissions) and Scenario 3 (NSW EfW regulatory emissions) with comparison against current drinking water guidelines, applicable to drinking water quality in all areas of Australia. The tables also present a calculated HI, which is the ratio of the exposure concentration to the drinking water guideline. For the assessment of exposure, it is only appropriate to consider the dissolved phase concentration as this is representative of concentrations present in the tank that may be accessed and used on a daily basis. The total (dissolved + particulate) concentration is only presented for comparison and as a worst-case concentration (which may reflect concentrations in a drought where water levels are low) but is not considered realistic in relation to long-term drinking water exposures.

Appendix C presents detail on the modelling undertaken and assumptions adopted, and **Appendices D and E** presents the calculated water concentrations for Scenario 2 (reference case maximum emissions) and Scenario 3 (NSW EfW regulatory emissions) respectively.

Table 4.13: Summary and review of exposures to chemicals in drinking water – Scenario 2: Reference case maximum emissions (maximum sensitive receptor, ARC + existing sources)

Persistent and bioaccumulative chemical	Calculated maximum concentration in rainwater tanks (mg/L)		Drinking water guideline (mg/L)	HI (ratio of dissolved concentration to drinking water guideline)
	Dissolved – relevant to exposure	**Total (particulate and dissolved) –** highly conservative (assumes sediment is stirred up in tank)		
Antimony	1.0×10^{-7}	2.4×10^{-6}	0.003 [A]	0.000035
Arsenic	6.4×10^{-7}	1.0×10^{-5}	0.01 [A]	0.000064
Beryllium	2.1×10^{-10}	8.3×10^{-8}	0.06 [A]	3.45×10^{-9}
Cadmium	5.8×10^{-8}	2.2×10^{-6}	0.002 [A]	0.000029
Chromium (Cr VI assumed)	8.2×10^{-12}	7.3×10^{-6}	0.05 [A]	1.6×10^{-10}
Copper	1.6×10^{-8}	3.0×10^{-7}	2 [A]	8.1×10^{-9}
Cobalt	6.0×10^{-6}	1.4×10^{-4}	0.006 [U]	0.0010
Lead	4.9×10^{-7}	2.2×10^{-4}	0.01 [A]	0.000049
Manganese	1.2×10^{-7}	4.0×10^{-6}	0.5 [A]	0.00000024
Mercury	1.4×10^{-8}	3.8×10^{-7}	0.001 [A]	0.000014
Nickel	1.2×10^{-7}	4.0×10^{-6}	0.02 [A]	0.0000059
Thallium	3.8×10^{-9}	1.4×10^{-7}	0.0002 [U]	0.000019
Vanadium	1.4×10^{-9}	6.9×10^{-7}	0.086 [U]	1.6×10^{-8}
Zinc	1.2×10^{-5}	3.7×10^{-4}	6 [U]	1.9×10^{-6}
PAHs (as BaP)	2.5×10^{-15}	7.4×10^{-8}	0.00001 [A]	2.5×10^{-10}
Dioxins and furans (WHO-TEQ)	9.7×10^{-21}	3.1×10^{-12}	1.6×10^{-8} [A]	6.1×10^{-13}
Dioxin-like PCBs (WHO-TEQ)	2.1×10^{-21}	6.6×10^{-13}	0.00014 [A]	1.5×10^{-17}

Total HI	**0.0012**
Acceptable/negligible HI	**≤1**

Refer to **Appendix C and D** for the methodology, assumptions and calculation of water concentrations

A = Australian Drinking Water Guidelines (NHMRC 2011 updated 2022), with the exception of dioxins (including dioxin-like PCBs) where the drinking water guideline in the recycled water guidelines has been adopted (NRMMC 2008)

U = Residential tap water guideline from USEPA Regional Screening Levels (USEPA 2022)

Table 4.14: Summary and review of exposures to chemicals in drinking water – Scenario 3: NSW EfW regulatory emissions (maximum sensitive receptor, ARC + existing sources)

Persistent and bioaccumulative chemical	Calculated maximum concentration in rainwater tanks (mg/L)		Drinking water guideline (mg/L)	HI (ratio of dissolved concentration to drinking water guideline)
	Dissolved – relevant to exposure	**Total (particulate and dissolved) –** highly conservative (assumes sediment is stirred up in tank)		
Antimony	5.6×10^{-7}	1.3×10^{-5}	0.003 A	0.00019
Arsenic	8.2×10^{-7}	1.3×10^{-5}	0.01 A	0.000082
Beryllium	7.4×10^{-10}	2.9×10^{-7}	0.06 A	1.2×10^{-8}
Cadmium	1.5×10^{-7}	5.6×10^{-6}	0.002 A	0.000073
Chromium (Cr VI assumed)	3.0×10^{-11}	2.7×10^{-5}	0.05 A	6.0×10^{-10}
Copper	1.6×10^{-7}	3.0×10^{-6}	2 A	8.2×10^{-8}
Cobalt	7.2×10^{-6}	1.7×10^{-4}	0.006 U	0.0012
Lead	5.4×10^{-7}	2.4×10^{-4}	0.01 A	0.000054
Manganese	8.0×10^{-7}	2.7×10^{-5}	0.5 A	0.0000016
Mercury	2.7×10^{-7}	7.3×10^{-6}	0.001 A	0.00027
Nickel	7.9×10^{-7}	2.6×10^{-5}	0.02 A	0.000039
Thallium	8.4×10^{-8}	3.1×10^{-6}	0.0002 U	0.00042
Vanadium	1.2×10^{-8}	6.0×10^{-6}	0.086 U	1.4×10^{-7}
Zinc	1.8×10^{-5}	5.7×10^{-4}	6 U	3.0×10^{-6}
Dioxins and furans (WHO-TEQ)	1.7×10^{-20}	5.3×10^{-12}	1.6×10^{-8} A	1.1×10^{-12}
			Total HI	**0.0023**
			Acceptable/negligible HI	**≤1**

Refer to **Appendix C and E** for the methodology, assumptions and calculation of water concentrations

A = Australian Drinking Water Guidelines (NHMRC 2011 updated 2022), with the exception of dioxins (including dioxin-like PCBs) where the drinking water guideline in the recycled water guidelines has been adopted (NRMMC 2008)

U = Residential tap water guideline from USEPA Regional Screening Levels (USEPA 2022)

Review of **Tables 4.13 and 4.14** indicates that the predicted water concentrations in rainwater tanks are all well below drinking water guidelines, for both Scenario 2 and Scenario 3. This is particularly relevant to the maximum dissolved phase concentration which is representative of concentrations that would be accessed and used from the rainwater tank. The total concentration only reflects a peak, where sediment is disturbed (unlikely to occur unless sediment is disturbed during cleaning or drought conditions where low levels of water may be present in the tank).

Where water samples are collected from a rainwater tank (or other water source) for the purpose of analysis, an analytical limit of reporting (LOR)[4] applies to the results, as follows:

- For metals, the LOR is commonly around 0.001 mg/L, with trace analysis reporting a LOR in the range of 0.0001 to 0.0005 mg/L with cadmium reported to a LOR of 0.00005 mg/L. All

[4] Limit of reporting (LOR) for chemical parameters is the minimum concentration of a substance in a sample that can be reliably detected by a laboratory. This will depend on the type of sample analysed and the methodology used by the laboratory. Where reported as not detected, this means that the concentration in the sample analysed is lower than the LOR that can be achieved by the laboratory.

concentrations of metals calculated in rainwater tanks are below these analytical LORs, and hence these chemicals would not be detected where water sampling occurred.

- For PAHs, the LOR is commonly around 0.00002 mg/L, with trace analysis reporting a LOR around 0.000005 mg/L. The concentration of PAHs calculated in rainwater tanks are well below the analytical LOR, and hence these chemicals would not be detected where water sampling occurred.
- For dioxins and furans (including dioxin-like PCBs) the LOR can be variable between laboratories, however, it is typically around 4 to 5 pg/L (or 4 to 5 x 10^{-9} mg/L) as an upper limit (i.e. using the LOR for all individual congeners) $WHO_{05}TEQ$. The concentration of dioxins and furans, and dioxin-like PCBs calculated in rainwater tanks are well below the analytical LOR, and hence these chemicals would not be detected where water sampling occurred.

Based on the above, emissions to air from the ARC (+existing sources) would not have a measurable change in water quality in rainwater tanks at the most affected relevant location, hence impacts on drinking water quality are considered to be negligible. Intakes and exposures (from using water from rainwater tanks) have not been calculated in detail and they have not been added to intakes from soil and produce, as the contribution to total exposure is considered negligible.

Note that the total HI calculated for the rainwater tank concentrations conservatively applies to both adults and young children. Where this is added to the total HI calculated for all other multi-pathway exposures for Scenario 2: Reference case maximum emissions (presented in **Table 4.11**) the following is noted:

- Young children (based on maximum HI calculated for all exposure pathways occurring all the time for 70 years), HI = 0.10 (**Table 4.11**) + 0.0012 (**Table 4.13**) = 0.10
- Adults (based on maximum HI calculated for all exposure pathways occurring all the time for 70 years), HI = 0.03 (**Table 4.11**) + 0.0012 (**Table 4.13**) = 0.03

These conservative maximum combined HI's are unchanged and remain representative of acceptable/negligible risks.

Based on the assessment undertaken, there are no risk issues of concern in relation to potential exposures of persistent and bioaccumulative chemicals that may be present in rainwater tanks surrounding the site.

<u>Groundwater sources of water</u>

It is noted that drinking water in the local area is also sourced from groundwater. The potential for emissions to air to deposit onto the ground and change water quality in groundwater extracted and used for drinking water is considered to be negligible. This is due to the following:

- The organic pollutants considered, namely PAHs, dioxins/furans and dioxin-like PCBs have very low water solubility. Hence when deposited to the ground these chemicals will not wash out from the soil and move into groundwater.
- In relation to metals, the concentration that may be present in soil as a result of deposition is very low (refer to **Section 4.10.2**) and would not be discernible from background soil. Hence

the impacts would not result in any change to regional groundwater which would reflect background/existing geology of the area.

4.8 Recreational exposures to water

Where there may be deposition of persistent chemicals in areas where there are water bodies that are used for recreational purposes, there is the potential for the deposition to impact on water quality in these areas.

In the areas surrounding the ARC site, the key recreational water bodies are Lake Bathurst and Lake George. These water bodies are large (though the volume of water present is variable) and they are located further away from the ARC than the sensitive receptors evaluated in this assessment. Calculations presented for the impact of the project on rainwater quality (**Section 4.7**) will be more conservative than any calculations that can be undertaken for these lakes, for the following reasons:

- The deposition rate for the maximum sensitive receptor is higher for the rainwater tanks as these are closer to the source. Also, the volume of water into which deposition accumulates is smaller for rainwater tanks. This means that at these lakes, the deposition rate will be lower and what is deposited would be mixed in a greater volume of water resulting in lower concentrations.
- The water quality guidelines that apply to recreational exposures are 10 times higher (less conservative) than for drinking water consistent with guidance provided by NHMRC (NHMRC 2008) and the WHO (WHO 2006b).

Given that the assessment risks related to rainwater tanks determined that the impacts from the Project (ARC + existing sources) for both Scenarios 2 and 3 are negligible and would not be measurable, the same conclusions can be inferred for recreational use of Lake Bathurst and Lake George.

Where there are no measurable changes to water quality, there would not be any changes to, or impacts on the presence of metals or persistent organic pollutants in fish species that may be recreationally caught and consumed in Lake Bathurst or Lake George.

4.9 Assessment of risk issues relevant to produce

4.9.1 Crops

Chemicals may be present attached to particles that are emitted from the proposed facility. Once emitted to the atmosphere the particles may fall out of the air and deposit onto the surface of plants, buildings, roads and soil. If attached chemicals are persistent and the particles mix into the soil or are present on the leaves of a plant, they may be taken up by plants into the parts people may consume – i.e. accumulation. This pathway can be assessed using relevant modelling calculations as shown in **Appendices D and E** for Scenario 2 (reference case maximum emissions) and Scenario 3 (NSW EfW regulatory emissions) respectively. Chemicals that are relevant for this pathway are the metals and persistent organics like dioxin-like compounds and PAHs.

Where rural properties in the surrounding areas are used for the growing of crops such as wheat, barley, canola, truffles or grapes, these crops may be sold to the market for use in a range of products.

Hence it is not appropriate to assess exposures associated with grain production and consumption for the rural properties where the grain is grown. However, it is relevant to evaluate if the grain produced would remain in compliance with the maximum limits (MLs) in the Food Standards Code (FSANZ 2017b). For PAHs, the EU (which is referenced by FSANZ in the absence of an Australian value) provides a maximum limit for cereal products. There are no other regulatory limits that can be referenced.

To enable evaluation of this pathway to be undertaken, the deposition rate for each relevant chemical at the maximum impacted rural residential receptor location has been considered. Using that rate, the maximum predicted concentration in soil has been estimated and that soil concentration has then been used to estimate concentrations in grain or similar crops (such as canola) using relevant uptake factors (refer to **Appendix C** for methodology and assumptions and **Appendices D and E** for calculations).

It is noted that the predicted concentrations are considered worst case as these relate to the deposition of pollutants from the ARC and other sources to ground continuously for 70 years while the lifetime of the ARC is expected to be around 25 years.

The predicted concentration in grain crops have then been directly compared with the MLs or other relevant information as described below.

It is noted that there are MLs for only 4 of the relevant pollutants (arsenic, cadmium, lead and PAHs – the value for PAHs is from the EU while the values for the elements are from FSANZ).

To determine if deposition from the project has the potential to be of significance to crops produced in the area for other relevant pollutants, the maximum predicted concentrations in crops have been compared with the range of concentrations reported by Food Standards in cereal products (breads, cereals and oats).

All of these comparisons are included in **Table 4.15**.

Table 4.15: Review of concentrations in grain (and similar) crops – maximum sensitive receptor (ARC + existing sources)

Pollutant	Estimated maximum concentration in grain (mg/kg)		Food Standards Code – ML for cereals, grains, wheat etc or equivalent (mg/kg)	Range of mean concentrations reported in cereal products evaluated in dietary surveys in Australia (mg/kg)
	Scenario 2: Reference case maximum emissions	**Scenario 3: NSW EfW regulatory emissions**		
Antimony	0.000097	0.00052	--	0.003 (F5)
Arsenic	0.00033	0.00043	1	--
Beryllium	0.00000023	0.00000081	--	NA
Cadmium	0.0011	0.0027	0.1	--
Chromium (Cr VI assumed)	0.000046	0.00017	--	0.015 to 0.13 (F3)
Copper	0.000097	0.00098	--	0.67 to 4.1 (F3)
Cobalt	0.00069	0.00083	--	0.0054 to 0.071 (F3)
Lead	0.0014	0.0016	0.2	--
Manganese	0.0016	0.011	--	6.7 to 35 (F3)
Mercury	0.000044	0.00083	--	0.005 (F2)
Nickel	0.000053	0.00035	--	0.212 to 0.41 (F4)
Thallium	0.00000075	0.000016	--	NA
Vanadium	0.0000013	0.000011	--	NA
Zinc	0.049	0.076	--	4.5 to 38 (F3)
PAHs (as BaP)	5.3×10^{-9}	--	0.001 [E]	--
Dioxins and furans (WHO-TEQ)	2.2×10^{-12}	3.8×10^{-12}	--	1×10^{-8} to 4×10^{-8} (F1)
Dioxin-like PCBs (WHO-TEQ)	4.7×10^{-13}	--	--	

E = Maximum limit for cereal products from the EU https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32006R1881
F = Food Standards Australian Total Diet Surveys
https://www.foodstandards.gov.au/science/surveillance/Pages/australiantotaldiets1914.aspx
F1 = 26th Diet Survey (2020)
F2= 25th Diet Survey (2019)
F3 = 23rd Diet Survey (2011)
F4 = 22nd Diet Survey (2008)
F5 = 20th Diet Survey (2003)

Review of **Table 4.15** indicates that:

- the maximum predicted concentrations for arsenic, cadmium, lead and PAHs relevant to both Scenario 2 and Scenario 3 are well below the MLs relevant to these pollutants
- maximum predicted concentrations for other pollutants relevant to both Scenario 2 and Scenario 3 are well below the range of mean concentrations reported in existing/typical food products.

The LOR for the analysis of food products varies depending on the chemical and the type of food product being evaluated. For most foods analysed (as reported by FSANZ), the LOR is as follows:

- Metals have a LOR typically around 0.005 to 0.01 mg/kg. Concentrations of most metals predicted in crops are lower than these LOR and hence would not be measurable. In relation to zinc, the predicted concentrations in grain crops are just above the analytical LOR, and while these levels may be measurable, they are only a very small proportion of the concentrations typically reported in grain products grown in Australia and would not result in any discernible change in the quality of produce derived from the local area.

- Dioxins and furans have a LOR typically around 1 to 2 x 10^{-7} mg/kg. All concentrations of dioxin-like compounds predicted in crops are well below than these LOR and hence would not be measurable.

On this basis, emissions from the ARC (+ existing sources) are considered to be negligible in terms of their contribution to existing background levels in cereal products consumed in the market.

The predicted concentrations in cereal crops, as a result of emissions from the ARC (+ existing sources), would not be detectable or discernible in any analysis.

In addition, deposition of particles from emissions from the Project would not result in any measurable change in soil quality in the area (refer to **Section 4.10.4**). Hence the Project would not change existing conditions or result in impacts on crops grown on farms with organic farming status.

4.9.2 Other produce

The assessment of potential multi-pathway exposures presented in **Section 4.6** included an assessment of risks to human health where metals and persistent organic compounds may accumulate into eggs, milk and meat. For some of these products, maximum limits (MLs) are detailed in the Food Standards Code for Australia (FSANZ 2017b). Where these produce are sold to the market, compliance with these maximum limits is a legal requirement. It is relevant to ensure that the maximum calculated concentrations estimated using deposition of particles from the emissions of the facility are below the MLs relevant to these products. There are limited MLs available for some metals, as follows (refer to **Appendices D and E** for calculations):

- For cadmium, the ML for meat is 0.05 mg/kg. The maximum concentrations of cadmium from the ARC + existing sources calculated in beef (0.0000073 mg/kg for Scenario 2 and 0.0000074 mg/kg for Scenario 3) and lamb (0.0000038 mg/kg for Scenario 2 and 0.0000095 mg/kg for Scenario 3) are well below the ML. The predicted concentrations are also noted to be well below the LOR for analysis of meat.
- For lead, the ML for meat is 0.1 mg/kg. The maximum concentrations of lead from the ARC + existing sources calculated in beef (0.000045 mg/kg for Scenario 2 and 0.000049 mg/kg for Scenario 3) and lamb (0.000058 mg/kg for Scenario 2 and 0.000063 mg/kg for Scenario 3) are well below the ML. The predicted concentrations are also noted to be well below the LOR for analysis of meat.

There are no MLs for dioxins and furans (i.e. dioxin-like compounds) in the Food Standards Code for Australia. In the absence of Australian MLs, general Code provisions apply including that food must be safe and suitable. This requirement has been demonstrated in the risk calculations presented in **Section 4.6**.

The Food Standards Code specifies MLs for total PCBs in mammalian meat and poultry fat, milk and milk products, and eggs (0.2 mg/kg). This ML relates to total PCBs and is well above the predicted concentration of dioxin-like PCBs in meat, milk and eggs relevant to this Project.

Another source of food guidelines for dioxin-like compounds is the European Union (EU). The EU[5] has established regulatory limits for the sum of all dioxin-like compounds (including dioxin-like PCBs) on a TEQ basis for meat, eggs and milk. The EU values are listed below along with the predicted concentrations from this assessment as provided in **Appendix D**).

- Beef and lamb meat
    - limit of 4 pg/g fat (or 0.000004 mg/kg (i.e. 4 x 10^{-6} mg/kg fat))
    - conversion to wet weight assuming meat contains 10-20% fat gives a limit of 0.4-0.8 pg/g wet weight (ww) or 4 x 10^{-7} to 8 x 10^{-7} mg/kg ww
    - the concentrations based on wet weight are relevant for use in this assessment
    - these concentrations are significantly higher than the maximum predicted concentrations relevant to the ARC + existing sources (as per calculations shown in **Appendices D and E**) in beef (1.5 x 10^{-9} mg/kg ww for dioxins/furans + dioxin-like PCBs for both Scenario 2 and Scenario 3) and lamb (2 x 10^{-9} mg/kg ww for dioxins/furans + dioxin-like PCBs for both Scenario 2 and Scenario 3).
- Eggs
    - limit of 5 pg/g fat (or 0.000005 mg/kg (i.e. 5 x 10^{-6} mg/kg fat))
    - conversion to wet weight assuming egg contains 11% fat gives a limit of 0.55 pg/g wet weight or 5.5 x 10^{-7} mg/kg ww
    - the concentration based on wet weight is relevant for use in this assessment
    - this is significantly higher than the maximum predicted concentration relevant to the ARC + existing sources (as per calculations shown in **Appendices D and E**) in eggs (3 to 5 x 10^{-10} mg/kg ww for dioxins/furans + dioxin-like PCBs for Scenario 2 and Scenario 3).
- Milk
    - limit of 5.5 pg/g fat (or 0.0000055 mg/kg (i.e. 5.5 x 10^{-6} mg/kg fat))
    - conversion to wet weight assuming milk contains around 4% fat gives a limit of 0.22 pg/g wet weight or 2.2 x 10^{-7} mg/kg ww
    - this is significantly higher than the maximum predicted concentration relevant to the ARC + existing sources (as per calculations shown in **Appendices D and E**) in milk (9 x 10^{-11} to 1 x 10^{-10} mg/kg ww for dioxins/furans + dioxin-like PCBs for Scenario 2 and Scenario 3).
- These comparisons indicate that the worst-case concentrations in produce predicted for this facility using conservative assumptions (particularly in regard to how long this plant might operate and deposit particles onto the ground surface) are at least 250 times lower than the limits put in place for food in the EU.

The predicted concentrations of dioxins/furans + dioxin-like PCBs in various produce noted above are also well below the analytical LOR and also the range of background concentrations reported in food products in Australia as reported by FSANZ (FSANZ 2020).

[5] Most recent assessment by EFSA of dioxin-like compounds in food (2018) – https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2018.5333

Based on the above, emissions from the ARC + existing emissions (for Scenario 2 (reference case maximum emissions) and Scenario 3 (NSW EfW regulatory emissions)) would not result in any measurable impact on produce grown in the local area. Concentrations of metals derived from these emissions are predicted to result in produce levels below the regulatory MLs, and concentrations of dioxin-like compounds are predicted to result in produce levels below EU regulatory levels. Hence the Project would not impact on the quality of produce sold from farms in the area.

The predicted concentrations in produce, as a result of emissions from the ARC (+ existing sources), would also not be detectable in any analysis. In addition, emissions from the Project would not have any measurable change in soil quality in the area (refer to **Section 4.10.4**). Therefore, the Project would not change existing conditions or result in impacts on crops grown on farms with organic farming status.

4.10 Uncertainties and additional considerations

4.10.1 General

The quantification of human health risks has relied on the modelling of emissions to air and prediction of worst-case or maximum impacts in the off-site community. Hazards associated with potential exposure to the chemicals evaluated is based on current toxicological information relevant to the chemicals evaluated. This includes the use of quantitative toxicity reference values selected in accordance with enHealth (enHealth 2012b) guidance that are protective of all adverse health effects for all members of the community. This includes the consideration of sensitive sub-populations that include the elderly, pregnant women and infants.

Quantification of risk has utilised a number of assumptions that are expected to overestimate actual exposure to chemicals derived from the ARC and the existing emission sources in the Eco Precinct and mine. It is noted that this assessment has not presented a separated assessment of potential exposures by infants potentially exposed via breast milk intakes. Consistent with advice from NSW Health, there are significant health benefits from breast feeding and these benefits far outweigh any potential health risks to an infant from any persistent and bioaccumulative chemicals (evaluated in the multi-pathway assessment) that may be transferred through breast milk. Further the quantification of intake and exposure has adopted a number of conservative assumptions (noted below) that provide a sufficient margin of safety to be protective of exposures for all infants (breast fed and bottle fed) and young children.

Some key assumptions adopted on how individual chemicals have been assessed are detailed in **Section 4.2**. These assumptions would result in overestimation of risk relevant to these individual chemicals. In addition, the following should be noted:

- The calculated soil concentrations assume that deposition occurs continuously throughout a 70-year period, which is an overly conservative assumption, given that the facility has an estimated operational lifetime of approximately 25 years. Further all impact derived from the ARC and other sources accumulate in surface soil and indoor dust for the whole 70 years. No cleaning of indoor dust or use of any other topsoil/mulch/soil conditioner or fertiliser is assumed to occur which would reduce concentrations in surface soil or indoor dust.
- Concentrations predicted in produce is based on the maximum accumulated concentration in soil over the whole 70-year period.

- Concentrations calculated for above ground plants that may be consumed (and also consumed by livestock) assumes that all dust settled on these parts of the plant are ingested, and that the produce is not washed prior to consumption.
- Rural residents live and work on their property as a child and adult 365 days per year for 70 years.

Further review of some aspects of the HHRA has been undertaken as detailed below.

4.10.2 Soil concentrations

The focus of the assessment of deposition and multi-pathway exposures has been for the closest sensitive receptor. The assessment has assumed that the maximum impacts occur at a location where a rural residential property may be located. The land, however, may be used for other purposes such as a school or open space. These land uses would require compliance with guidelines relevant to low density residential use (adopted for day care and primary schools) and open space (also relevant for secondary schools).

It is also relevant to understand the contribution of the ARC (+ existing sources) to existing soil concentrations in the area.

To address these considerations, the maximum predicted surface soil concentrations for Scenario 2 Reference case maximum emissions (refer to **Appendices C and D**), have been compared against soil guidelines protective of both low-density residential land use (which is protective of ingestion, dermal contact, dust inhalation and ingestion of homegrown produce) and recreational use (protective of ingestion, dermal contact and dust inhalation). Background levels of metals and dioxin-like compounds in soil are also presented. Where possible, background levels in soil have been sourced from data relevant to the area, however, where no data from the area are available, data from NSW have been used. This comparison is presented in **Table 4.16**.

It is noted that the maximum soil concentration evaluated is the maximum predicted concentration following 70 years of deposition to the ground surface at the maximum sensitive receptor location, which is considered to be conservative, given that the plant lifetime is expected to be around 30 years.

Table 4.16: Review of maximum predicted surface soil concentrations against background and low-density residential and recreational soil guidelines – Scenario 2: Reference case maximum emissions

Persistent chemical	Maximum calculated concentration from ARC + existing sources – Scenario 2 (mg/kg)#		Background levels in soil** (mg/kg)	Health based guideline (mg/kg)	
	Surface soil	Agricultural soil		Low density residential	Recreational
Antimony	0.049	0.0032	NA	31 U	31 U
Arsenic	0.19	0.013	27 (<5 – 71)	100 N	300 N
Beryllium	0.0017	0.00011	NA	60 N	90 N
Cadmium	0.045	0.003	1.7 (<1 – 2)	20 N	90 N
Chromium (Cr VI assumed)	0.15	0.01	32 (6 – 67)	100 N	300 N
Copper	0.0058	0.00039	234 (16 – 562)	6,000 N	17,000 N
Cobalt	2.8	0.19	NA	100 N	300 N
Lead	4.6	0.31	873 (38 – 1500)	300 N	600 N
Manganese	0.08	0.0054	NA	3,800 N	19,000 N
Mercury (inorganic)	0.0077	0.00051	0.2 (<0.1 – 0.3)	40 N	80 N
Nickel	0.08	0.0053	7.3 (<2 – 16)	400 N	1,200 N
Thallium	0.0028	0.00019	NA	0.78 U	0.78 U
Vanadium	0.014	0.00095	NA	390 U	390 U
Zinc	7.4	0.49	243 (63 – 439)	7,400 N	30,000 N
PAHs (BaP)	0.000037	0.0000025	NA	3 N	3 N
Dioxins and furans (WHO-TEQ)	3.7×10^{-8}	2.5×10^{-9}	4.4×10^{-6} to 1.1×10^{-5} (A)	5×10^{-5} U	5×10^{-5} U
Dioxin-like PCBs (WHO-TEQ)	8.1×10^{-9}	5.4×10^{-10}			

\# Calculated concentration in soil assumes maximum deposition rate from all off-site receptors occurs continuously and cumulatively for 70 years and accumulates in surface soil, or soil mixed in the top 15 cm (agricultural soil)

** Average (min-max) value reported for background soil data for local area reported by Golder (2009[6]), < is where the concentration is reported to be less than the relevant LOR (as indicated)

A = data for dioxin-like compounds relevant to urban soil in Sydney. It is noted that the range for all Australian soils collected for the National Dioxins Program in 2004 was 0.05 pg TEQ/g to 23 pg TEQ /g dw (i.e. 5×10^{-8} to 2.3×10^{-5} mg/kg). The concentrations in urban soils in Sydney ranged from 4.4 to 10.8 pg TEQ/g (for dioxins, furans and DL-PCBs). These values are equivalent to the range 4.4×10^{-6} to 1.1×10^{-5} mg TEQ/kg dw. (DEH 2004)

N = NEPM Health Investigation levels (HILs) for low density residential and recreational land use (NEPC 1999 amended 2013a)

U = USEPA Regional Screening Levels (RSLs) for residential soil, adopted for the assessment of residential and recreational exposures (USEPA 2021)

Review of **Table 4.16** indicates the following:

- the maximum predicted concentrations in soil derived from the ARC (+ existing sources) are well below soil guidelines protective of residential and recreational exposures
- the contribution of emissions derived from the ARC (+ existing sources) are considered negligible compared with typical background soil concentrations in the area
- the analytical LOR for metals in soil is typically around 1 to 5 mg/kg and the maximum concentrations predicted in soil from the ARC (+ existing sources) are generally below these LOR. For cobalt, lead and zinc the maximum predicted surface soil concentration is higher than 1 mg/kg, however the predicted concentration is a small proportion of background and

[6] Golder 2009, Human Health and Ecological Risk Assessment, Former Woodlawn Mine Plant Area, Tarago, NSW. Report dated August 2009, report number 097623063 001 R Rev0.

the relevant guideline and hence would not be discernible in any assessment of soil quality in the area.

Based on the above, the worst-case cumulative emissions derived from the ARC (+ existing sources) would not be detectable or discernible in soil and would not make any measurable change to existing soil concentrations in areas surrounding the Project. Hence impacts to soil from the Project are considered to be negligible.

It is noted that the predicted soil concentrations for Scenario 3 NSW EfW regulatory emissions are not significantly different to those presented in **Table 4.16** and do not change the outcome of this assessment.

4.10.3 PFAS

Another group of chemicals that has been of concern to communities is the per- and polyfluoroalkyl substances (PFAS) which have been discussed in the media for sites where fire fighting foams may have been used (Defence bases and airports, in particular).

PFAS constitute a family of man-made fluorine-containing chemicals. They do not occur naturally in the environment. They have unique properties that make materials stain- and water-resistant. These unique properties also make them persistent in the environment and highly mobile in soil and water (i.e. they readily leach into groundwater). These chemicals are highly water soluble (and often present as ions in solution) and most of the commonly present substances are not volatile (HEPA 2020).

These chemicals have been used in a wide range of products including:

- fire fighting foams
- packaging materials for food
- waterproofing or stainproofing agents (e.g. Scotchguard)
- non-stick products (e.g. Teflon)
- polishes
- waxes
- paints
- cleaning products
- surfactants used in chrome plating or electronics manufacture (HEPA 2020).

It is possible that low levels may be present in the proposed residual waste fuel due to the low levels of PFAS that have been used in various consumer products and packaging (especially fast-food packaging) that would be present in domestic MSW.

Concerns regarding this group of chemicals were raised internationally around the year 2000. A number of chemicals in this group have since been included on the list of chemicals regulated by the Stockholm Convention – an international treaty to which Australia is a party that requires uses of listed chemicals (long lived/persistent ones) to be reduced or eliminated.

Since 2000 many uses of these chemicals have been phased out. Such reductions are expected to continue given the listing of these chemicals on the Stockholm Convention. As a result, the presence of these chemicals in current and future waste fuel would be expected to continue to decrease and to already be much lower than the levels currently discussed in the scientific literature relating to waste materials.

Methods for the analysis of these chemicals in air are not routinely available (HEPA 2020). There is no requirement for analysis of these chemicals in emissions from similar plants in Europe due to the difficulty in undertaking such analysis and the expected low levels. As a result, there are no monitoring data available, and it is not currently possible to undertake a detailed quantitative assessment. In addition, the NSW EPA Policy and EU BREF emission limits do not include consideration of PFAS emissions.

It is noted, however, that the ARC has the capacity to manage small amounts of such chemicals appropriately if they were to be present in the fuel. The flue gas treatment technology proposed can address the presence of these chemicals using the following:

- Combustion chamber – PFAS are usually present in materials that could be in the residual waste as mixtures. Within those mixtures some chemicals are readily degradable at temperatures easily reached in the chamber. Some of the chemicals do require higher temperatures to breakdown. It is noted that much of the chamber will have temperatures in excess of 850^{o}C and these temperatures along with sufficient oxygen will allow for effective combustion (at least 90%) of these chemicals.
- Acid gas treatment (injection of hydrated lime) – the flue gas treatment technology proposed includes a process for removing acid gases from the air – this treatment process will also assist in the removal of the breakdown products from the destruction of PFAS.
- Activated carbon treatment – activated carbon is added to the waste gases to remove metals and a range of other chemicals – this technology will also assist in removing PFAS.
- Baghouse – chemicals attached to particles (including activated carbon particles) are captured within the baghouse – this will include any remaining PFAS.

Risks due to the presence of the expected very low to negligible levels of these chemicals within the fuel to be combusted at this facility are expected to be low to negligible.

4.10.4 Community studies

The assessment presented in this report provides a quantitative evaluation of risks to community health following enHealth guidelines (enHealth 2012b). These guidelines are consistent with the approaches to assessing health risks for such facilities from international jurisdictions.

The scientific literature also provides a number of other studies, specifically epidemiological studies that have focused on emissions to air from waste to energy facilities and potential health effects within communities surrounding the particular facility. Many of the published studies relate to older facilities that do not comply with more recent EU directives (IED emission limits and BREF limits). Only studies that relate to more recent facilities complying with these emissions standards and guidance (or equivalent such as the NSW EfW Policy) are relevant for any comparison with the proposed ARC. Many of the energy from waste facilities evaluated in the epidemiological studies are facilities combusting domestic waste (along with other non-putrescible waste). This is consistent with the proposed ARC Project.

Reports or studies that have reviewed published information and studies on EfW facilities designed to meet EU IED or equivalent emissions limits, have not identified evidence of adverse impacts on community health. Most studies also acknowledge that the number of available studies is limited in relation to these newer facilities, however, in the available studies relevant to modern facilities that meet these standards, no adverse health effects have been identified.

These studies include:

- Literature review undertaken for EPA Victoria (EPA Victoria 2018) and by other Australian researchers (Cole-Hunter et al. 2020; Morgan et al. 2019; Tait et al. 2020) as well as the review completed by the NSW Chief Scientist (NSW Chief Scientist & Engineer 2020)
- Review of research into health effects of EfW facilities focusing on facilities operating in the UK (Broomfield 2012; Marner, Richardson & Laxen 2020), with a series of more recent epidemiological studies (Freni-Sterrantino et al. 2019; Ghosh et al. 2019; Parkes et al. 2019) specifically addressing foetal growth, stillbirth, congenital abnormalities, infant mortality and sex ratio and other birth outcomes finding no evidence of adverse effects in the community. These studies also indicate that the results should be generalisable to other facilities operating to similar standards.

It should be noted that studies related to older facilities[7], where emissions did not or do not meet the EU IED or equivalent emission limits, have shown measurable impacts and links with adverse health effects (Tait et al. 2020). Further, the former operation of these older waste incinerators has resulted in the accumulation of dioxin-like compounds in soil and produce (specifically eggs and vegetables) in areas surrounding the facilities (for example a facility operating in France from 1974 to 2002 and a facility operating from 1958 to 1982 in Lausanne Switzerland[8] (Petrlik et al. 2022; Pirard et al. 2004)). Investigations conducted in the 1990s, in relation to these older facilities, identified the need to reduce emissions from waste incineration facilities and ongoing technology reviews. These changes have resulted in significant measured improvements in emissions. For example, emissions of dioxin-like compounds from waste incineration in France and Japan have reduced more than 99% from the 1990's to around 2010 (Coudon et al. 2019; Li et al. 2019; Nzihou et al. 2012). This means impacts on air quality from these types of facilities are significantly smaller now than they were previously.

Studies related to these older facilities are not relevant to the assessment of potential health impacts from new energy from waste facilities that comply with the more stringent emissions limits from the EU IED and BREF limits or the NSW Policy (NSW EPA 2021).

[7] Older facilities are those that were constructed and operated prior to the introduction and enforcement of emission limits in the European Union Waste Incineration Directive (EU-WID) (2000/76/EC), which was incorporated into and further revised in the EU Industrial Emissions Directive (IED) (2010/75/EU) where emission limits for some pollutants were reduced. IED 2010/75/EU is incorporated into the Best Available Technologies (BAT) Reference Document for Waste Incineration (BREF)(2019) where the emission limits for some pollutants were further reduced, and emission limits were recommended for ammonia and total volatile organic compounds (TVOCs) which were not included in the IED.

[8] https://www.euronews.com/green/2021/10/17/lausanne-discovers-soil-has-been-polluted-with-dangerous-chemicals-for-more-than-years ; https://www.vd.ch/themes/environnement/sols/pollution-des-sols-aux-dioxines/

There are few studies available that measure concentrations of pollutants in soil and produce in rural areas surrounding operational modern energy from waste facilities (that meet IED emission limits or equivalent).

The study by van Dijk et al (van Dijk, van Doorn & van Alfen 2015) involved testing for levels of cadmium, mercury and PAHs in crops (spinach and kale) and dioxin-like compounds (i.e. dioxins, furans and dioxin-like PCBs) in milk from dairy farms and fluoride in pasture grass around three waste incinerators (combusting municipal solid waste) operating in the Netherlands between 2004 and 2013. The facilities were operating using best available technology applicable at the time of operation. The study showed that emissions from these facilities did not affect the quality of crops and milk in the surrounding areas. Concentrations reported were similar to background levels and did not exceed maximum allowable standards applicable to food products in the Netherlands.

Monitoring of dioxins and furans has also been undertaken in areas surrounding other EfW facilities in Europe (CEWEP 2022) where the following is noted in relation to soil and produce:

- Dioxins and furans were measured in vegetation surrounding an Austrian EfW facility – no significant difference was seen between areas close to the facility and distant
- Dioxins and furans were measured in blood of people living near and distant from an EfW facility in Turin over a period of 3 years – there was no increase in dioxin levels in blood [i.e. no evidence of bioaccumulation] and no difference in levels between those close to the facility and those distant from the facility (background)
- Dioxins and furans were measured in cow milk in areas surrounding a Dutch EfW facility between 2009 and 2020 – levels in milk near the plant were no different from background
- Dioxins and furans were measured in soil samples collected in the area surrounding an EfW facility in Mallorca (Spain) from 1997 to 2020 –the levels reported were variable (with no clear trend of accumulation), but all samples were well below the maximum limit value relevant for soil

Sampling of dioxins and furans was also undertaken in the area of Harlingen (Netherlands). Levels in grass and eggs were reported to be higher within 2 km of a waste incinerator (noting the area also includes a range of other industries) and some concentrations in eggs exceeded the EU guidelines (Arkenbout 2014; Arkenbout & Esbensen 2017). The facility is an industrial waste incinerator (not a municipal waste incinerator) that was commissioned in 2011 and has a low emissions limit for dioxins and furans. However, the facility has had a number of reported operational issues that resulted in elevated dioxin and furan emissions at times (including levels that exceeded their emissions limit). These elevated emissions are reflected in the egg data reported for 2014/2015 (Arkenbout & Esbensen 2017), however it should be noted that more than one source of dioxin-like compounds was identified for this area (Arkenbout 2014). Another study also reported elevated levels of dioxins and furans in chicken eggs in other areas in Europe. These findings were found to be related to keeping chickens in industrial areas or areas affected by backyard burning of waste (Hoogenboom et al. 2016).

Consistent with the approach outlined by the NSW Chief Scientist (NSW Chief Scientist & Engineer 2020), the potential for accumulation of persistent and bioaccumulative chemicals into produce, including chicken eggs, meat, milk and other produce has been evaluated for this facility using robust risk assessment methods. This is presented in this assessment for the ARC and is relevant to the proposed operation of the EfW facility.

Section 5. Conclusions

The assessment has evaluated potential risks to community health in relation to emissions to air from the proposed Woodlawn Advanced Energy Recovery Centre (ARC), an energy recovery facility (ERF), at the existing Woodlawn Eco Precinct near Tarago, NSW. The assessment of human health risks has relied on air modelling undertaken and presented in the Air Quality Impact Assessment (EMM 2022).

The area surrounding the Project site includes the Eco Precinct, mine as well as a number of rural residential and residential properties (including the town of Tarago). The area also includes schools, churches, community areas and the recreational water bodies of Lake Bathurst and Lake George.

A detailed assessment of risks to human health has considered acute and chronic inhalation exposures as well as multi-pathway exposures associated with the deposition of metals and persistent organic pollutants (specifically PAHs, dioxins/furans and dioxin-like PCBs) to the ground and the potential for direct contact with soil and dust (indoors) and uptake of these chemicals into homegrown produce (fruit and vegetables, eggs, milk, and meat [beef and lamb]) and consumption of this produce. The assessment has also considered whether the deposition of metals and dioxins/furans would have the potential to adversely affect water quality in rainwater tanks, recreational water in the nearby lakes and the quality of produce such as grain, canola, truffles and vineyard crops, as well as meat, milk and eggs grown in the area.

This assessment has considered impacts in the off-site community for two worst-case emissions scenarios relevant to the operation of the ARC as well as existing sources (Eco Precinct and mine). These include:

- Scenario 2: Reference case emissions – maximum emissions
- Scenario 3: NSW EfW Policy regulatory case emissions.

Scenario 1: Reference case average emissions is considered more representative of long-term emissions to air from the ARC as well as existing sources (Eco Precinct and mine). However, the focus of this assessment relates to the worst-case emission scenarios, hence the average emissions scenario was not evaluated further.

Based on the available data and conservative assumptions adopted in this assessment, the following has been concluded in relation to the worst-case emissions scenarios (Scenarios 2 and 3):

- Inhalation exposures
    - All risks to human health are considered negligible for the duration of the Project. More specifically the following has been concluded:
        - no acute inhalation risk issues of concern
        - no chronic risk issues of concern
        - exposure to particulates derived from the ARC within the community are considered negligible.
- Multi-pathway exposures
    - All chronic risks to human health are considered negligible for the duration of the Project. More specifically the following has been concluded:

    - all calculated risks for individual exposure pathways are negligible and essentially representative of zero risk
    - all calculated risks for combined multiple pathway exposures are negligible and essentially representative of zero risk.
  - Emissions from the ARC would have a negligible impact on water quality in rainwater tanks used for drinking water
  - Emissions from the ARC would have a negligible impact on recreational water quality within Lake Bathurst and Lake George
  - Emissions from the ARC would have a negligible impact on crops and produce grown in the area.

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Appendix A Calculation of risks from $PM_{2.5}$

Calculation of risk: $PM_{2.5}$

A quantitative assessment of risk for these endpoints uses a mathematical relationship between an exposure concentration (i.e. concentration in air) and a response (namely a health effect). This relationship is termed an exposure-response relationship and is relevant to the range of health effects (or endpoints) identified as relevant (to the nature of the emissions assessed) and robust (as identified in the main document). An exposure-response relationship can have a threshold, where there is a safe level of exposure, below which there are no adverse effects; or the relationship can have no threshold (and is regarded as linear) where there is some potential for adverse effects at any level of exposure.

In relation to the health effects associated with exposure to particulate matter, no threshold has been identified. Non-threshold exposure-response relationships have been identified for the health endpoints considered in this assessment.

Risk calculations relevant to exposures to $PM_{2.5}$ by the community have been undertaken utilising concentration-response functions relevant to the most significant health effect associated with exposure to $PM_{2.5}$, namely mortality (all cause).

The assessment of potential risks associated with exposure to particulate matter involves the calculation of a relative risk (RR). For the purpose of this assessment the shape of the exposure-response function used to calculate the relative risk is assumed to be linear[9]. The calculation of a relative risk based on the change in relative risk exposure concentration from baseline/existing (ie based on incremental impacts from the project) can be calculated on the basis of the following equation (Ostro 2004):

Equation 1 $$RR = \exp[\beta(X-X0)]$$

Where:
X-X0 = the change in particulate matter concentration to which the population is exposed (µg/m³)
β = regression/slope coefficient, or the slope of the exposure-response function which can also be expressed as the per cent change in response per 1 µg/m³ increase in particulate matter exposure.

Based on this equation, where the published studies have derived relative risk values that are associated with a 10 micrograms per cubic metre increase in exposure, the β coefficient can be calculated using the following equation:

9 Some reviews have identified that a log-linear exposure-response function may be more relevant for some of the health endpoints considered in this assessment. Review of outcomes where a log-linear exposure-response function has been adopted (Ostro 2004) for $PM_{2.5}$ identified that the log-linear relationship calculated slightly higher relative risks compared with the linear relationship within the range 10–30 micrograms per cubic metre,(relevant for evaluating potential impacts associated with air quality goals or guidelines) but lower relative risks below and above this range. For this assessment (where impacts from a particular project are being evaluated) the impacts assessed relate to concentrations of $PM_{2.5}$ that are well below 10 micrograms per cubic metre and hence use of the linear relationship is expected to provide a more conservative estimate of relative risk.

Equation 2 $$\beta = \frac{\ln(RR)}{10}$$

Where:
RR = relative risk for the relevant health endpoint as published (µg/m³)
10 = increase in particulate matter concentration associated with the RR (where the RR is associated with a 10 µg/m³ increase in concentration).

The assessment of health impacts for a particular population associated with exposure to particulate matter has been undertaken utilising the methodology presented by the WHO (Ostro 2004)[10] where the exposure-response relationships identified have been directly considered on the basis of the approach outlined below.

An additional risk can be calculated as:

Equation 3 **Risk=β x ∆X x B**

Where:
β = slope coefficient relevant to the per cent change in response to a 1 µg/m³ change in exposure
ΔX = change (increment) in exposure concentration in µg/m³ relevant to the project at the point of exposure
B = baseline incidence of a given health effect per person (eg annual mortality rate)

The calculation of the incremental individual risk for relevant health endpoints associated with exposure to particulate matter as outlined by the WHO (Ostro 2004) has considered the following four elements:

- Estimates of the changes in particulate matter exposure levels (ie incremental impacts) due to the project for the relevant modelled scenarios – these have been modelled for the Project, with the maximum change from all community receptors (where regional air quality is of most relevance) adopted in this calculation. For this assessment the change in $PM_{2.5}$ relates to the change in annual average air concentrations and the value considered in this assessment is 0.002 µg/m³ for the reference case scenario and 0.04 µg/m³ for the regulatory case scenario, as maximum changes.
- Baseline incidence of the key health endpoints that are relevant to the population exposed – the assessment undertaken has considered the baseline mortality data relevant to the

10 For regional guidance, such as that provided for Europe by the WHO WHO 2006a, Health risks or particulate matter from long-range transboundary air pollution regional background incidence data for relevant health endpoints are combined with exposure-response functions to present an impact function, which is expressed as the number/change in incidence/new cases per 100,000 population exposed per microgram per cubic metre change in particulate matter exposure. These impact functions are simpler to use than the approach adopted in this assessment, however in utilising this approach it is assumed that the baseline incidence of the health effects is consistent throughout the whole population (as used in the studies) and is specifically applicable to the sub-population group being evaluated. For the assessment of exposures in the areas evaluated surrounding the project it is more relevant to utilise local data in relation to baseline incidence rather than assume that the population is similar to that in Europe (where these relationships are derived).

Goulburn Mulwaree LGA, with the most recent data indicating a rate of 590.1 per 100,000 as an age standardised rate which has been adopted in this assessment.

- Exposure-response relationships expressed as a percentage change in health endpoint per microgram per cubic metre change in particulate matter exposure, where a relative risk (RR) is determined (refer to Equation 1). The concentration response function used in this report is that recommended in a NEPC published report (Jalaudin & Cowie 2012). It was derived from a study in the United States which examined the health outcomes of hundreds of thousands of people living in cities all over the United States. These people were exposed to all different concentrations of $PM_{2.5}$ (Pope et al. 2002). The study found a relative risk (RR) of all-cause mortality of 1.06 per 10 µg/m^3 change in $PM_{2.5}$, and that this risk relationship was in the form of an exponential function. Based on a RR of 1.06 per 10 µg/m^3 change in $PM_{2.5}$, this results in a β = 0.0058. It is noted that the exposure response relationship established in this study was re-affirmed in a follow-up study (that included approximately 500,000 participants in the US) (Krewski et al. 2009) and is consistent with findings from California (Ostro et al. 2006). The relationship is also more conservative than a study undertaken in Australia and New Zealand (EPHC 2010).

The above approach (while presented slightly differently) is consistent with that presented in Australia (Burgers & Walsh 2002), US (OEHHA 2002; USEPA 2005b, 2010) and Europe (Martuzzi et al. 2002; Sjoberg et al. 2009).

Based on the calculations undertaken the calculated incremental individual risk (rounded to 1 significant figure):

Reference case scenario

$Risk = \beta \times \Delta X \times B$

$= 0.002 \times 0.005901 \times 0.0058$

$= 7 \times 10^{-8}$

Regulatory case scenario

$Risk = \beta \times \Delta X \times B$

$= 0.04 \times 0.005901 \times 0.0058$

$= 1 \times 10^{-6}$

Appendix B Toxicity of key chemicals evaluated

B1 Approach to the identification of toxicity reference values

The quantitative assessment of potential risks to human health for any substance requires the consideration of the health end-points and where carcinogenicity is identified; the mechanism of action needs to be understood. This will determine whether the chemical substance is considered a threshold or non-threshold chemical substance. A threshold chemical has a concentration below which health effects are not considered to occur. A non-threshold chemical substance is believed to theoretically cause health effects at any concentration, and it is the level of health risk posed by the concentration of the chemical substance that is assessed. The following paragraphs provide further context around these concepts.

For chemical substances that are not carcinogenic, a threshold exists below which there are no adverse effects (for all relevant end-points). The threshold typically adopted in risk calculations (a tolerable daily intake [TDI] or tolerable concentration [TC]) is based on the lowest no observed adverse effect level (NOAEL), typically from animal or human (e.g. occupational) studies, and the application of a number of safety or uncertainty factors. Intakes/exposures lower than the TDI/TC is considered safe, or not associated with an adverse health risk (NHMRC 1999).

Where the chemical substance has the potential for carcinogenic effects the mechanism of action needs to be understood as this defines the way that the dose-response is assessed. Carcinogenic effects are associated with multi-step and multi-mechanism processes that may include genetic damage, altering gene expression and stimulating proliferation of transformed cells. Some carcinogens have the potential to result in genetic (DNA) damage (gene mutation, gene amplification, chromosomal rearrangement) and are termed genotoxic carcinogens. For these carcinogens it is assumed that any exposure may result in one mutation or one DNA damage event that is considered sufficient to initiate the process for the development of cancer sometime during a lifetime (NHMRC 1999). Hence no safe-dose or threshold is assumed and assessment of exposure is based on a linear non-threshold approach using slope factors or unit risk values.

For other (non-genotoxic) carcinogens, while some form of genetic damage (or altered cell growth) is still necessary for cancer to develop, it is not the primary mode of action for these chemical substances. For these chemical substances carcinogenic effects are associated with indirect mechanisms (that do not directly interact with genetic material) where a threshold is believed to exist.

In the case of particulate matter (PM_{10} or $PM_{2.5}$), current health evidence has not been able to find a concentration below which health impacts do not exist. Thus, the quantification of risk for $PM_{2.5}$ follows a non-threshold approach as described in **Appendix A**.

B2 Values adopted for the assessment of acute exposures

The assessment of potential acute exposures relates to inhalation exposures only. The assessment is based on the maximum predicted 1-hour average air concentration. Hence the selection of relevant and appropriate acute toxicity reference values (TRVs) has focused on guidelines that relate to a peak 1-hour exposure. There are other guidelines available that can be termed acute or short-term, however these relate to exposure periods longer than 1-hour, e.g. an 8-hour average or averaging periods up to 14 days (as is adopted by ATSDR). Guidelines for averaging periods longer than 1-hour are not preferred as the assessment would not then be comparing exposure concentrations and guidelines on the same basis.

The acute TRVs are protective of all adverse health effects for all members of the community including sensitive groups, such as children and the elderly.

For this assessment the acute TRVs have been selected on the basis of the following approach:

- Acute guidelines relevant to a 1-hour average exposure period are preferred
- The TRVs have been selected on the basis of the following hierarchy:
  1. Western Australian Guidelines for ammonia and protection of public health (WA Department of Health 2009), with the guideline adopted for 24-hours converted to a 1-hour average guideline
  2. Texas Commission on Environmental Quality (TCEQ) Acute Reference Value (Acute ReV), which is based on a target HI of 1, consistent with the target HI adopted in the derivation of guidelines in Australia (enHealth 2012b; NEPC 1999 amended 2013c, 2004) by the WHO (WHO 2000c, 2000a, 2010). These are used as the primary source of acute guidelines as they specifically relate to and consider studies relevant to a 1-hour exposure and they have undergone the most recent detailed review process.
  3. California Office of Environmental Health Hazard Assessment (OEHHA) acute Reference Exposure Level (REL), which are all based on a target HI of 1 with RELs relevant to 1-hour average exposures adopted.
  4. Ontario Ministry of the Environment and Climate Change, with 24-hour average guidelines converted to 1-hour average guidelines.

As part of their air dispersion modelling guideline, the Ontario Ministry for the Environment reviewed the use of the power relationship to convert between averaging times (Ontario MfE 2004).

The equation used to convert between different averaging times is:

$$\text{Concentration (averaging time A)} = \text{concentration (averaging time B)} \times \left(\frac{\text{Averaging time B}}{\text{Averaging time A}}\right)^{n}$$

Where

n = stability dependent exponent based on the stability classes commonly used in air dispersion models.

These stability classes are as follows:

Stability class	n value
A&B	0.5
C	0.33
D	0.2
E&F	0.167

The literature around air dispersion modelling includes a wide range of values for n. The Ontario MfE reviewed these values. They have historically used a value of 0.28 which relates to the C & D stabilities. During consultation for this guidance in Ontario, comments were received that an average power exponent would be more relevant given that a number of the air dispersion models commonly used do not actually use stability classes. The average of the n values for the stability classes A-F is also approximately 0.28. Consequently, this value has been adopted for this review (Ontario MfE 2004).

This approach is also consistent with guidance provided by the Californian Office of Environmental Health Hazard Assessment (OEHHA 2015).

The conversion factors to be used in this review are listed in the following table.

Averaging time A	Averaging time B	Adjustment factor
Annual average	1 hour average	Multiply by 12.5
24 hour average	1 hour average	Multiply by 2.5
8 hour average	1 hour average	Multiply by 1.7
3 minute average	1 hour average	Multiply by 0.43

For this assessment, all air concentrations have been provided from the AQIA model, for the correct averaging periods that need to be evaluated. Hence there has been no need to convert any of the data received to different averaging periods.

Based on the above the following acute TRVs have been adopted in this assessment. It is noted that no acute TRVs are available for a number of chemicals, specifically beryllium, cobalt[11], lead, thallium, zinc, PAHs, dioxins and furans and dioxin-like PCBs as these chemicals are either not acute toxicants or no suitable acute inhalation TRVs are available. All these chemicals have been assessed in relation to chronic exposures.

[11] In relation to cobalt, an acute TRV is available from TCEQ, however this value is based on data from occupational exposures to cobalt metal (hard metal) particulates from the metal industry which is not relevant to the presence of inorganic cobalt compounds bound to particulates following combustion (which would not include metal particles). There are no suitable acute TRVs for cobalt that can be used in this assessment.

Table B1: Acute TRVs adopted in this assessment

Chemicals	Acute air guideline (1-hour average) (mg/m^3)
Hydrogen chloride (HCl)	0.66[1]
Hydrogen fluoride (HF)	0.06[1]
Ammonia	0.59[1]
VOCs and benzene	0.58[1]
Antimony	0.001[3]
Arsenic	0.0099[1]
Cadmium	0.018[1]
Chromium (Cr VI assumed)	0.0013[1]
Copper	0.1[2]
Manganese	0.0091[1]
Mercury (as elemental)	0.0006[2]
Nickel	0.0011[1]
Vanadium	0.03[2]

References for health-based acute air guidelines (1-hour average):
1 = Guideline (as acute ReV) available from the Texas Commission on Environmental Quality (TCEQ), https://www.tceq.texas.gov/toxicology/dsd/final.html
2 = Guideline available from California Office of Environmental Health Hazard Assessment (OEHHA) https://oehha.ca.gov/air/general-info/oehha-acute-8-hour-and-chronic-reference-exposure-level-rel-summary
3 = Guideline available from the Agency for Toxic Substances and Disease Registry (ATSDR), as an acute air guideline (relevant to exposures from 1 hour to 14 days) https://www.atsdr.cdc.gov/mrls/index.html

B3 Values adopted for the assessment of chronic exposures

Chronic toxicity reference values (TRVs) associated with inhalation, ingestion and dermal exposures have been adopted from credible peer-reviewed sources as detailed in the NEPM (NEPC 1999 amended 2013b) and enHealth (enHealth 2012b). The identification of the most appropriate and robust TRVs has followed guidance from Australia (enHealth 2012b), as noted above.

For carcinogens, this guidance requires consideration of the mechanism of action for the development of cancer. Some cancers are caused by a threshold mechanism, where there needs to be sufficient exposures to trigger the damage that results in or promotes the development of cancer. Other carcinogens are genotoxic/mutagenic and act in a way such that and any level of exposure is assumed to result in damage that may increase the lifetime risk of cancer. Not all carcinogenic (and not all mutagenic) pollutants cause cancer in the same way and hence the mechanism of action has been considered in the identification of appropriate TRVs for use in this assessment.

For the gaseous chemicals considered in this assessment, only inhalation TRVs have been adopted. For inorganics as well as dioxins, TRVs relevant to all exposure pathways have been adopted. Background intakes of these chemicals have been estimated on the basis of existing available information as noted.

Tables B2 and B3 present the TRVs adopted for the assessment of chronic health effects associated with exposure to the other chemicals considered in this assessment. **Table B2** presents the threshold TRVs, while **Table B3** presents the non-threshold TRVs.

Table B2: Summary of chronic TRVs adopted for chemicals – threshold effects

Chemical	Inhalation TRV (mg/m^3)	Oral/dermal TRV (mg/kg/day)	GI absorption factor*	Dermal absorption*	Background intakes (as percentage of TRV)	
					Oral/dermal**	Inhalation**
Hydrogen chloride (HCl)	0.026 [T]	NA (gaseous chemical)			NA	0%
Hydrogen fluoride (HF)	0.029 [T]	NA (gaseous chemical)			NA	0%
Ammonia	0.32 [T]	NA (gaseous chemical)			NA	0%
Benzene	0.03 [U]	NA (gaseous chemical)			NA	10%
Antimony	0.0002 [U]	0.00086 [NH]	10%	0	0%	0%
Arsenic	0.000067 [T]	0.002 [N]	100%	0.005	50%	0%
Beryllium	0.00002 [W]	0.002 [NH]	0.7%	0	0%	0%
Cadmium	0.000005 [W]	0.0008 [W]	100%	0	60%	20%
Chromium (Cr VI assumed)	0.0001 [U]	0.0009 [A]	100%	0	10%	0%
Copper	0.49 [R]	0.14 [W]	100%	0	10%	0%
Cobalt	0.0001 [W]	0.0014 [D]	100%	0	20%	0%
Lead	0.0005 [N]	0.0035 [NH]	100%	0	50%	0%
Manganese	0.00015 [W]	0.14 [A]	4%	0	50%	20%
Mercury (as inorganic and elemental)	0.0002 [W]	0.0006 [W]	7%	0.001	40%	10%
Nickel	0.00002 [E]	0.012 [W]	100%	0.005	60%	20%
Thallium	0.0028 [R]	0.0008 [U]	100%	0	0%	0%
Vanadium	0.007 [R]	0.002 [D]	2.6%	0	0%	0%
Zinc	1.75 [R]	0.5 [NH]	100%	0.14	80%	80%
Dioxins and furans, including dioxin-like PCBs assumed to be WHO_{05} TEQs	8.05E-09 [R]	2.3E-09 [NH]	100%	0.03	54%	54%

Table B3: Summary of chronic TRVs adopted for chemicals – non-threshold effects

Chemical	Non-threshold inhalation TRV $(mg/m^3)^{-1}$	Non-threshold oral/dermal TRV $(mg/kg/day)^{-1}$	Dermal absorption*	Background intakes**
Benzene	0.006 W	NA (gaseous chemical)	NA	NA for non-threshold effects
PAHs assuming 100% as BaP	0.6 U	0.233 N	0.06	

Notes for Tables B2 and B3

* GI factor and dermal absorption values adopted from RAIS (accessed in 2021) (RAIS)

** Background intakes relate to intakes from inhalation, drinking water and food products. The values adopted based on information provided in the ASC-NEPM (NEPC 1999 amended 2013c) and relevant sources as noted for the TRVs. Gaseous chemical background intakes are not known and hence for this assessment they have been assumed to be negligible

R = No inhalation-specific TRV available, hence inhalation exposures assessed on the basis of route-extrapolation from the oral TRV, as per USEPA guidance (USEPA 2009)

A = TRV available from ATSDR, relevant to chronic intakes (ATSDR 2012c, 2012b, 2012a)

D = TRV available from RIVM (Baars et al. 2001; van Vlaardingen, Posthumus & Posthuma-Doodeman 2005)

E = TRV available from the UK Environment Agency (UK EA 2009)

N = Arsenic and BaP values consistent with the ASC-NEPM evaluation (NEPC 1999 amended 2013c) and lead value from NEPC (NEPC 2016)

NH = Dioxin value (and background intakes, which includes natural soil) adopted from NHMRC (NHMRC 2002) and Environment Australia (DEH 2005; EPHC 2005), and other values consistent with that adopted by NHMRC to assess intakes in drinking water (NHMRC 2011 updated 2021)

T = TRV available from TCEQ, relevant to chronic inhalation exposures (and HI=1) (TCEQ 2012, 2013, 2014, 2015a, 2015b)

U = TRV available from the USEPA IRIS (current database) (USEPA IRIS)

W = TRV available from the WHO, relevant to chronic inhalation exposures (WHO 1999, 2000a, 2006c, 2017), noting inhalation value adopted for mercury is for elemental mercury (WHO 2003)

All chronic TRVs adopted for the assessment of chronic exposures are protective of all adverse health effects for all members of the community including sensitive groups such as children and the elderly.

For this assessment the following pollutants have been classified as class 1 carcinogens by the International Agency for Research on Cancer (IARC), and a review has been undertaken on the mechanism of action relevant to the way in which they cause cancer as follows:

Arsenic:

The mechanism by which cancer is caused does not appear to be mutagenic, with a threshold mode of action identified for the assessment of cancer (where damage to cells and sufficient exposure to result in cancer proliferation required) (NEPC 1999 amended 2013c). Hence a threshold TRV has been adopted in the NEPM for the assessment of exposure to arsenic. In relation to inhalation exposures, the WHO indicates that a linear (non-threshold) dose–response relationship for lung cancer is supported by the occupational and epidemiological studies. It is difficult to mix threshold and non-threshold approaches, hence a threshold value for the assessment of chronic inhalation exposure to arsenic has been adopted based on the chronic air guideline developed by TCEQ (TCEQ 2012) that is protective of lung cancer effects (based on a non-threshold approach and adopting a 1 in 100,000 incremental risk consistent with the approach adopted in this assessment).

This approach ensures all adverse effects are appropriately addressed and risks from multi-pathway exposures added.

Cadmium:

Inhalation of cadmium has been associated with carcinogenic effects (as well as others). Sufficient evidence is available (IARC 1993) to conclude that cadmium can produce lung cancers via inhalation (IARC 2012). While cadmium is thought to be potentially genotoxic, the weight of evidence is not clear. In addition, epidemiology studies associated with lung cancer have confounding issues that limit useful interpretation (WHO 2000b). It is noted that the USEPA derived their inhalation unit risk on the basis of the same study that the WHO dismissed due to confounding factors. Further, most of the epidemiological data available also includes co-exposures with zinc and in some cases both zinc and lead.

Cadmium is not volatile and hence inhalation exposures are only relevant to dust intakes. These are not likely to be significant for soil contamination and hence the consideration of carcinogenic effects (where the mode of action is not clear) using a non-threshold approach is not considered appropriate. It is appropriate to consider intakes on the basis of a threshold approach associated with the most significant end-point. This is consistent with the approach noted by RIVM (2001) and considered by the WHO (2000) and UK EA (2009) where a threshold value for inhalation based on the protection of kidney toxicity (the most significant endpoint) has been considered. The value derived was then reviewed (based on the US cancer value) and considered to be adequately protective of lung cancer effects. On this basis, the WHO (2000) derived a guideline value of 0.005 $\mu g/m^3$ and the UK EA (2009) derived an inhalation TDI of 0.0014 µg/kg/day (which can be converted to a guideline value of 0.005 $\mu g/m^3$ – the same as the WHO value).

It is also noted that where carcinogenic effects are evaluated using a non-threshold approach the air guideline is higher (less conservative) than that calculated using a threshold (TCEQ 2016). The threshold TRV adopted in this assessment is lower than that evaluated by TCEQ (2016). Hence the threshold TRV adopted is protective of all health effects including carcinogenicity.

Chromium VI:

The available data suggests the compound may have some genotoxic potential however review by NEPC (NEPC 1999 amended 2013c) indicates that carcinogenicity is likely to act on the basis of a threshold mode of action, which has been adopted in the NEPM.

Epidemiological studies have shown an association between inhalation exposure to Cr VI and lung cancer. These studies have involved chromate production, chromate pigment production and use, chromium plating, stainless steel welding, ferrochromium alloy production and leather tanning. Various Cr VI compounds have also been shown to be carcinogenic via inhalation in experimental animals. Cr VI has also been shown to be genotoxic. As noted by UK DEFRA & EA (UK DEFRA & EA 2002), there is some suggestion that chromium-induced cancer of the respiratory tract may be exclusively a high-dose phenomenon with a threshold approach relevant to low-dose exposures but quantitative data is lacking.

Chromium is not volatile and hence inhalation exposures are only relevant to dust intakes. These are not likely to be significant for soil contamination and hence the consideration of carcinogenic effects using a non-threshold approach may not be appropriate. It is appropriate to consider intakes on the basis of a threshold approach associated with the most significant end-point. In addition, inhalation exposures relating to soil contamination (dust) are expected to differ from the occupation studies from which the non-threshold criteria are derived (where inhalation of fine dust and chromic acid mists occurs). These issues were considered by ITER (ITER 1998) in the derivation of an RfC that is relevant for environmental exposures only, not to occupational exposures associated with mists and aerosols, and USEPA (USEPA 1998) in the derivation of an RfC.

The following are available for inhalation exposures for Cr VI particulates or dust from Level 1 Australian and International sources:

- No Australian guideline values are available for Cr VI.
- The USEPA (USEPA 1998) derived an inhalation RfC of 0.0001 mg/m^3 for Cr VI particulates based on lower respiratory effects in a subchronic rat study. The USEPA review of particulate exposures indicated chromium inhalation induced pneumocyte toxicity and suggested that inflammation is essential for the induction of most chromium inhalation effects and may influence the carcinogenicity of Cr VI compounds. The USEPA has also derived a separate RfC (lower) for exposure to chromic acid mists and dissolved Cr VI aerosols, which would be relevant for the assessment of an occupational environment.
- ITER (ITER 1998) derived an inhalation RfC of 0.0003 mg/m^3 for Cr VI particulates based on the same study as USEPA considered but the value derived was on the basis of an arithmetic average of benchmark concentrations for the pulmonary inflammation end point.

The threshold value from the USEPA has been adopted for the assessment of chronic inhalation exposures. This is considered protective of all adverse health effects.

Nickel:

The available data indicates that the compound may be genotoxic, however the mechanism of action is not well understood. The WHO (WHO 1991) indicates that very high concentrations of nickel are required to produce genotoxic effects (after cell damage/death) and hence a threshold mode of action is considered appropriate (NEPC 1999 amended 2013c). Hence the threshold TRV adopted is protective of all health effects including carcinogenicity.

Dioxins and furans (including dioxin-like PCBs), as 2,3,7,8-TCDD:

Review of carcinogenicity by NHMRC (NHMRC 2002) and the WHO (FAO/WHO 2018; WHO 2019) indicates that TCDD is not genotoxic and hence a threshold approach is considered appropriate. Hence the threshold TRV adopted is protective of all health effects including carcinogenicity.

Appendix C Methodology and assumptions

C1 Introduction

This appendix presents the methodology and assumptions adopted in the calculation of risk related to the assessment of chronic risks via inhalation or other pathways that may occur following deposition of chemical substances that are persistent.

C2 Quantification of inhalation exposure

Intakes via inhalation has been assessed on the basis of the inhalation guidance available from the USEPA and recommended for use in the ASC NEPM and enHealth (enHealth 2012b; NEPC 1999 amended 2013c; USEPA 2009).

This guidance requires the calculation of an exposure concentration which is based on the concentration in air and the time/duration spent in the area of impact. It is not dependent on age or body weight. The following equation outlines the calculation of an inhalation exposure concentration, and **Table C1** provides details on the assumptions adopted in this assessment:

$$\text{Exposure Concentration} = C_a \bullet \frac{ET \bullet EF \bullet ED}{AT} \quad (mg/m^3)$$

Table C1: Inhalation exposure assumptions

<table>
<tr><th colspan="2">Parameter</th><th>Value adopted</th><th>Basis</th></tr>
<tr><td>Ca</td><td>Concentration of chemical substance in air (mg/m^3)</td><td>Maximum from receptors modelled</td><td>Calculations undertaken on the basis of the maximum predicted impacts</td></tr>
<tr><td>FI</td><td>Fraction inhaled from site</td><td>100%</td><td>All exposures occur at the same location</td></tr>
<tr><td>RF</td><td>Dust lung retention factor (unitless)</td><td>Gasses = 1
Particulate bound chemicals = 1</td><td>100% of gases reach the lungs. For particulates, these assessed on the basis of the concentration bound to $PM_{2.5}$, which is assumed to all reach the lungs and behave similar to gases</td></tr>
<tr><td>ET</td><td>Exposure time (dependant on activity) (hours/day)</td><td>Residents = 24 hours/day
Workers = 8 hours/day</td><td rowspan="2">Residents: Assume someone is exposed at the maximum location all day, every day of the year.
Workers: Working 8 hours per day, 5 days per week for 48 weeks of the year (enHealth 2012b)</td></tr>
<tr><td>EF</td><td>Exposure frequency (days/year)</td><td>Residents = 365 days
Workers = 240 days</td></tr>
<tr><td>ED</td><td>Exposure duration (years)</td><td>Residents = 70 years
Workers = 30 years</td><td>For residents in the surrounding areas the duration of residency has been assumed to be 70 years (longer than the expected operational time of the facility) to provide a conservative assessment of potential exposures by long-term residents (multi-generational farms).
Time at the same workplace as per enHealth (enHealth 2012b)</td></tr>
<tr><td>AT</td><td>Averaging time (hours)</td><td>Threshold = ED x 365 days/year x 24 hours/day
Non-threshold = 70 years x 365 days/year x 24 hours/day</td><td>As per enHealth (enHealth 2012b) guidance</td></tr>
</table>

C3 Multiple pathway exposures

C3.1 Ingestion and dermal absorption

Chemical substances that are deposited on the ground have the potential to be ingested either directly through accidental consumption of dirt or indirectly through food grown or raised in the soil (fruit and vegetables, eggs, beef, lamb and milk) that is subsequently consumed.

The assessment of the potential ingestion of chemical substances has been undertaken using the approach presented by enHealth and the USEPA (enHealth 2012b; USEPA 1989). This approach is presented in the following equation, and parameters adopted in this assessment are presented in **Table C2**:

$$\text{Daily Chemical Intake}_{\text{Ingestion}} = C_M \bullet \frac{IR_M \bullet FI \bullet B \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Chemical substances that are deposited on the ground have the potential to be absorbed through the skin when skin comes in contact with soil or dust.

The assessment of the potential dermal absorption of chemical substances has been generally undertaken using the approach presented by the USEPA (USEPA 1989, 2004). The USEPA define a simple approach to the evaluation of dermal absorption associated with soil contact. This is presented in the following equation and parameters adopted in this assessment are presented in **Table C2**:

$$\text{Daily Chemical Intake}_{\text{Dermal}} = C_M \bullet \frac{SA \bullet AF \bullet ABSd \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Table C2: Ingestion and dermal exposure assumptions

Parameter		Value adopted		Basis
		Young children	Adults	
C_M	Concentration of chemical substance in media or relevance (soil, fruit and vegetables, eggs, milk or meat) (mg/kg or mg/L)	Modelled based on deposition of particulates to soil, adopting the maximum from all sensitive receptors		Calculations undertaken on the basis of the maximum predicted impacts relevant to areas where multi-pathway exposures may occur
IR_M	Ingestion rate of media			
	Soil (mg/day)	100 mg/day	50 mg/day	Ingestion rate of outdoor soil and dust (tracked or deposited indoors) as per enHealth (enHealth 2012a)
	Fruit and vegetables (kg/day)	0.28 kg/day 85% from aboveground crops 16% from root crops	0.4 kg/day 73% from aboveground crops 27% from root crops	Total fruit and vegetable intakes per day as per ASC NEPM (NEPC 1999 amended 2013c)
	Eggs (kg/day)	0.006 kg/day	0.014 kg/day	Ingestion rate of eggs per day as per enHealth (enHealth 2012a)

Parameter		Value adopted		Basis
		Young children	Adults	
	Milk (L/day)	1.097	1.295	Ingestion rate consistent with P90 intakes from FSANZ (FSANZ 2017a)
	Beef (kg/day)	0.085	0.16	Ingestion rate consistent with P90 intakes from FSANZ (FSANZ 2017a)
	Lamb (kg/day)	0.036	0.085	Ingestion rate consistent with P90 intakes from FSANZ (FSANZ 2017a)
FI	Fraction of media ingested derived from impacted media, or fraction of produce consumed each day derived from the property			
	Soil	100%	100%	Assume all soil contact occurs on the one property
	Fruit and vegetables	35%	35%	Default of 35% for rural areas (NEPC 1999 amended 2013c)
	Eggs and milk	100%	100%	Assume all eggs and milk are from the property
	Beef and lamb	35%	35%	Assume 35% all meat consumed is from the property (note conclusions remain unchanged if this was assumed to be 100%)
B	Bioavailability or absorption of chemical substance via ingestion	100%	100%	Conservative assumption
SA	Surface area of body exposed to soil per day (cm^2/day)	2700	6300	Exposed skin surface area relevant to adults as per ASC NEPM (NEPC 1999 amended 2013c)
AF	Adherence factor, amount of soil that adheres to the skin per unit area which depends on soil properties and area of body (mg/cm^2 per event)	0.5	0.5	Default (conservative) value from ASC NEPM (NEPC 1999 amended 2013c)
ABSd	Dermal absorption fraction (unitless)	Chemical specific		Refer to **Tables B2 and B3**
CF	Conversion factor			
	Soil	1×10^{-6} to convert mg to kg		Conversion of units relevant to soil ingestion and dermal contact
	Produce	1		No units conversion required for these calculations
BW	Body weight	15	70	As per enHealth (enHealth 2012a) and ASC NEPM (NEPC 1999 amended 2013c)
EF	Exposure frequency (days/year)	365	365	Assume residents exposed every day
ED	Exposure duration (years)	6	29	Duration of residency as per enHealth (enHealth 2012a) and split between young children and adults as per ASC NEPM (NEPC 1999 amended 2013c)
AT	Averaging time (days)	Threshold = ED x 365 days/year Non-threshold = 70 years x 365 days/year		As per enHealth (enHealth 2012b) guidance

C3.2 Calculation of concentrations in various media

Potential Concentrations in Soil

The potential accumulation of persistent and bioaccumulative chemical substances in soil, which may be the result of deposition from a number of air emissions source, can be estimated using a soil accumulation model (OEHHA 2015; Stevens 1991).

The concentration in soil, which may be the result of deposition following emission of persistent chemical substances, can be calculated using the following equation from Stevens (1991), with assumptions adopted in this assessment presented in **Table C3**.

$$C_s = \frac{DR \bullet [1-e^{-k \bullet t}]}{d \bullet \rho \bullet k} \bullet 1000 \qquad \text{(mg/kg)}$$

Table C3: Assumptions adopted to estimate soil concentrations

Parameter		Value adopted		Basis
		Surface soil*	Agricultural soil*	
DR	Particle deposition rate for accidental release (mg/m^2/year)	Modelled for the particulates emitted from the facility based on the deposition of TSP		Relevant to areas where multi-pathway exposures may occur
k	Chemical-specific soil-loss constant (1/year) = ln(2)/$T^{0.5}$	Calculated	Calculated	
$T^{0.5}$	Chemical half-life in soil (years)	Chemical specific	Chemical specific	Default values adopted for pollutants considered as per OEHHA (2015) with the value for dioxins from Lowe (Lowe, Dietrich & Alberts 1991)
t	Accumulation time (years)	70 years	70 years	Default value (OEHHA 2015) which is conservative for the operation of the Project but also covers the movement of wind-blown dust derived from Project deposition over time
d	Soil mixing depth (m)	0.01 m	0.15 m	Default values (OEHHA 2015)
ρ	Soil bulk-density (g/m^3)	1600000	1600000	Default for fill material (CRC CARE 2011)
1000	Conversion from g to kg	Default conversion of units		

* Surface soil values adopted for the assessment of direct contact exposures. All other exposures including produce intakes utilise soil concentrations calculated for agricultural intakes (OEHHA 2015)

Homegrown fruit and vegetables

Plants may become contaminated with persistent chemical substances via deposition directly onto the plant outer surface and following uptake via the root system. Both mechanisms have been assessed.

The potential concentration of persistent chemical substances that may be present within the plant following atmospheric deposition can be estimated using the following equation (Stevens 1991), with the parameters and assumptions adopted outlined in **Table C4**:

$$C_p = \frac{DR \cdot F \cdot [1-e^{-k \cdot t}]}{Y \cdot k}$$ (mg/kg plant – wet weight)

The potential uptake of persistent chemical substances into edible crops via the roots can be estimated using the following equation (OEHHA 2015; USEPA 2005), with the parameters and assumptions adopted outlined in **Table C4:**

$$C_{rp} = C_s \cdot RUF$$ (mg/kg plant – wet weight)

For the assessment of concentrations in grain crops (or similar crops), only the uptake from roots and translocation to grain or upper parts of the plant has been considered. Any deposition on the surface of the plant would be minor and would also be removed during processing of the grain (or other crop). The RUF adopted for this calculation is then specific to the movement of the chemical from soil to grain of upper part of the plant. This differs from the RUF from soil to the root.

Table C4: Assumptions adopted to estimate concentration in fruit and vegetables

Parameter		Value adopted	Basis
DR	Particle deposition rate for accidental release (mg/m^2/day)	Modelled for the particulates emitted from the facility based on the deposition of TSP	Relevant to areas where multi-pathway exposures may occur
F	Fraction for the surface area of plant (unitless)	0.051	Relevant to aboveground exposed crops as per Stevens (1991) and OEHHA (OEHHA 2012)
k	Chemical-specific loss constant for particles on plants (1/days) = ln(2)/$T^{0.5}$	calculated	
$T^{0.5}$	Chemical half-life on plant (day)	14 days	Weathering of particulates on plant surfaces does occur and in the absence of measured data, it is generally assumed that organics deposited onto the outer portion of plant surfaces have a weathering half-life of 14 days (Stevens, 1991)
t	Deposition time or length of growing season (days)	70 days	Relevant to aboveground crops based on the value relevant to tomatoes, consistent with the value adopted by Stevens (1991)
Y	Crop yield (kg/m^2)	2 kg/m^2	Value for aboveground crops (OEHHA 2015)
Cs	Concentration of pollutant in soil (mg/kg)	Calculated value for agricultural soil	Calculated as described above and assumptions in **Table C3**
RUF for root crops	Root uptake factor (unitless)	Chemical specific value adopted	Root uptake factors from RAIS (RAIS) (soil to wet weight of plant)
RUF for grains and upper parts of plant	Root uptake factor (unitless)	Chemical specific value adopted	Uptake factors adopted for grain based bioconcentration factors for grains and cereals (geometric mean value) from USEPA (USEPA 1996) and Staven (Staven et al. 2003). Where no value is available the root uptake factor has been assumed to be relevant to the uptake into grains (relevant to vanadium, dioxins/furans, dioxin-like PCBs and PAHs). Note that for PAHs the translocation from root to grain is expected to be negligible hence this approach is conservative

Eggs, milk, beef and lamb

The concentration of bioaccumulative chemicals in animal products is calculated on the basis of the intakes of these chemicals by the animal (chicken or cow) and the transfer of these chemicals to the edible produce. The approach adopted in this assessment has involved calculation of intakes from soil and pasture, where grown.

The concentration (C_P) calculated in eggs, milk, beef and lamb meat is calculated using the following equation (OEHHA 2015), with parameters and assumptions adopted presented in **Table C5**:

$$C_P = (FI \times IR_C \times C + IR_S \times C_s \times B) \times TF_P$$

Table C5: Assumptions adopted to estimate concentration in animal produce

Parameter		Value adopted	Basis
FI	Fraction of grain/crop ingested by animals each day derived from the property (unitless)	100%	Assume pasture is grown on the property
IR_C	Ingestion rate of pasture/crops by each animal considered (kg/day)		
	Chickens	0.12	As per OEHHA (2015)
	Beef cattle	9	Ingestion rate from OEHHA (2015)
	Lactating cattle	22	Ingestion rate for lactating cattle from OEHHA (2015)
	Lambs	1.1	Based on assumption of consuming 4.2% body weight per day dry matter (and assuming 20% moisture in feed)
C	Concentration of chemical in crops consumed by animals (mg/kg)	Assume equal to that calculated in aboveground produce	Calculated as described above with assumptions in **Table C4**
IR_S	Ingestion rate of soil by animals each day (kg/day)		
	Chickens	0.01 kg/day	As per OEHHA (2015) and advice from Ag Vic
	Beef cattle	0.45 kg/day	Based on data from OEHHA 2015 (5% total produce intakes from soil from pasture)
	Lactating cattle	1.1 kg/day	Based on data from OEHHA 2015 (5% total produce intakes from soil from pasture)
	Lambs	0.055	Assumed to be 5% crop intake
Cs	Concentration of chemical in soil (mg/kg)	Calculated value for agricultural soil	Calculated as described above and assumptions in **Table C3**
B	Bioavailability of soil ingested (unitless)	100%	Conservative assumption
TF_P	Transfer factor for the produce of interest		
	Eggs	Chemical specific	Transfer factors adopted from OEHHA (2015), with the exception of chromium where the value was derived from an earlier OEHHA (OEHHA 2003) evaluation and cobalt where the uptake value from an Australian database has been used (MacLachlan 2011). Other values are the 95% value for the transfer of heavy metals into eggs (Leeman, Van Den Berg & Houben 2007).

Parameter		Value adopted	Basis
	Beef	Chemical specific	Transfer factors adopted from OEHHA (OEHHA 2003, 2015) and RAIS (RAIS).
	Milk	Chemical specific	Transfer factors adopted from OEHHA (2015) and RAIS (RAIS).
	Lamb	Chemical specific	Transfer factors calculated using a metabolic weight adjustment factor of 10.4 from beef as per OEHHA (2012 and 2015 guidance).

All calculations relevant to the estimation of chemical concentrations in soil, fruit and vegetables as well as animal products are presented in **Appendices D and E**.

Rainwater tanks

The concentration in rainwater tanks depends on the deposition rate of dust, the size of the roof, the volume of rainfall each year and how much of the rain that falls onto the roof is captured in the tank. When dust is deposited onto a roof, some will be remobilised into air (wind) and blown off the roof before it can be washed into the tank. This has not been considered in this assessment.

In addition, health authorities[12] recommends the use of first flush devices to minimise the movement of accumulated dust, bird droppings and organic matter into the tank which can affect water quality (contamination and bacterial load). The use of a first flush device has not been considered in this assessment as it is unknown how many existing tanks use this device. For rainwater tanks used for drinking water purposes, it is expected that these would be maintained appropriately, in line with NSW Health and enHealth guidance (enHealth 2010), which includes the regular cleaning of tanks to remove accumulated sediments, maintaining roof materials, gutters and tank inlet, use of first flush devices and disinfection. The proper maintenance of rainwater tanks (specifically the cleaning out of sediments) would further reduce concentrations below those estimated in this assessment.

Based on mass balance modelling undertaken on rainwater tanks with first flush devices (Martinson & Thomas 2009) and measurements conducted in Australia (Kus et al. 2010), first flush devices can reduce concentrations in rainwater tanks by 90% or more. As noted above the use of a first flush devise has not been considered in this assessment.

The concentration in rainwater for project related emissions, which may be used for all household purposes is calculated as follows, where the parameters adopted for this assessment are detailed in **Table C6**:

$$C_W = \frac{DM}{VR \times Kd \times \rho}$$

[12] https://www.health.nsw.gov.au/environment/water/Documents/rainwater_tanks.pdf

$$VR = \frac{R \times Area \times Rc \times 1000}{1000}$$

Table C6: Assumptions adopted to estimate concentration in rainwater tanks

Parameter		Value adopted	Basis
DM	Mass of dust deposited on the roof each year that would enter the tank (mg)	DR x Area x 1 year	Conservative assumption that 100% of the dust deposited on the roof for a full year, washes into the rainwater tank (i.e., there is no first flush device and no dust is blown of the roof before being washed into the tank)
DR	Particle deposition rate (mg/m^2/year)	Relevant to the maximum sensitive receptor (for deposition of chemicals attached to TSP)	Relevant to areas where multi-pathway exposures may occur
Area	Area of the roof (m^2)	200	Based on the average roof size for a 4-bedroom house in Australia (refer to Footnote 1)
VR	Volume of water collected from the roof each year (L)	calculated	Equation as above
R	Rainfall each year (mm)	675.6	Average rainfall at Lake Bathurst for all years (1931 to 2020) from the Bureau of Meteorology
Rc	Runoff coefficient	0.7	Assumes 30% loss in capture of water into the tank (Lizárraga-Mendiola et al. 2015)
1000	Conversion from m^3 to L Conversion from mm to m		
Kd	Soil-water partition coefficient (cm^3/g)	Chemical-specific	All values for metals from RAIS (RAIS). For organics Kd has been calculated as Kd = Koc x Foc. Koc values obtained from RAIS or PubChem (for dioxins). FoC (fraction of organic carbon) assumed to be 1%.
ρ	Soil bulk density (g/cm^3)	0.5	Assumed for loose deposited dust on roof (upper end measured for powders)

1 - https://www.nedlands.wa.gov.au/sites/default/files/Rainwater%20tank%20factsheet.pdf

All calculations relevant to the estimation of pollutant concentrations in water are presented in **Appendix D**.

Appendix D Risk calculations for Scenario 2: Reference case maximum emissions

Inhalation exposures

Predicted ground level concentrations and screening assessment - acute exposures

		Air Concentration - Maximum 1 hour average (mg/m^3)				Calculated HI			
COPC	Acute air guideline - health (mg/m^3)	Maximum anywhere	Maximum - commercial/ industrial receptors	Maximum - residential, rural, school receptors	Maximum – Workers in wind turbine	Maximum anywhere	Maximum - commercial/ industrial receptors	Maximum - residential, rural, school receptors	Maximum – Workers in wind turbine
Hydrogen chloride (HCl)	0.66	0.012	0.0049	0.0015	0.023	0.018	0.0074	0.0023	0.035
Hydrogen fluoride (HF)	0.06	0.000031	0.0000128	0.0000040	0.000061	0.00052	0.00021	0.000067	0.0010
Ammonia	0.59	0.021	0.0085	0.0026	0.040	0.035	0.014	0.0045	0.068
VOCs - as benzene	0.58	0.0045	0.0019	0.00058	0.0089	0.0078	0.0032	0.0010	0.015
Antimony	0.001	0.000010	0.00000099	0.00000029		0.010	0.00099	0.00029	
Arsenic	0.0099	0.0000090	0.0000036	0.00000040		0.00091	0.00036	0.000041	
Cadmium	0.018	0.0000026	0.00000084	0.00000014		0.00014	0.000047	0.0000075	
Chromium (Cr VI assumed)	0.0013	0.0000084	0.0000034	0.00000071		0.0065	0.0026	0.00055	
Copper	0.1	0.0000016	0.00000086	0.00000018		0.000016	0.0000086	0.0000018	
Manganese	0.0091	0.000014	0.0000049	0.00000099		0.0016	0.00053	0.00011	
Mercury	0.0006	0.0000012	0.00000052	0.00000016		0.0021	0.00087	0.00027	
Nickel	0.0011	0.000019	0.0000098	0.0000019		0.017	0.0089	0.0017	
Vanadium	0.03	0.0000069	0.0000035	0.00000066		0.00023	0.00012	0.000022	
						0.10	0.032	0.0085	0.084

Inhalation - gases and particulates (Reference case)

$$InhalationExposureConc_V = C_a \bullet \frac{ET \bullet FI \bullet EF \bullet ED}{AT} \quad (mg/m^3)$$

Parameters Relevant to Quantification of Community Exposures - Commercial/industrial workers		
Exposure Time (ET, hr/day)	8	Assume exposure for 8 hours per day (enHealth 2012)
Fraction Inhaled from Source (FI, unitless)	1	Assume worker is at the same location all the time
Dust lung retention factor (unitless)	1	Percentage of respirable dust that is small enough to reach and be retained in the lungs (NEPM 1999 amended 2013) - assumed dust is PM2.5 for inhalation
Exposure Frequency - normal conditions (EF, days/yr)	240	Number of workdays per year as per enHealth (2012)
Exposure Duration (ED, years)	30	Duration of work at any one location as per enHealth (2012)
Averaging Time - NonThreshold (Atc, hours)	613200	US EPA 2009
Averaging Time - Threshold (Atn, hours)	262800	US EPA 2009

Maximum anywhere (boundary and off-site)

Key Chemical	Toxicity Data				Concentration	Daily Exposure		Calculated Risk			
	Inhalation Unit Risk $(mg/m^3)^{-1}$	Chronic TC Air (mg/m^3)	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background) (mg/m^3)	Estimated Concentration in Air - Maximum anywhere (Ca) (mg/m^3)	Inhalation Exposure Concentration - NonThreshold (mg/m^3)	Inhalation Exposure Concentration - Threshold (mg/m^3)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Hydrogen chloride (HCl)	0.0E+00	2.6E-02	0%	2.6E-02	3.5E-04	3.3E-05	7.7E-05	--		0.0029	6%
Hydrogen fluoride (HF)	0.0E+00	2.9E-02	0%	2.9E-02	9.2E-07	8.6E-08	2.0E-07	--		0.0000070	0%
Ammonia	0.0E+00	3.2E-01	0%	3.2E-01	6.1E-04	5.7E-05	1.3E-04	--		0.00042	1%
VOCs - as benzene	6.0E-03	3.0E-02	10%	2.7E-02	1.3E-04	1.3E-05	2.9E-05	7.6E-8		0.0011	2%
Antimony	0.0E+00	2.0E-04	0%	2.0E-04	8.6E-07	8.1E-08	1.9E-07	--		0.00095	2%
Arsenic	0.0E+00	6.7E-05	0%	6.7E-05	3.9E-07	3.6E-08	8.5E-08	--		0.0013	3%
Beryllium	0.0E+00	2.0E-05	0%	2.0E-05	1.0E-07	9.5E-09	2.2E-08	--		0.0011	2%
Cadmium	0.0E+00	5.0E-06	20%	4.0E-06	2.0E-07	1.9E-08	4.3E-08	--		0.011	22%
Chromium (Cr VI assumed)	0.0E+00	1.0E-04	0%	1.0E-04	2.9E-07	2.7E-08	6.3E-08	--		0.00063	1%
Copper	0.0E+00	4.9E-01	60%	2.0E-01	8.0E-08	7.5E-09	1.7E-08	--		0.000000089	0%
Cobalt	0.0E+00	1.0E-04	0%	1.0E-04	5.5E-06	5.2E-07	1.2E-06	--		0.012	24%
Lead	0.0E+00	5.0E-04	0%	5.0E-04	9.2E-06	8.7E-07	2.0E-06	--		0.0041	8%
Manganese	0.0E+00	1.5E-04	20%	1.2E-04	5.4E-07	5.0E-08	1.2E-07	--		0.00098	2%
Mercury	0.0E+00	2.0E-04	0%	2.0E-04	3.7E-08	3.4E-09	8.0E-09	--		0.000040	0%
Nickel	0.0E+00	2.0E-05	20%	1.6E-05	9.6E-07	9.0E-08	2.1E-07	--		0.013	26%
Thallium	0.0E+00	2.8E-03	0%	2.8E-03	1.6E-08	1.5E-09	3.4E-09	--		0.0000012	0%
Vanadium	0.0E+00	7.0E-03	0%	7.0E-03	3.6E-07	3.4E-08	8.0E-08	--		0.000011	0%
Zinc	0.0E+00	1.8E+00	80%	3.5E-01	1.3E-05	1.3E-06	2.9E-06	--		0.0000084	0%
PAHs (as BaP)	6.0E-01	0.0E+00	0%	0.0E+00	1.8E-08	1.7E-09	3.9E-09	1.0E-9		--	
Dioxins and furans (WHO-TEQ)	0.0E+00	8.1E-09	54%	3.7E-09	7.4E-13	6.9E-14	1.6E-13	--		0.000044	0%
Dioxin-like PCBs (WHO-TEQ)	0.0E+00	8.1E-09	54%	3.7E-09	1.6E-13	1.5E-14	3.5E-14	--		0.0000094	0%
							TOTAL	**8E-08**		**0.050**	

Maximum (commercial/industrial receptors)

Key Chemical	Toxicity Data				Concentration	Daily Exposure		Calculated Risk			
	Inhalation Unit Risk (mg/m^3)$^{-1}$	Chronic TC Air (mg/m^3)	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background) (mg/m^3)	Estimated Concentration in Air - Maximum C/I receptors (Ca) (mg/m^3)	Inhalation Exposure Concentration - NonThreshold (mg/m^3)	Inhalation Exposure Concentration - Threshold (mg/m^3)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Hydrogen chloride (HCl)	0.0E+00	2.6E-02	0%	2.6E-02	3.3E-04	3.1E-05	7.3E-05	--		0.0028	11%
Hydrogen fluoride (HF)	0.0E+00	2.9E-02	0%	2.9E-02	8.7E-07	8.2E-08	1.9E-07	--		0.0000066	0%
Ammonia	0.0E+00	3.2E-01	0%	3.2E-01	5.8E-04	5.4E-05	1.3E-04	--		0.00040	2%
VOCs - as benzene	6.0E-03	3.0E-02	10%	2.7E-02	1.3E-04	1.2E-05	2.8E-05	7.2E-8		0.0010	4%
Antimony	0.0E+00	2.0E-04	0%	2.0E-04	6.0E-08	5.6E-09	1.3E-08	--		0.000066	0%
Arsenic	0.0E+00	6.7E-05	0%	6.7E-05	1.8E-07	1.7E-08	4.0E-08	--		0.00059	2%
Beryllium	0.0E+00	2.0E-05	0%	2.0E-05	7.7E-08	7.2E-09	1.7E-08	--		0.00084	3%
Cadmium	0.0E+00	5.0E-06	20%	4.0E-06	3.1E-08	2.9E-09	6.7E-09	--		0.0017	7%
Chromium (Cr VI assumed)	0.0E+00	1.0E-04	0%	1.0E-04	1.8E-07	1.6E-08	3.8E-08	--		0.00038	1%
Copper	0.0E+00	4.9E-01	60%	2.0E-01	6.4E-08	6.0E-09	1.4E-08	--		0.000000072	0%
Cobalt	0.0E+00	1.0E-04	0%	1.0E-04	2.6E-06	2.4E-07	5.7E-07	--		0.0057	22%
Lead	0.0E+00	5.0E-04	0%	5.0E-04	2.6E-06	2.4E-07	5.6E-07	--		0.0011	4%
Manganese	0.0E+00	1.5E-04	20%	1.2E-04	2.8E-07	2.6E-08	6.2E-08	--		0.00051	2%
Mercury	0.0E+00	2.0E-04	0%	2.0E-04	3.5E-08	3.3E-09	7.7E-09	--		0.000038	0%
Nickel	0.0E+00	2.0E-05	20%	1.6E-05	7.6E-07	7.1E-08	1.7E-07	--		0.010	41%
Thallium	0.0E+00	2.8E-03	0%	2.8E-03	1.5E-08	1.4E-09	3.3E-09	--		0.0000012	0%
Vanadium	0.0E+00	7.0E-03	0%	7.0E-03	2.8E-07	2.7E-08	6.2E-08	--		0.0000088	0%
Zinc	0.0E+00	1.8E+00	80%	3.5E-01	6.0E-06	5.6E-07	1.3E-06	--		0.0000038	0%
PAHs (as BaP)	6.0E-01	0.0E+00	0%	0.0E+00	1.7E-08	1.6E-09	3.7E-09	9.5E-10		--	
Dioxins and furans (WHO-TEQ)	0.0E+00	8.1E-09	54%	3.7E-09	7.0E-13	6.6E-14	1.5E-13	--		0.000041	0%
Dioxin-like PCBs (WHO-TEQ)	0.0E+00	8.1E-09	54%	3.7E-09	1.5E-13	1.4E-14	3.3E-14	--		0.0000090	0%

Total	**7E-08**	**0.026**

Inhalation - gases and particulates (Reference case)

$$InhalationExposureConc_V = C_a \bullet \frac{ET \bullet FI \bullet EF \bullet ED}{AT} \quad (mg/m^3)$$

Parameters Relevant to Quantification of Community Exposures - Residents		
Exposure Time at Home (ET, hr/day)	24	Assume residents at home or on property 24 hours per day
Fraction Inhaled from Source (FI, unitless)	1	Assume resident at the same property
Dust lung retention factor (unitless)	1	Percentage of respirable dust that is small enough to reach and be retained in the lungs (NEPM 1999 amended 2013) - assumed dust is PM2.5 for inhalation
Exposure Frequency - normal conditions (EF, days/yr)	365	Days at home (normal conditions), as per NEPM (1999 amended 2013)
Exposure Duration (ED, years)	70	Duration at one residence - assumed for area
Averaging Time - NonThreshold (Atc, hours)	613200	US EPA 2009
Averaging Time - Threshold (Atn, hours)	613200	US EPA 2009

Maximum for sensitive receptors

Key Chemical	Toxicity Data				Concentration	Daily Exposure		Calculated Risk			
	Inhalation Unit Risk $(mg/m^3)^{-1}$	Chronic TC Air (mg/m^3)	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background) (mg/m^3)	Estimated Concentration in Air - Maximum sensitive receptors (Ca) (mg/m^3)	Inhalation Exposure Concentration - NonThreshold (mg/m^3)	Inhalation Exposure Concentration - Threshold (mg/m^3)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Hydrogen chloride (HCl)	0.0E+00	2.6E-02	0%	2.6E-02	6.4E-05	6.4E-05	6.4E-05	--		0.0024	24%
Hydrogen fluoride (HF)	0.0E+00	2.9E-02	0%	2.9E-02	1.7E-07	1.7E-07	1.7E-07	--		0.0000058	0%
Ammonia	0.0E+00	3.2E-01	0%	3.2E-01	1.1E-04	1.1E-04	1.1E-04	--		0.00035	3%
VOCs - as benzene	6.0E-03	3.0E-02	10%	2.7E-02	2.4E-05	2.4E-05	2.4E-05	1.5E-7		0.00090	9%
Antimony	0.0E+00	2.0E-04	0%	2.0E-04	1.1E-08	1.1E-08	1.1E-08	--		0.000056	1%
Arsenic	0.0E+00	6.7E-05	0%	6.7E-05	9.3E-09	9.3E-09	9.3E-09	--		0.00014	1%
Beryllium	0.0E+00	2.0E-05	0%	2.0E-05	2.8E-09	2.8E-09	2.8E-09	--		0.00014	1%
Cadmium	0.0E+00	5.0E-06	20%	4.0E-06	4.6E-09	4.6E-09	4.6E-09	--		0.0012	11%
Chromium (Cr VI assumed)	0.0E+00	1.0E-04	0%	1.0E-04	2.4E-08	2.4E-08	2.4E-08	--		0.00024	2%
Copper	0.0E+00	4.9E-01	60%	2.0E-01	4.3E-09	4.3E-09	4.3E-09	--		0.000000022	0%
Cobalt	0.0E+00	1.0E-04	0%	1.0E-04	1.4E-07	1.4E-07	1.4E-07	--		0.0014	14%
Lead	0.0E+00	5.0E-04	0%	5.0E-04	1.3E-07	1.3E-07	1.3E-07	--		0.00025	3%
Manganese	0.0E+00	1.5E-04	20%	1.2E-04	3.0E-08	3.0E-08	3.0E-08	--		0.00025	2%
Mercury	0.0E+00	2.0E-04	0%	2.0E-04	6.6E-09	6.6E-09	6.6E-09	--		0.000033	0%
Nickel	0.0E+00	2.0E-05	20%	1.6E-05	4.3E-08	4.3E-08	4.3E-08	--		0.0027	27%
Thallium	0.0E+00	2.8E-03	0%	2.8E-03	2.8E-09	2.8E-09	2.8E-09	--		0.0000010	0%
Vanadium	0.0E+00	7.0E-03	0%	7.0E-03	1.4E-08	1.4E-08	1.4E-08	--		0.0000020	0%
Zinc	0.0E+00	1.8E+00	80%	3.5E-01	4.7E-07	4.7E-07	4.7E-07	--		0.0000013	0%
PAHs (as BaP)	6.0E-01	0.0E+00	0%	0.0E+00	3.2E-09	3.2E-09	3.2E-09	1.9E-9		--	
Dioxins and furans (WHO-TEQ)	0.0E+00	8.1E-09	54%	3.7E-09	1.3E-13	1.3E-13	1.3E-13	--		0.000036	0%
Dioxin-like PCBs (WHO-TEQ)	0.0E+00	8.1E-09	54%	3.7E-09	2.9E-14	2.9E-14	2.9E-14	--		0.0000078	0%
							TOTAL	1E-07		0.010	

Multi-pathway exposures for maximum sensitive receptor

Soil exposures

Calculation of Concentrations in Soil (Reference case)

$$C_s = \frac{DR \bullet \left[1 - e^{-k \bullet t}\right]}{d \bullet \rho \bullet k} \bullet 1000$$ **(mg/kg)** ref: Stevens B. (1991)

where:

DR=	Particle deposition rate (mg/m^2/year)
K =	Chemical-specific soil-loss constant (1/year) = ln(2)/T0.5
T0.5 =	Chemical half-life in soil (years)
t =	Accumulation time (years)
d =	Soil mixing depth (m)
ρ =	Soil bulk-density (g/m^3)
1000 =	Conversion from g to kg

General Parameters		Surface (for direct contact)	Depth (for agricultural pathways)	
Soil bulk density (p)	g/m^3	1600000	1600000	Default for fill materials
General mixing depth (d)	m	0.01	0.15	As per OEHHA (2015) guidance
Duration of deposition (T)	years	70	70	Duration of operation (conservative assumption)

Chemical-specific Inputs and calculations - maximum sensitive receptors

Chemical	Half-life in soil years	Loss constant (K) per year	Deposition Rate (DR) mg/m^2/year	Surface Concentration in Soil mg/kg	Agricultural Concentration in Soil mg/kg
Antimony	273973	2.5E-06	1.1E-02	4.9E-02	3.2E-03
Arsenic	273973	2.5E-06	4.4E-02	1.9E-01	1.3E-02
Beryllium	273973	2.5E-06	3.9E-04	1.7E-03	1.1E-04
Cadmium	273973	2.5E-06	1.0E-02	4.5E-02	3.0E-03
Chromium (Cr VI assumed)	273973	2.5E-06	3.5E-02	1.5E-01	1.0E-02
Copper	273973	2.5E-06	1.3E-03	5.8E-03	3.9E-04
Cobalt	273973	2.5E-06	6.4E-01	2.8E+00	1.9E-01
Lead	273973	2.5E-06	1.1E+00	4.6E+00	3.1E-01
Manganese	273973	2.5E-06	1.8E-02	8.0E-02	5.4E-03
Mercury	273973	2.5E-06	1.8E-03	7.7E-03	5.1E-04
Nickel	273973	2.5E-06	1.8E-02	8.0E-02	5.3E-03
Thallium	273973	2.5E-06	6.4E-04	2.8E-03	1.9E-04
Vanadium	273973	2.5E-06	3.3E-03	1.4E-02	9.5E-04
Zinc	273973	2.5E-06	1.7E+00	7.4E+00	4.9E-01
PAHs (as BaP)	1.18	5.9E-01	3.5E-04	3.7E-05	2.5E-06
Dioxins and furans (WHO-TEQ)	41	0.017	1.4E-08	3.7E-08	2.5E-09
Dioxin-like PCBs (WHO-TEQ)	41	0.017	3.1E-09	8.1E-09	5.4E-10

Half-life in soil: dioxin value from Lowe et al (1991) and metals, PAHs from OEHHA (2015)

Exposure to Chemicals via Incidental Ingestion of Soil (Reference case)

$$Daily\ Chemical\ Intake_{IS} = C_S \bullet \frac{IR_S \bullet FI \bullet CF \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Adults		
Ingestion Rate (IRs, mg/day)	50	As per NEPM 2013
Fraction Ingested from Source (FI, unitless)	100%	All of daily soil intake occurs from site
Exposure Frequency (EF, days/year)	365	Days at home (normal conditions), as per NEPM (1999 amended 2013)
Exposure Duration (ED, years)	64	Time at one residence as adult (child and adult adds to 70 yrs)
Body Weight (BW, kg)	70	For male and females combined (enHealth 2012)
Conversion Factor (CF)	1.00E-06	conversion from mg to kg
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	23360	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Soil Concentration (mg/kg)	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)			NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	4.9E-02	3.2E-08	3.5E-08	--		4.0E-05	1%
Arsenic		2.0E-03	50%	1.0E-03	100%	1.9E-01	1.3E-07	1.4E-07	--		1.4E-04	3%
Beryllium		2.0E-03		2.0E-03	100%	1.7E-03	1.1E-09	1.2E-09	--		6.1E-07	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	4.5E-02	2.9E-08	3.2E-08	--		1.0E-04	2%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	1.5E-01	9.9E-08	1.1E-07	--		1.3E-04	3%
Copper		1.4E-01	60%	5.6E-02	100%	5.8E-03	3.8E-09	4.2E-09	--		7.5E-08	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	2.8E+00	1.8E-06	2.0E-06	--		1.8E-03	42%
Lead		3.5E-03	50%	1.8E-03	100%	4.6E+00	3.0E-06	3.3E-06	--		1.9E-03	45%
Manganese		1.4E-01	50%	7.0E-02	100%	8.0E-02	5.2E-08	5.7E-08	--		8.2E-07	0%
Mercury		6.0E-04	40%	3.6E-04	100%	7.7E-03	5.0E-09	5.5E-09	--		1.5E-05	0%
Nickel		1.2E-02	60%	4.8E-03	100%	8.0E-02	5.2E-08	5.7E-08	--		1.2E-05	0%
Thallium		8.0E-04		8.0E-04	100%	2.8E-03	1.8E-09	2.0E-09	--		2.5E-06	0%
Vanadium		2.0E-03		2.0E-03	100%	1.4E-02	9.3E-09	1.0E-08	--		5.1E-06	0%
Zinc		5.0E-01	80%	1.0E-01	100%	7.4E+00	4.8E-06	5.3E-06	--		5.3E-05	1%
PAHs (as BaP)	2.3E-01				100%	3.7E-05	2.4E-11	2.7E-11	5.7E-12		--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	3.7E-08	2.4E-14	2.7E-14	--		2.5E-05	1%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	8.1E-09	5.3E-15	5.8E-15	--		5.4E-06	0%

TOTAL	**5.7E-12**	**4.2E-3**

Exposure to Chemicals via Incidental Ingestion of Soil (Reference case)

$$\textit{Daily Chemical Intake}_{IS} = C_S \bullet \frac{IR_S \bullet FI \bullet CF \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Young Children		
Ingestion Rate (IRs, mg/day)	100	Assumed daily soil ingestion rate for young children, enHealth (2012)
Fraction Ingested from Source (FI, unitless)	100%	All of daily soil intake occurs from site
Exposure Frequency (EF, days/year)	365	Days at home (normal conditions), as per NEPM (1999 amended 2013)
Exposure Duration (ED, years)	6	Duration as young child
Body Weight (BW, kg)	15	Representative weight as per NEPM (2013)
Conversion Factor (CF)	1.00E-06	conversion from mg to kg
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Soil Concentration	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/kg)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	4.9E-02	2.8E-08	3.2E-07	--		3.8E-04	1%
Arsenic		2.0E-03	50%	1.0E-03	100%	1.9E-01	1.1E-07	1.3E-06	--		1.3E-03	3%
Beryllium		2.0E-03		2.0E-03	100%	1.7E-03	9.8E-10	1.1E-08	--		5.7E-06	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	4.5E-02	2.6E-08	3.0E-07	--		9.3E-04	2%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	1.5E-01	8.7E-08	1.0E-06	--		1.3E-03	3%
Copper		1.4E-01	60%	5.6E-02	100%	5.8E-03	3.3E-09	3.9E-08	--		7.0E-07	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	2.8E+00	1.6E-06	1.9E-05	--		1.7E-02	42%
Lead		3.5E-03	50%	1.8E-03	100%	4.6E+00	2.6E-06	3.1E-05	--		1.8E-02	45%
Manganese		1.4E-01	50%	7.0E-02	100%	8.0E-02	4.6E-08	5.4E-07	--		7.6E-06	0%
Mercury		6.0E-04	40%	3.6E-04	100%	7.7E-03	4.4E-09	5.1E-08	--		1.4E-04	0%
Nickel		1.2E-02	60%	4.8E-03	100%	8.0E-02	4.6E-08	5.3E-07	--		1.1E-04	0%
Thallium		8.0E-04		8.0E-04	100%	2.8E-03	1.6E-09	1.9E-08	--		2.3E-05	0%
Vanadium		2.0E-03		2.0E-03	100%	1.4E-02	8.2E-09	9.5E-08	--		4.8E-05	0%
Zinc		5.0E-01	80%	1.0E-01	100%	7.4E+00	4.2E-06	4.9E-05	--		4.9E-04	1%
PAHs (as BaP)	2.3E-01				100%	3.7E-05	2.1E-11	2.5E-10	5.0E-12		--	
Dioxins and furans (WHO-TE		2.3E-09	54%	1.1E-09	100%	3.7E-08	2.1E-14	2.5E-13	--		2.3E-04	1%
Dioxin-like PCBs (WHO-TE(		2.3E-09	54%	1.1E-09	100%	8.1E-09	4.6E-15	5.4E-14	--		5.1E-05	0%
								TOTAL	**5.0E-12**		**3.9E-2**	

Dermal Exposure to Chemicals via Contact with Soil (Reference case)

$$Daily\ Chemical\ Intake_{DS} = C_S \bullet \frac{SA_S \bullet AF \bullet FE \bullet ABS \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Adults		
Surface Area (SAs, cm^2)	6300	Exposed skin surface area for adults as per NEPM (2013)
Adherence Factor (AF, mg/cm^2)	0.5	Default as per NEPM (2013)
Fraction of Day Exposed	1	Assume skin is washed after 24 hours
Conversion Factor (CF)	1.E-06	Conversion of units
Dermal absorption (ABS, unitless)	Chemical-specific (as below)	
Exposure Frequency (EF, days/year)	365	Days at home (normal conditions), as per NEPM (1999 amended 2013)
Exposure Duration (ED, years)	64	Time at one residence as adult (child and adult adds to 70 yrs)
Body Weight (BW, kg)	70	For male and females combined (enHealth 2012)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	23360	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data					Soil Concentration	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Dermal Absorption (ABS)		Non-Threshold	Threshold	Non-Threshold Risk	% Total Risk	Chronic Hazard Quotient	% Total HI
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)		(unitless)	
Antimony		8.6E-04		8.6E-04		4.9E-02			--		--	
Arsenic		2.0E-03	50%	1.0E-03		1.9E-01			--		--	
Beryllium		2.0E-03		2.0E-03		1.7E-03			--		--	
Cadmium		8.0E-04	60%	3.2E-04		4.5E-02			--		--	
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04		1.5E-01			--		--	
Copper		1.4E-01	60%	5.6E-02		5.8E-03			--		--	
Cobalt		1.4E-03	20%	1.1E-03	0.001	2.8E+00	1.1E-07	1.3E-07	--		1.1E-04	
Lead		3.5E-03	50%	1.8E-03		4.6E+00			--		--	
Manganese		1.4E-01	50%	7.0E-02		8.0E-02			--		--	
Mercury		6.0E-04	40%	3.6E-04	0.001	7.7E-03	3.2E-10	3.5E-10	--		9.6E-07	
Nickel		1.2E-02	60%	4.8E-03		8.0E-02			--		--	
Thallium		8.0E-04		8.0E-04		2.8E-03			--		--	
Vanadium		2.0E-03		2.0E-03		1.4E-02			--		--	
Zinc		5.0E-01	80%	1.0E-01	0.001	7.4E+00	3.0E-07	3.3E-07	--		3.3E-06	
PAHs (as BaP)	2.3E-01				0.06	3.7E-05	9.2E-11	1.0E-10	2.1E-11		--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	0.03	3.7E-08	4.6E-14	5.0E-14	--		4.7E-05	
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	0.03	8.1E-09	9.9E-15	1.1E-14	--		1.0E-05	
								TOTAL	**2.1E-11**		**1.7E-04**	

Dermal Exposure to Chemicals via Contact with Soil (Reference case)

$$Daily\ Chemical\ Intake_{DS} = C_S \bullet \frac{SA_S \bullet AF \bullet FE \bullet ABS \bullet CF \bullet EF \bullet ED}{BW \bullet AT}$$ **(mg/kg/day)**

Parameters Relevant to Quantification of Exposure by Young Children		
Surface Area (SAs, cm^2)	2700	Exposed skin surface area for young children as per NEPM (2013)
Adherence Factor (AF, mg/cm^2)	0.5	Default as per NEPM (2013)
Fraction of Day Exposed	1	Assume skin is washed after 24 hours
Conversion Factor (CF)	1.E-06	Conversion of units
Dermal absorption (ABS, unitless)	Chemical-specific (as below)	
Exposure Frequency (EF, days/year)	365	Days at home (normal conditions), as per NEPM (1999 amended 2013)
Exposure Duration (ED, years)	6	Duration as young child
Body Weight (BW, kg)	15	Representative weight as per NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data					Soil Concentration	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Dermal Absorption (ABS)		Non-Threshold	Threshold	Non-Threshold Risk	% Total Risk	Chronic Hazard Quotient	% Total HI
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)		(unitless)	
Antimony		8.6E-04		8.6E-04		4.9E-02			--		--	
Arsenic		2.0E-03	50%	1.0E-03		1.9E-01			--		--	
Beryllium		2.0E-03		2.0E-03		1.7E-03			--		--	
Cadmium		8.0E-04	60%	3.2E-04		4.5E-02			--		--	
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04		1.5E-01			--		--	
Copper		1.4E-01	60%	5.6E-02		5.8E-03			--		--	
Cobalt		1.4E-03	20%	1.1E-03	0.001	2.8E+00	2.2E-08	2.5E-07	--		2.2E-04	
Lead		3.5E-03	50%	1.8E-03		4.6E+00			--		--	
Manganese		1.4E-01	50%	7.0E-02		8.0E-02			--		--	
Mercury		6.0E-04	40%	3.6E-04	0.001	7.7E-03	5.9E-11	6.9E-10	--		1.9E-06	
Nickel		1.2E-02	60%	4.8E-03		8.0E-02			--		--	
Thallium		8.0E-04		8.0E-04		2.8E-03			--		--	
Vanadium		2.0E-03		2.0E-03		1.4E-02			--		--	
Zinc		5.0E-01	80%	1.0E-01	0.001	7.4E+00	5.7E-08	6.6E-07	--		6.6E-06	
PAHs (as BaP)	2.3E-01				0.06	3.7E-05	1.7E-11	2.0E-10	4.0E-12		--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	0.03	3.7E-08	8.6E-15	1.0E-13	--		9.5E-05	
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	0.03	8.1E-09	1.9E-15	2.2E-14	--		2.1E-05	

TOTAL	**4.0E-12**	**3.5E-04**

Homegrown fruit and vegetables and crops

Calculation of Concentrations in Plants

ref: Stevens B. (1991)

Uptake Due to Deposition in Aboveground Crops	**Uptake via Roots from Soil**
$C_p = \frac{DR \bullet F \bullet \left[1 - e^{-k \bullet t}\right]}{Y \bullet k}$ (mg/kg plant – wet weight)	$C_{rp} = C_s \bullet RUF$ (mg/kg plant – wet weight)
where: DR= Particle deposition rate for accidental release (mg/m^2/day) F= Fraction for the surface area of plant (unitless) k= Chemical-specific soil-loss constant (1/years) = ln(2)/$T_{0.5}$ $T_{0.5}$= Chemical half-life as particulate on plant (days) t= Deposition time (days) Y= Crop yield (kg/m^2)	**where**: Cs = Concentration of persistent chemical in soil assuming 15cm mixing depth within gardens, calculated using Soil Equation for each chemical assessed (mg/kg) RUF = Root uptake factor which differs for each Chemical (unitless)

General Parameters	Units	Value
Crop		Edible crops
Crop Yield (Y)	kg/m^2	2
Deposition Time (t)	days	70
Plant Interception fraction (F)	unitless	0.051

Chemical-specific Inputs and calculations - Maximum sensitive receptors

Chemical	Half-life in plant ($T_{0.5}$)	Loss constant (k)	Deposition Rate (DR)	Aboveground Produce Concentration via Deposition	Root Uptake Factor (RUF) (A)	Soil Concentration (Cs)	Below Ground Produce Concentration	Uptake factor into grain crops (from soil) (B)	Concetration in grain crops
	days	per day	mg/m^2/day	mg/kg ww	unitless	mg/kg	mg/kg ww	unitless	mg/kg ww
Antimony	14	0.05	3.0E-05	1.5E-05	0.05	3.2E-03	1.6E-04	0.03	9.7E-05
Arsenic	14	0.05	1.2E-04	6.0E-05	0.01	1.3E-02	1.3E-04	0.026	3.3E-04
Beryllium	14	0.05	1.1E-06	5.3E-07	0.0025	1.1E-04	2.9E-07	0.002	2.3E-07
Cadmium	14	0.05	2.8E-05	1.4E-05	0.125	3.0E-03	3.7E-04	0.36	1.1E-03
Chromium (Cr VI assumed)	14	0.05	9.5E-05	4.8E-05	0.00188	1.0E-02	1.9E-05	0.0045	4.6E-05
Copper	14	0.05	3.7E-06	1.8E-06	0.1	3.9E-04	3.9E-05	0.25	9.7E-05
Cobalt	14	0.05	1.7E-03	8.7E-04	0.005	1.9E-01	9.3E-04	0.0037	6.9E-04
Lead	14	0.05	2.9E-03	1.4E-03	0.0113	3.1E-01	3.5E-03	0.0047	1.4E-03
Manganese	14	0.05	5.0E-05	2.5E-05	0.0625	5.4E-03	3.3E-04	0.3	1.6E-03
Mercury	14	0.05	4.8E-06	2.4E-06	0.225	5.1E-04	1.2E-04	0.0854	4.4E-05
Nickel	14	0.05	5.0E-05	2.5E-05	0.015	5.3E-03	8.0E-05	0.01	5.3E-05
Thallium	14	0.05	1.8E-06	8.8E-07	0.001	1.9E-04	1.9E-07	0.004	7.5E-07
Vanadium	14	0.05	9.0E-06	4.5E-06	0.00138	9.5E-04	1.3E-06	0.00138	1.3E-06
Zinc	14	0.05	4.6E-03	2.3E-03	0.264	4.9E-01	1.3E-01	0.1	4.9E-02
PAHs (as BaP)	14	0.05	9.6E-07	4.8E-07	0.00214	2.5E-06	5.3E-09	0.00214	5.3E-09
Dioxins and furans (WHO-TEQ)	14	0.05	4.0E-11	2.0E-11	0.000876	2.5E-09	2.2E-12	0.000876	2.2E-12
Dioxin-like PCBs (WHO-TEQ)	14	0.05	8.6E-12	4.3E-12	0.000876	5.4E-10	4.7E-13	0.000876	4.7E-13

(A) Root uptake factors from RAIS (soil to wet weight of plant)
Note uptake into plants from soil considered insignificant as dioxins are very poorly soluble (OEHHA 2015 and USEPA 1994)
(B) Uptake factors adopted for grain based bioconcentration factors for grains and cereals (geometric mean value) from USEPA (1996) and Staven (2003)
Where no value is available the root uptake factor has been assumed to be relevant to the uptake into grains (relevant to vanadium, dioxins/furans and PAHs). Note that for PAHs the translocation from root to grain is expected to be negligible hence this approach is conservative

Exposure to Chemicals via Ingestion of Homegrown Fruit and Vegetables (Reference case)

$$\text{Daily chemical intake} = C_A \times \frac{IR_P \times \%A \times FI \times ME \times EF \times ED}{BW \times AT} + C_R \times \frac{IR_P \times \%R \times FI \times ME \times ED \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Adults		
Ingestion Rate of Produce (IRp) (kg/day)	0.4	Total fruit and vegetable consumption rate for adults as per NEPM (2013)
Proportion of total intake from aboveground crops (%A	73%	Proportions as per NEPM (2013)
Proportion of total intake from root crops (%R)	27%	Proportions as per NEPM (2013)
Fraction ingested that is homegrown (%)	10%	Relevant to urban areas as per NEPM (2013)
Matrix effect (unitless)	1	Assume chemicals ingested in produce is 100% bioavailable
Exposure Frequency (EF, days/year)	365	Days at home (normal conditions), as per NEPM (1999 amended 2013)
Exposure Duration (ED, years)	64	Time at one residence as adult (child and adult adds to 70 yrs)
Body Weight (BW, kg)	70	For male and females combined (enHealth 2012)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	23360	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Above ground produce concentration	Root crops concentrations	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/kg wet weight)	(mg/kg wet weight)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	1.5E-05	1.6E-04	2.9E-08	3.1E-08	--		3.6E-05	2%
Arsenic		2.0E-03	50%	1.0E-03	100%	6.0E-05	1.3E-04	4.1E-08	4.5E-08	--		4.5E-05	3%
Beryllium		2.0E-03		2.0E-03	100%	5.3E-07	2.9E-07	2.4E-10	2.7E-10	--		1.3E-07	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	1.4E-05	3.7E-04	5.8E-08	6.3E-08	--		2.0E-04	12%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	4.8E-05	1.9E-05	2.1E-08	2.3E-08	--		2.8E-05	2%
Copper		1.4E-01	60%	5.6E-02	100%	1.8E-06	3.9E-05	6.2E-09	6.8E-09	--		1.2E-07	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	8.7E-04	9.3E-04	4.6E-07	5.1E-07	--		4.5E-04	27%
Lead		3.5E-03	50%	1.8E-03	100%	1.4E-03	3.5E-03	1.0E-06	1.1E-06	--		6.5E-04	38%
Manganese		1.4E-01	50%	7.0E-02	100%	2.5E-05	3.3E-04	5.7E-08	6.2E-08	--		8.9E-07	0%
Mercury		6.0E-04	40%	3.6E-04	100%	2.4E-06	1.2E-04	1.7E-08	1.9E-08	--		5.2E-05	3%
Nickel		1.2E-02	60%	4.8E-03	100%	2.5E-05	8.0E-05	2.1E-08	2.3E-08	--		4.7E-06	0%
Thallium		8.0E-04		8.0E-04	100%	8.8E-07	1.9E-07	3.6E-10	3.9E-10	--		4.9E-07	0%
Vanadium		2.0E-03		2.0E-03	100%	4.5E-06	1.3E-06	1.9E-09	2.1E-09	--		1.0E-06	0%
Zinc		5.0E-01	80%	1.0E-01	100%	2.3E-03	1.3E-01	1.9E-05	2.1E-05	--		2.1E-04	12%
PAHs (as BaP)	2.3E-01				100%	4.8E-07	5.3E-09	1.8E-10	2.0E-10	4.3E-11		--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	2.0E-11	2.2E-12	7.9E-15	8.6E-15	--		8.1E-06	0%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	4.3E-12	4.7E-13	1.7E-15	1.9E-15	--		1.8E-06	0%
									TOTAL	4.3E-11		1.7E-03	

Exposure to Chemicals via Ingestion of Homegrown Fruit and Vegetables (Reference case)

$$\text{Daily chemical intake} = C_A \times \frac{IR_P \times \%A \times FI \times ME \times EF \times ED}{BW \times AT} + C_R \times \frac{IR_P \times \%R \times FI \times ME \times ED \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

Scenario 2

Parameters Relevant to Quantification of Exposure by Young children		
Ingestion Rate of Produce (IRp) (kg/day)	0.28	Total fruit and vegetable consumption rate for children as per NEPM (2013)
Proportion of total intake from aboveground crops (%A	84%	Proportions as per NEPM (2013)
Proportion of total intake from root crops (%R)	16%	Proportions as per NEPM (2013)
Fraction ingested that is homegrown (%)	10%	Relevant to urban areas as per NEPM (2013)
Matrix effect (unitless)	1	Assume chemicals ingested in produce is 100% bioavailable
Exposure Frequency (EF, days/year)	365	Days at home (normal conditions), as per NEPM (1999 amended 2013)
Exposure Duration (ED, years)	6	Duration as young child
Body Weight (BW, kg)	15	Representative weight as per NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Above ground produce concentration	Root crops concentrations	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/kg wet weight)	(mg/kg wet weight)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	1.5E-05	1.6E-04	6.2E-09	7.2E-08	--		8.4E-05	2%
Arsenic		2.0E-03	50%	1.0E-03	100%	6.0E-05	1.3E-04	1.1E-08	1.3E-07	--		1.3E-04	3%
Beryllium		2.0E-03		2.0E-03	100%	5.3E-07	2.9E-07	7.9E-11	9.2E-10	--		4.6E-07	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	1.4E-05	3.7E-04	1.1E-08	1.3E-07	--		4.2E-04	9%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	4.8E-05	1.9E-05	6.9E-09	8.0E-08	--		9.9E-05	2%
Copper		1.4E-01	60%	5.6E-02	100%	1.8E-06	3.9E-05	1.2E-09	1.5E-08	--		2.6E-07	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	8.7E-04	9.3E-04	1.4E-07	1.6E-06	--		1.5E-03	31%
Lead		3.5E-03	50%	1.8E-03	100%	1.4E-03	3.5E-03	2.8E-07	3.3E-06	--		1.9E-03	40%
Manganese		1.4E-01	50%	7.0E-02	100%	2.5E-05	3.3E-04	1.2E-08	1.4E-07	--		2.0E-06	0%
Mercury		6.0E-04	40%	3.6E-04	100%	2.4E-06	1.2E-04	3.3E-09	3.8E-08	--		1.1E-04	2%
Nickel		1.2E-02	60%	4.8E-03	100%	2.5E-05	8.0E-05	5.4E-09	6.3E-08	--		1.3E-05	0%
Thallium		8.0E-04		8.0E-04	100%	8.8E-07	1.9E-07	1.2E-10	1.4E-09	--		1.8E-06	0%
Vanadium		2.0E-03		2.0E-03	100%	4.5E-06	1.3E-06	6.3E-10	7.4E-09	--		3.7E-06	0%
Zinc		5.0E-01	80%	1.0E-01	100%	2.3E-03	1.3E-01	3.6E-06	4.2E-05	--		4.2E-04	9%
PAHs (as BaP)	2.3E-01				100%	4.8E-07	5.3E-09	6.5E-11	7.5E-10	1.5E-11		--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	2.0E-11	2.2E-12	2.7E-15	3.2E-14	--		3.0E-05	1%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	4.3E-12	4.7E-13	5.9E-16	6.9E-15	--		6.5E-06	0%

TOTAL	**1.5E-11**	**4.7E-03**

Ingestion of eggs

Calculation of Concentrations in Eggs (Reference case)

Uptake in to chicken eggs

$$C_E = (FI \times IR_C \times C + IR_S \times C_S \times B) \times TF_E$$ (mg/kg egg – wet weight)

where:
FI = Fraction of pasture/crop ingested by chickens each day (unitless)
IRc = Ingestion rate of pasture/crop by chicken each day (kg/day)
C = Concentration of chemical in grain/crop eaten by chicken (mg/kg)
IRs = Ingestion rate of soil by chickens each day (kg/day)
Cs = Concentration in soil the chickens ingest (mg/kg)
B = Bioavailability of soil ingested by chickens (%)
TFE = Transfer factor from ingestion to eggs (day/kg)

General Parameters	Units	Value	
FI (fraction of crops ingested from property)		1	Assume pasture is grown on the site
IRc (ingestion rate of crops)	kg/day	0.12	As per OEHHA (2015)
IRs (ingestion rate of soil)	kg/day	0.01	As per OEHHA (2015) and advice from AgVIC
B (bioavailability)	%	100%	

Chemical-specific Inputs and calculations - Maximum sensitive receptors

Chemical	Concentration in crops ingested by chickens mg/kg ww	Soil Concentration - Agriculture (Cs) mg/kg	Transfer factor to eggs day/kg	Egg Concentration mg/kg ww	
Antimony	1.5E-05	3.2E-03	1.7E-01	5.8E-06	95% from Leeman et al (2007)
Arsenic	6.0E-05	1.3E-02	7.0E-02	9.5E-06	
Beryllium	5.3E-07	1.1E-04	9.0E-02	1.1E-07	
Cadmium	1.4E-05	3.0E-03	1.0E-02	3.1E-07	
Chromium (Cr VI assumed)	4.8E-05	1.0E-02	9.2E-03	9.9E-07	OEHHA (2003)
Copper	1.8E-06	3.9E-04	1.7E-01	7.0E-07	95% from Leeman et al (2007)
Cobalt	8.7E-04	1.9E-01	3.3E-03	6.5E-06	MacLachlan (2011)
Lead	1.4E-03	3.1E-01	4.0E-02	1.3E-04	
Manganese	2.5E-05	5.4E-03	1.7E-01	9.6E-06	
Mercury	2.4E-06	5.1E-04	8.0E-01	4.3E-06	
Nickel	2.5E-05	5.3E-03	2.0E-02	1.1E-06	
Thallium	8.8E-07	1.9E-04	1.7E-01	3.4E-07	95% from Leeman et al (2007)
Vanadium	4.5E-06	9.5E-04	1.7E-01	1.7E-06	95% from Leeman et al (2007)
Zinc	2.3E-03	4.9E-01	1.7E-01	8.8E-04	95% from Leeman et al (2007)
PAHs (as BaP)	4.8E-07	2.5E-06	3.0E-03	2.5E-10	
Dioxins and furans (WHO-TEQ)	2.0E-11	2.5E-09	1.0E+01	2.7E-10	
Dioxin-like PCBs (WHO-TEQ)	4.3E-12	5.4E-10	1.0E+01	5.9E-11	

Transfer factors from OEHHA 2015 unless otherwise noted

Exposure to Chemicals via Ingestion of Eggs (Reference case)

$$\text{Daily chemical intake} = C_E \times \frac{IR_E \times FI \times ME \times EF \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Adults		
Ingestion Rate of Eggs (IRE) (kg/day)	0.014	Ingestion rate of eggs relevant for adults as per enHealth (2012)
Fraction ingested that is homegrown (%)	100%	Assume all eggs consumed in urban area are from backyard chickens
Matrix effect (unitless)	1	Assume chemicals ingested in produce is 100% bioavailable
Exposure Frequency (EF, days/year)	365	Days at home (normal conditions), as per NEPM (1999 amended 2013)
Exposure Duration (ED, years)	64	Time at one residence as adult (child and adult adds to 70 yrs)
Body Weight (BW, kg)	70	For male and females combined (enHealth 2012)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	23360	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Egg concentration	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/kg wet weight)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	5.8E-06	1.1E-09	1.2E-09	--		1.4E-06	2%
Arsenic		2.0E-03	50%	1.0E-03	100%	9.5E-06	1.7E-09	1.9E-09	--		1.9E-06	2%
Beryllium		2.0E-03		2.0E-03	100%	1.1E-07	2.0E-11	2.2E-11	--		1.1E-08	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	3.1E-07	5.7E-11	6.3E-11	--		2.0E-07	0%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	9.9E-07	1.8E-10	2.0E-10	--		2.4E-07	0%
Copper		1.4E-01	60%	5.6E-02	100%	7.0E-07	1.3E-10	1.4E-10	--		2.5E-09	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	6.5E-06	1.2E-09	1.3E-09	--		1.2E-06	1%
Lead		3.5E-03	50%	1.8E-03	100%	1.3E-04	2.4E-08	2.6E-08	--		1.5E-05	17%
Manganese		1.4E-01	50%	7.0E-02	100%	9.6E-06	1.8E-09	1.9E-09	--		2.7E-08	0%
Mercury		6.0E-04	40%	3.6E-04	100%	4.3E-06	7.9E-10	8.6E-10	--		2.4E-06	3%
Nickel		1.2E-02	60%	4.8E-03	100%	1.1E-06	2.1E-10	2.3E-10	--		4.7E-08	0%
Thallium		8.0E-04		8.0E-04	100%	3.4E-07	6.1E-11	6.7E-11	--		8.4E-08	0%
Vanadium		2.0E-03		2.0E-03	100%	1.7E-06	3.1E-10	3.4E-10	--		1.7E-07	0%
Zinc		5.0E-01	80%	1.0E-01	100%	8.8E-04	1.6E-07	1.8E-07	--		1.8E-06	2%
PAHs (as BaP)	2.3E-01				100%	2.5E-10	4.5E-14	4.9E-14	1.1E-14		--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	2.7E-10	5.0E-14	5.4E-14	--		5.1E-05	59%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	5.9E-11	1.1E-14	1.2E-14	--		1.1E-05	13%

TOTAL	**1.1E-14**	**8.7E-05**

Exposure to Chemicals via Ingestion of Eggs (Reference case)

$$\text{Daily chemical intake} = C_E \times \frac{IR_E \times FI \times ME \times EF \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Young children		
Ingestion Rate of Eggs (IRE) (kg/day)	0.006	Ingestion rate of eggs relevant for young children as per enHealth (2012)
Fraction ingested that is homegrown (%)	100%	Assume all eggs consumed in urban area are from backyard chickens
Matrix effect (unitless)	1	Assume chemicals ingested in produce is 100% bioavailable
Exposure Frequency (EF, days/year)	365	Days at home (normal conditions), as per NEPM (1999 amended 2013)
Exposure Duration (ED, years)	6	Duration as young child
Body Weight (BW, kg)	15	Representative weight as per NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Egg concentration (mg/kg wet weight)	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)			NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	5.8E-06	2.0E-10	2.3E-09	--		2.7E-06	2%
Arsenic		2.0E-03	50%	1.0E-03	100%	9.5E-06	3.3E-10	3.8E-09	--		3.8E-06	2%
Beryllium		2.0E-03		2.0E-03	100%	1.1E-07	3.7E-12	4.3E-11	--		2.2E-08	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	3.1E-07	1.1E-11	1.3E-10	--		3.9E-07	0%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	9.9E-07	3.4E-11	3.9E-10	--		4.9E-07	0%
Copper		1.4E-01	60%	5.6E-02	100%	7.0E-07	2.4E-11	2.8E-10	--		5.0E-09	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	6.5E-06	2.2E-10	2.6E-09	--		2.3E-06	1%
Lead		3.5E-03	50%	1.8E-03	100%	1.3E-04	4.4E-09	5.2E-08	--		3.0E-05	17%
Manganese		1.4E-01	50%	7.0E-02	100%	9.6E-06	3.3E-10	3.8E-09	--		5.5E-08	0%
Mercury		6.0E-04	40%	3.6E-04	100%	4.3E-06	1.5E-10	1.7E-09	--		4.8E-06	3%
Nickel		1.2E-02	60%	4.8E-03	100%	1.1E-06	3.9E-11	4.5E-10	--		9.4E-08	0%
Thallium		8.0E-04		8.0E-04	100%	3.4E-07	1.2E-11	1.3E-10	--		1.7E-07	0%
Vanadium		2.0E-03		2.0E-03	100%	1.7E-06	5.9E-11	6.9E-10	--		3.4E-07	0%
Zinc		5.0E-01	80%	1.0E-01	100%	8.8E-04	3.0E-08	3.5E-07	--		3.5E-06	2%
PAHs (as BaP)	2.3E-01				100%	2.5E-10	8.5E-15	9.9E-14	2.0E-15		--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	2.7E-10	9.3E-15	1.1E-13	--		1.0E-04	59%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	5.9E-11	2.0E-15	2.4E-14	--		2.2E-05	13%
								TOTAL	2.0E-15		1.7E-04	

Ingestion of beef

Calculation of Concentrations in Homegrown Beef (Reference case)

Uptake in to beef meat

$$C_E = (FI \times IR_C \times C + IR_S \times C_S \times B) \times TF_B$$ (mg/kg beef – wet weight)

where:
FI = Fraction of grain/crop ingested by cattle each day (unitless)
IRc = Ingestion rate of grain/crop by cattle each day (kg/day)
C = Concentration of chemical in grain/crop eaten by cattle (mg/kg)
IRs = Ingestion rate of soil by cattle each day (kg/day)
Cs = Concentration in soil the cattle ingest (mg/kg)
B = Bioavailability of soil ingested by cattle (%)
TFE = Transfer factor from ingestion to beef (day/kg)

General Parameters	Units	Value	
FI (fraction of crops ingested from property)		1	Assume 100% of pasture consumed by cattle is grown in the same soil
IRc (ingestion rate of crops)	kg/day	9	Assumed ingestion rate from OEHHA 2015 (assume concentration the same as predicted for aboveground crops)
IRs (ingestion rate of soil)	kg/day	0.45	Based on data from OEHHA 2015 (5% total produce intakes from soil from pasture)
B (bioavailability)	%	100%	

Chemical-specific Inputs and calculations - maximum sensitive receptors

Chemical	Concentration in crops ingested by cattle mg/kg ww	Soil Concentration - Agriculture (Cs) mg/kg	Transfer factor to beef day/kg	Beef Concentration mg/kg ww	
Antimony	1.5E-05	3.2E-03	1.0E-03	1.6E-06	RAIS
Arsenic	6.0E-05	1.3E-02	2.0E-03	1.3E-05	
Beryllium	5.3E-07	1.1E-04	3.0E-04	1.7E-08	
Cadmium	1.4E-05	3.0E-03	2.0E-03	2.9E-06	
Chromium (Cr VI assumed)	4.8E-05	1.0E-02	5.5E-03	2.7E-05	RAIS
Copper	1.8E-06	3.9E-04	1.0E-02	1.9E-06	RAIS
Cobalt	8.7E-04	1.9E-01	2.0E-02	1.8E-03	RAIS
Lead	1.4E-03	3.1E-01	3.0E-04	4.5E-05	
Manganese	2.5E-05	5.4E-03	4.0E-04	1.1E-06	RAIS
Mercury	2.4E-06	5.1E-04	4.0E-02	1.0E-05	
Nickel	2.5E-05	5.3E-03	3.0E-04	7.9E-07	
Thallium	8.8E-07	1.9E-04	4.0E-02	3.7E-06	RAIS
Vanadium	4.5E-06	9.5E-04	2.5E-03	1.2E-06	RAIS
Zinc	2.3E-03	4.9E-01	1.0E-01	2.4E-02	RAIS
PAHs (as BaP)	4.8E-07	2.5E-06	7.0E-02	3.8E-07	
Dioxins and furans (WHO-TEQ)	2.0E-11	2.5E-09	7.0E-01	9.1E-10	
Dioxin-like PCBs (WHO-TEQ)	4.3E-12	5.4E-10	2.0E+00	5.6E-10	

Transfer factors from OEHHA 2015 unless otherwise noted

Exposure to Chemicals via Ingestion of Beef (Reference case)

$$\text{Daily chemical intake} = C_B \times \frac{IR_B \times FI \times ME \times EF \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Adults		
Ingestion Rate of Beef (IRB) (kg/day)	0.16	Ingestion rate of beef for adults >19 years (enHealth 2012, noted to be the same as P90 from FSANZ 2017)
Fraction ingested that is homegrown (%)	35%	Assume 35% beef intakes from home-sourced meat
Matrix effect (unitless)	1	Assume chemicals ingested in produce is 100% bioavailable
Exposure Frequency (EF, days/year)	365	Exposure occurs every day
Exposure Duration (ED, years)	64	Time at one residence as adult (child and adult adds to 70 yrs)
Body Weight (BW, kg)	70	For male and females combined (enHealth 2012)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	23360	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Beef concentration	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor $(mg/kg\text{-}day)^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/kg wet weight)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	1.6E-06	1.2E-09	1.3E-09	--		1.5E-06	0%
Arsenic		2.0E-03	50%	1.0E-03	100%	1.3E-05	9.3E-09	1.0E-08	--		1.0E-05	0%
Beryllium		2.0E-03		2.0E-03	100%	1.7E-08	1.2E-11	1.3E-11	--		6.7E-09	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	2.9E-06	2.1E-09	2.3E-09	--		7.3E-06	0%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	2.7E-05	2.0E-08	2.2E-08	--		2.7E-05	1%
Copper		1.4E-01	60%	5.6E-02	100%	1.9E-06	1.4E-09	1.5E-09	--		2.7E-08	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	1.8E-03	1.3E-06	1.5E-06	--		1.3E-03	48%
Lead		3.5E-03	50%	1.8E-03	100%	4.5E-05	3.3E-08	3.6E-08	--		2.1E-05	1%
Manganese		1.4E-01	50%	7.0E-02	100%	1.1E-06	7.7E-10	8.4E-10	--		1.2E-08	0%
Mercury		6.0E-04	40%	3.6E-04	100%	1.0E-05	7.4E-09	8.1E-09	--		2.2E-05	1%
Nickel		1.2E-02	60%	4.8E-03	100%	7.9E-07	5.8E-10	6.3E-10	--		1.3E-07	0%
Thallium		8.0E-04		8.0E-04	100%	3.7E-06	2.7E-09	2.9E-09	--		3.7E-06	0%
Vanadium		2.0E-03		2.0E-03	100%	1.2E-06	8.6E-10	9.4E-10	--		4.7E-07	0%
Zinc		5.0E-01	80%	1.0E-01	100%	2.4E-02	1.8E-05	1.9E-05	--		1.9E-04	7%
PAHs (as BaP)	2.3E-01				100%	3.8E-07	2.8E-10	3.0E-10	6.5E-11	100%	--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	9.1E-10	6.6E-13	7.2E-13	--		6.8E-04	25%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	5.6E-10	4.1E-13	4.5E-13	--		4.2E-04	16%
								TOTAL	**6.5E-11**		**2.7E-03**	

Exposure to Chemicals via Ingestion of Beef (Reference case)

$$\text{Daily chemical intake} = C_B \times \frac{IR_B \times FI \times ME \times EF \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Children		
Ingestion Rate of Beef (IRB) (kg/day)	0.085	Ingestion rate of beef by children aged 2-6 years (P90 value) FSANZ (2017)
Fraction ingested that is homegrown (%)	35%	Assume 35% beef intakes from home-sourced meat
Matrix effect (unitless)	1	Assume chemicals ingested in produce is 100% bioavailable
Exposure Frequency (EF, days/year)	365	Exposure occurs every day
Exposure Duration (ED, years)	6	Duration as young child
Body Weight (BW, kg)	15	Representative weight as per NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Beef concentration	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/kg wet weight)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	1.6E-06	2.7E-10	3.2E-09	--		3.7E-06	0%
Arsenic		2.0E-03	50%	1.0E-03	100%	1.3E-05	2.2E-09	2.5E-08	--		2.5E-05	0%
Beryllium		2.0E-03		2.0E-03	100%	1.7E-08	2.9E-12	3.3E-11	--		1.7E-08	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	2.9E-06	5.0E-10	5.8E-09	--		1.8E-05	0%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	2.7E-05	4.7E-09	5.4E-08	--		6.7E-05	1%
Copper		1.4E-01	60%	5.6E-02	100%	1.9E-06	3.3E-10	3.8E-09	--		6.8E-08	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	1.8E-03	3.1E-07	3.6E-06	--		3.2E-03	48%
Lead		3.5E-03	50%	1.8E-03	100%	4.5E-05	7.7E-09	9.0E-08	--		5.1E-05	1%
Manganese		1.4E-01	50%	7.0E-02	100%	1.1E-06	1.8E-10	2.1E-09	--		3.0E-08	0%
Mercury		6.0E-04	40%	3.6E-04	100%	1.0E-05	1.7E-09	2.0E-08	--		5.5E-05	1%
Nickel		1.2E-02	60%	4.8E-03	100%	7.9E-07	1.3E-10	1.6E-09	--		3.3E-07	0%
Thallium		8.0E-04		8.0E-04	100%	3.7E-06	6.3E-10	7.3E-09	--		9.1E-06	0%
Vanadium		2.0E-03		2.0E-03	100%	1.2E-06	2.0E-10	2.3E-09	--		1.2E-06	0%
Zinc		5.0E-01	80%	1.0E-01	100%	2.4E-02	4.1E-06	4.8E-05	--		4.8E-04	7%
PAHs (as BaP)	2.3E-01				100%	3.8E-07	6.5E-11	7.5E-10	1.5E-11	100%	--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	9.1E-10	1.5E-13	1.8E-12	--		1.7E-03	25%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	5.6E-10	9.5E-14	1.1E-12	--		1.1E-03	16%
								TOTAL	1.5E-11		6.7E-03	

Milk ingestion

Calculation of Concentrations in Dairy Milk (Reference case)

Uptake in to milk (dairy cows)

$$C_E=(FI \times IR_C \times C+IR_S \times C_S \times B) \times TF_B$$ (mg/kg beef – wet weight)

where:
FI = Fraction of grain/crop ingested by cattle each day (unitless)
IRc = Ingestion rate of grain/crop by cattle each day (kg/day)
C = Concentration of chemical in grain/crop eaten by cattle (mg/kg)
IRs = Ingestion rate of soil by cattle each day (kg/day)
Cs = Concentration in soil the cattle ingest (mg/kg)
B = Bioavailability of soil ingested by cattle (%)
TFE = Transfer factor from ingestion to milk (day/kg)

General Parameters	Units	Value	
FI (fraction of crops ingested from property)		1	Assume 100% of pasture consumed by cattle is grown in the same soil
IRc (ingestion rate of crops)	kg/day	22	Assumed ingestion rate from OEHHA 2015 for lactating cattle (assume concentration the same as predicted for aboveground crops)
IRs (ingestion rate of soil)	kg/day	1.1	Based on data from OEHHA 2015 (5% total produce intakes from soil from pasture)
B (bioavailability)	%	100%	

Chemical-specific Inputs and calculations - maximum sensitive receptors

Chemical	Concentration in crops ingested by cattle mg/kg ww	Soil Concentration - Agriculture (Cs) mg/kg	Transfer factor to milk day/kg	Milk Concentration mg/kg or mg/L	
Antimony	1.5E-05	3.2E-03	1.0E-04	3.9E-07	RAIS
Arsenic	6.0E-05	1.3E-02	5.0E-05	7.7E-07	
Beryllium	5.3E-07	1.1E-04	9.0E-07	1.2E-10	
Cadmium	1.4E-05	3.0E-03	2.0E-03	7.2E-06	
Chromium (Cr VI assumed)	4.8E-05	1.0E-02	9.0E-06	1.1E-07	
Copper	1.8E-06	3.9E-04	1.5E-03	7.0E-07	RAIS
Cobalt	8.7E-04	1.9E-01	2.0E-03	4.5E-04	RAIS
Lead	1.4E-03	3.1E-01	6.0E-05	2.2E-05	
Manganese	2.5E-05	5.4E-03	3.5E-04	2.3E-06	RAIS
Mercury	2.4E-06	5.1E-04	7.0E-05	4.3E-08	
Nickel	2.5E-05	5.3E-03	3.0E-05	1.9E-07	
Thallium	8.8E-07	1.9E-04	2.0E-03	4.5E-07	RAIS
Vanadium	4.5E-06	9.5E-04	2.0E-05	2.3E-08	RAIS
Zinc	2.3E-03	4.9E-01	2.7E-09	1.6E-09	RAIS
PAHs (as BaP)	4.8E-07	2.5E-06	1.0E-02	1.3E-07	
Dioxins and furans (WHO-TEQ)	2.0E-11	2.5E-09	2.0E-02	6.3E-11	
Dioxin-like PCBs (WHO-TEQ)	4.3E-12	5.4E-10	4.0E-02	2.7E-11	

Transfer factors from OEHHA 2015 unless otherwise noted

Exposure to Chemicals via Ingestion of Milk (Reference case)

$$\text{Daily chemical intake} = C_M \times \frac{IR_M \times FI \times ME \times EF \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Adults		
Ingestion Rate of Milk (IRM) (L/day)	1.295	Ingestion rate of cows milk for adults (P90 value from FSANZ 2017)
Fraction ingested that is homegrown (%)	100%	Assume all milk consumed is from the dairy farm
Matrix effect (unitless)	1	Assume chemicals ingested in produce is 100% bioavailable
Exposure Frequency (EF, days/year)	365	Exposure occurs every day
Exposure Duration (ED, years)	64	Time at one residence as adult (child and adult adds to 70 yrs)
Body Weight (BW, kg)	70	For male and females combined (enHealth 2012)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	23360	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Milk concentration	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/L)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	3.9E-07	6.6E-09	7.2E-09	--		8.4E-06	0%
Arsenic		2.0E-03	50%	1.0E-03	100%	7.7E-07	1.3E-08	1.4E-08	--		1.4E-05	0%
Beryllium		2.0E-03		2.0E-03	100%	1.2E-10	2.1E-12	2.3E-12	--		1.1E-09	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	7.2E-06	1.2E-07	1.3E-07	--		4.1E-04	4%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	1.1E-07	1.9E-09	2.0E-09	--		2.5E-06	0%
Copper		1.4E-01	60%	5.6E-02	100%	7.0E-07	1.2E-08	1.3E-08	--		2.3E-07	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	4.5E-04	7.6E-06	8.3E-06	--		7.4E-03	76%
Lead		3.5E-03	50%	1.8E-03	100%	2.2E-05	3.7E-07	4.1E-07	--		2.3E-04	2%
Manganese		1.4E-01	50%	7.0E-02	100%	2.3E-06	3.8E-08	4.2E-08	--		6.0E-07	0%
Mercury		6.0E-04	40%	3.6E-04	100%	4.3E-08	7.3E-10	8.0E-10	--		2.2E-06	0%
Nickel		1.2E-02	60%	4.8E-03	100%	1.9E-07	3.3E-09	3.6E-09	--		7.4E-07	0%
Thallium		8.0E-04		8.0E-04	100%	4.5E-07	7.6E-09	8.3E-09	--		1.0E-05	0%
Vanadium		2.0E-03		2.0E-03	100%	2.3E-08	3.9E-10	4.2E-10	--		2.1E-07	0%
Zinc		5.0E-01	80%	1.0E-01	100%	1.6E-09	2.7E-11	2.9E-11	--		2.9E-10	0%
PAHs (as BaP)	2.3E-01				100%	1.3E-07	2.2E-09	2.5E-09	5.2E-10	100%	--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	6.3E-11	1.1E-12	1.2E-12	--		1.1E-03	11%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	2.7E-11	4.6E-13	5.1E-13	--		4.8E-04	5%
								TOTAL	5.2E-10		9.7E-03	

Exposure to Chemicals via Ingestion of Milk (Reference case)

$$\text{Daily chemical intake} = C_M \times \frac{IR_M \times FI \times ME \times EF \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Children		
Ingestion Rate of Milk (IRM) (L/day)	1.097	Ingestion rate of cows milk for children aged 2-6 years (P90 value from FSANZ 2017)
Fraction ingested that is homegrown (%)	100%	Assume all milk consumed is from the dairy farm
Matrix effect (unitless)	1	Assume chemicals ingested in produce is 100% bioavailable
Exposure Frequency (EF, days/year)	365	Exposure occurs every day
Exposure Duration (ED, years)	6	Duration as young child
Body Weight (BW, kg)	15	Representative weight as per NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Milk concentration	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/L)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	3.9E-07	2.4E-09	2.8E-08	--		3.3E-05	0%
Arsenic		2.0E-03	50%	1.0E-03	100%	7.7E-07	4.9E-09	5.7E-08	--		5.7E-05	0%
Beryllium		2.0E-03		2.0E-03	100%	1.2E-10	7.7E-13	9.0E-12	--		4.5E-09	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	7.2E-06	4.5E-08	5.2E-07	--		1.6E-03	4%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	1.1E-07	6.9E-10	8.0E-09	--		9.9E-06	0%
Copper		1.4E-01	60%	5.6E-02	100%	7.0E-07	4.4E-09	5.1E-08	--		9.2E-07	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	4.5E-04	2.8E-06	3.3E-05	--		2.9E-02	76%
Lead		3.5E-03	50%	1.8E-03	100%	2.2E-05	1.4E-07	1.6E-06	--		9.3E-04	2%
Manganese		1.4E-01	50%	7.0E-02	100%	2.3E-06	1.4E-08	1.6E-07	--		2.4E-06	0%
Mercury		6.0E-04	40%	3.6E-04	100%	4.3E-08	2.7E-10	3.2E-09	--		8.8E-06	0%
Nickel		1.2E-02	60%	4.8E-03	100%	1.9E-07	1.2E-09	1.4E-08	--		2.9E-06	0%
Thallium		8.0E-04		8.0E-04	100%	4.5E-07	2.8E-09	3.3E-08	--		4.1E-05	0%
Vanadium		2.0E-03		2.0E-03	100%	2.3E-08	1.4E-10	1.7E-09	--		8.4E-07	0%
Zinc		5.0E-01	80%	1.0E-01	100%	1.6E-09	1.0E-11	1.2E-10	--		1.2E-09	0%
PAHs (as BaP)	2.3E-01				100%	1.3E-07	8.3E-10	9.7E-09	1.9E-10	100%	--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	6.3E-11	4.0E-13	4.6E-12	--		4.4E-03	11%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	2.7E-11	1.7E-13	2.0E-12	--		1.9E-03	5%
								TOTAL	1.9E-10		3.8E-02	

Lamb ingestion

Calculation of Concentrations in Homegrown Lamb

Uptake in to lamb meat

$$C_E = (FI \times IR_C \times C + IR_S \times C_S \times B) \times TF_B$$ (mg/kg meat – wet weight)

where:
FI = Fraction of grain/crop ingested by lambs each day (unitless)
IRc = Ingestion rate of grain/crop by lambs each day (kg/day)
C = Concentration of chemical in grain/crop eaten by lamb (mg/kg)
IRs = Ingestion rate of soil by lambs each day (kg/day)
Cs = Concentration in soil the lambs ingest (mg/kg)
B = Bioavailability of soil ingested by lambs (%)
TFE = Transfer factor from ingestion to lamb (day/kg)

General Parameters	Units	Value	
FI (fraction of crops ingested from property)		1	Assume 100% of pasture consumed by lambs is grown in the same soil
IRc (ingestion rate of crops)	kg/day	1.1088	4.2% body weight per day dry weight, then correcting for 20% moisture (assuming 22 kg weight)**
IRs (ingestion rate of soil)	kg/day	0.05544	Assumes 5% total produce intakes from soil from pasture, consistent with cattle
B (bioavailability)	%	100%	

** https://www.mla.com.au/contentassets/34ac9a74c56e4dbf8273d2a9bb2900c5/l.lsm.0022_-_production_feeding_for_lamb_growth__.pdf

Chemical-specific Inputs and calculations - maximum sensitive receptors

Chemical	Concentration in crops ingested by lambs mg/kg ww	Soil Concentration - Agriculture (Cs) mg/kg	Transfer factor to lambs day/kg	Lamb Concentration mg/kg ww	
Antimony	1.5E-05	3.2E-03	1.0E-02	2.0E-06	MW adjustment
Arsenic	6.0E-05	1.3E-02	2.1E-02	1.6E-05	MW adjustment
Beryllium	5.3E-07	1.1E-04	3.1E-03	2.2E-08	MW adjustment
Cadmium	1.4E-05	3.0E-03	2.1E-02	3.8E-06	MW adjustment
Chromium (Cr VI assumed)	4.8E-05	1.0E-02	5.7E-02	3.5E-05	MW adjustment
Copper	1.8E-06	3.9E-04	1.0E-01	2.5E-06	MW adjustment
Cobalt	8.7E-04	1.9E-01	2.1E-01	2.3E-03	MW adjustment
Lead	1.4E-03	3.1E-01	3.1E-03	5.8E-05	MW adjustment
Manganese	2.5E-05	5.4E-03	4.2E-03	1.4E-06	MW adjustment
Mercury	2.4E-06	5.1E-04	4.2E-01	1.3E-05	MW adjustment
Nickel	2.5E-05	5.3E-03	3.1E-03	1.0E-06	MW adjustment
Thallium	8.8E-07	1.9E-04	4.2E-01	4.7E-06	MW adjustment
Vanadium	4.5E-06	9.5E-04	2.6E-02	1.5E-06	MW adjustment
Zinc	2.3E-03	4.9E-01	1.0E+00	3.1E-02	MW adjustment
PAHs (as BaP)	4.8E-07	2.5E-06	7.3E-01	4.9E-07	MW adjustment
Dioxins and furans (WHO-TEQ)	2.0E-11	2.5E-09	7.3E+00	1.2E-09	MW adjustment
Dioxin-like PCBs (WHO-TEQ)	4.3E-12	5.4E-10	2.1E+01	7.2E-10	MW adjustment

Transfer factors from OEHHA 2015 unless otherwise noted

MW weight adjustment = metabolic weight adjustmenta approach, modifying the TF for beef meet to pigs to acount for differences in tissue trasnfer due to different weights.

Approach adopted for pigs as per OEHHA (2012) to calculate transfer factors Tco as below. Approach also adopted for lambs (cattle = 500 kg and lambs = 22 kg (average for Australian lambs))

$$\text{Pig } Tco_i = (W^{0.75}_{cow}) / (W^{0.75}_{pig}) \times \text{cow } Tco_i$$

Transfer factor adjustment for lambs = 10.4

Exposure to Chemicals via Ingestion of Lamb (Reference case)

$$\text{Daily chemical intake} = C_B \times \frac{IR_B \times FI \times ME \times EF \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Adults		
Ingestion Rate of Beef (IRB) (kg/day)	0.085	Ingestion rate of sheep meat for adults, P90 from FSANZ 2017
Fraction ingested that is homegrown (%)	35%	Assume 35% beef intakes from home-sourced meat
Matrix effect (unitless)	1	Assume chemicals ingested in produce is 100% bioavailable
Exposure Frequency (EF, days/year)	365	Exposure occurs every day
Exposure Duration (ED, years)	64	Time at one residence as adult (child and adult adds to 70 yrs)
Body Weight (BW, kg)	70	For male and females combined (enHealth 2012)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	23360	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Lamb concentration	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)^-1	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/kg wet weight)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	2.0E-06	7.9E-10	8.7E-10	--		1.0E-06	0%
Arsenic		2.0E-03		2.0E-03	100%	1.6E-05	6.3E-09	6.9E-09	--		3.5E-06	0%
Beryllium		2.0E-03	20%	1.6E-03	100%	2.2E-08	8.4E-12	9.2E-12	--		5.7E-09	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	3.8E-06	1.5E-09	1.6E-09	--		5.0E-06	0%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	3.5E-05	1.4E-08	1.5E-08	--		1.8E-05	1%
Copper		1.4E-01	60%	5.6E-02	100%	2.5E-06	9.6E-10	1.0E-09	--		1.9E-08	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	2.3E-03	9.1E-07	1.0E-06	--		8.9E-04	48%
Lead		3.5E-03	50%	1.8E-03	100%	5.8E-05	2.3E-08	2.5E-08	--		1.4E-05	1%
Manganese		1.4E-01	50%	7.0E-02	100%	1.4E-06	5.2E-10	5.7E-10	--		8.2E-09	0%
Mercury		6.0E-04	40%	3.6E-04	100%	1.3E-05	5.0E-09	5.5E-09	--		1.5E-05	1%
Nickel		1.2E-02	60%	4.8E-03	100%	1.0E-06	3.9E-10	4.3E-10	--		8.9E-08	0%
Thallium		8.0E-04		8.0E-04	100%	4.7E-06	1.8E-09	2.0E-09	--		2.5E-06	0%
Vanadium		2.0E-03	54%	9.2E-04	100%	1.5E-06	5.8E-10	6.4E-10	--		7.0E-07	0%
Zinc		5.0E-01	80%	1.0E-01	100%	3.1E-02	1.2E-05	1.3E-05	--		1.3E-04	7%
PAHs (as BaP)	2.3E-01				100%	4.9E-07	1.9E-10	2.1E-10	4.4E-11	100%	--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	1.2E-09	4.5E-13	4.9E-13	--		4.7E-04	25%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	7.2E-10	2.8E-13	3.1E-13	--		2.9E-04	16%
								TOTAL	4.4E-11		1.8E-03	

Exposure to Chemicals via Ingestion of Lamb (Reference case)

$$\text{Daily chemical intake} = C_B \times \frac{IR_B \times FI \times ME \times EF \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Children		
Ingestion Rate of Beef (IRB) (kg/day)	0.036	Ingestion rate of sheep meat by children aged 2-6 years (P90 value) FSANZ (2017)
Fraction ingested that is homegrown (%)	35%	Assume 35% beef intakes from home-sourced meat
Matrix effect (unitless)	1	Assume chemicals ingested in produce is 100% bioavailable
Exposure Frequency (EF, days/year)	365	Exposure occurs every day
Exposure Duration (ED, years)	6	Duration as young child
Body Weight (BW, kg)	15	Representative weight as per NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Lamb concentration	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/kg wet weight)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	2.0E-06	1.5E-10	1.7E-09	--		2.0E-06	0%
Arsenic		2.0E-03		2.0E-03	100%	1.6E-05	1.2E-09	1.4E-08	--		6.8E-06	0%
Beryllium		2.0E-03	20%	1.6E-03	100%	2.2E-08	1.6E-12	1.8E-11	--		1.1E-08	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	3.8E-06	2.7E-10	3.2E-09	--		9.9E-06	0%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	3.5E-05	2.5E-09	3.0E-08	--		3.6E-05	1%
Copper		1.4E-01	60%	5.6E-02	100%	2.5E-06	1.8E-10	2.1E-09	--		3.7E-08	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	2.3E-03	1.7E-07	2.0E-06	--		1.8E-03	48%
Lead		3.5E-03	50%	1.8E-03	100%	5.8E-05	4.2E-09	4.9E-08	--		2.8E-05	1%
Manganese		1.4E-01	50%	7.0E-02	100%	1.4E-06	9.7E-11	1.1E-09	--		1.6E-08	0%
Mercury		6.0E-04	40%	3.6E-04	100%	1.3E-05	9.3E-10	1.1E-08	--		3.0E-05	1%
Nickel		1.2E-02	60%	4.8E-03	100%	1.0E-06	7.3E-11	8.5E-10	--		1.8E-07	0%
Thallium		8.0E-04		8.0E-04	100%	4.7E-06	3.4E-10	4.0E-09	--		5.0E-06	0%
Vanadium		2.0E-03	54%	9.2E-04	100%	1.5E-06	1.1E-10	1.3E-09	--		1.4E-06	0%
Zinc		5.0E-01	80%	1.0E-01	100%	3.1E-02	2.2E-06	2.6E-05	--		2.6E-04	7%
PAHs (as BaP)	2.3E-01				100%	4.9E-07	3.5E-11	4.1E-10	8.2E-12	100%	--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	1.2E-09	8.4E-14	9.8E-13	--		9.2E-04	25%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	7.2E-10	5.2E-14	6.0E-13	--		5.7E-04	16%

TOTAL	**8.2E-12**	**3.6E-03**

Rainwater tanks

Calculation of Concentrations in Rainwater tank (Reference case)

CW = DM/(VR*Kd*ρ) **(mg/L)**

where:

DM =	Mass of dust deposited on roof each year that enters tank (mg) = DR x Area x 0.1 x 1 year
DR =	Deposition rate from model for TSP ($mg/m^2/year$)
Area =	Area of roof (m^2)
VR =	Volume of water collected from roof over year (L) = (R x Area x Rc x 1000)/1000
R =	Rainfall each year (mm)
ρ =	Soil bulk-density (g/cm^3)
Rc =	Runoff coefficient (unitless)
Kd =	Soil-water partition coefficient (cm^3/g)
1000 =	Conversion from mm to m; and conversion from m^3 to L

General Parameters			
Average rainfall (R)	mm	675.8	mean for all years (1931 to 2020) for Lake Bathurst (BoM data)
Roof area (Area)	m^2	200	4 bedroom australian home
Runoff coefficient (Rc)	-	0.7	assumes 30% loss in capture into tank
Volume of rainwater (VR)	L	94612	calculated
Bulk density of deposited dust	g/cm^3	0.5	assumed for loose deposited dust on roof (similar to upper end measured for powders)

Chemical-specific Inputs and calculations - maximum sensitive receptors

Chemical	Deposited dust entering tank: Deposition Rate TSP (DR) mg/m²/year	Deposited dust entering tank: Mass deposited each year into tank (DM) mg	Kd (cm³/g)	Particulate Concentration in water mg/L	Dissolved Concentration in water mg/L	Total (particulate and dissolved) - worst-case mg/L
Antimony	1.1E-02	2.22E-01	45	2.3E-06	1.0E-07	2.4E-06
Arsenic	4.4E-02	8.83E-01	29	9.3E-06	6.4E-07	1.0E-05
Beryllium	3.9E-04	7.82E-03	790	8.3E-08	2.1E-10	8.3E-08
Cadmium	1.0E-02	2.04E-01	75	2.2E-06	5.8E-08	2.2E-06
Chromium (Cr VI assumed)	3.5E-02	6.95E-01	1800000	7.3E-06	8.2E-12	7.3E-06
Copper	1.3E-03	2.67E-02	35	2.8E-07	1.6E-08	3.0E-07
Cobalt	6.4E-01	1.27E+01	45	1.3E-04	6.0E-06	1.4E-04
Lead	1.1E+00	2.10E+01	900	2.2E-04	4.9E-07	2.2E-04
Manganese	1.8E-02	3.67E-01	65	3.9E-06	1.2E-07	4.0E-06
Mercury	1.8E-03	3.51E-02	52	3.7E-07	1.4E-08	3.8E-07
Nickel	1.8E-02	3.65E-01	65	3.9E-06	1.2E-07	4.0E-06
Thallium	6.4E-04	1.28E-02	71	1.4E-07	3.8E-09	1.4E-07
Vanadium	3.3E-03	6.54E-02	1000	6.9E-07	1.4E-09	6.9E-07
Zinc	1.7E+00	3.38E+01	62	3.6E-04	1.2E-05	3.7E-04
PAHs (as BaP)	3.5E-04	7.01E-03	58740000	7.4E-08	2.5E-15	7.4E-08
Dioxins and furans (WHO-TEQ)	1.4E-08	2.90E-07	630957344	3.1E-12	9.7E-21	3.1E-12
Dioxin-like PCBs (WHO-TEQ)	3.1E-09	6.28E-08	630957344	6.6E-13	2.1E-21	6.6E-13

Appendix E Risk calculations for Scenario 3: NSW EfW regulatory emissions

Inhalation exposures

Predicted ground level concentrations and screening assessment - acute exposures

		Air Concentration - Maximum 1 hour average (mg/m^3)				Calculated HI			
COPC	Acute air guideline - health (mg/m^3)	Maximum anywhere	Maximum - commercial/ industrial receptors	Maximum - residential, rural, school receptors	Maximum – Workers in wind turbine	Maximum anywhere	Maximum - commercial/ industrial receptors	Maximum - residential, rural, school receptors	Maximum – Workers in wind turbine
Hydrogen chloride (HCl)	0.66	0.021	0.0085	0.0027	0.041	0.032	0.013	0.0040	0.062
Hydrogen fluoride (HF)	0.06	0.0017	0.00068	0.00021	0.0033	0.028	0.011	0.0036	0.054
Ammonia	0.59	0.0021	0.00085	0.00027	0.0041	0.0035	0.0014	0.00045	0.0069
VOCs - as benzene	0.58	0.0033	0.00135	0.00042	0.0064	0.0056	0.0023	0.00072	0.011
Antimony	0.001	0.000043	0.000018	0.0000055		0.043	0.018	0.0055	
Arsenic	0.0099	0.000013	0.0000063	0.0000017		0.0013	0.00064	0.00017	
Cadmium	0.018	0.000014	0.0000059	0.0000018		0.00078	0.00033	0.00010	
Chromium (Cr VI assumed)	0.0013	0.000082	0.000034	0.000011		0.063	0.026	0.0082	
Copper	0.1	0.000012	0.0000047	0.0000015		0.00012	0.000047	0.000015	
Manganese	0.0091	0.000096	0.000039	0.000012		0.010	0.0043	0.0014	
Mercury	0.0006	0.000028	0.000011	0.0000036		0.046	0.019	0.0059	
Nickel	0.0011	0.00010	0.000041	0.000013		0.093	0.037	0.012	
Vanadium	0.03	0.000027	0.000010	0.0000034		0.00089	0.00035	0.00011	
						0.33	0.11	0.034	0.018

Inhalation - gases and particulates (Regulatory case)

$$InhalationExposureConc_V = C_a \bullet \frac{ET \bullet FI \bullet EF \bullet ED}{AT}$$ (mg/m^3)

Parameters Relevant to Quantification of Community Exposures - Commercial/industrial workers		
Exposure Time (ET, hr/day)	8	Assume exposure for 8 hours per day (enHealth 2012)
Fraction Inhaled from Source (FI, unitless)	1	Assume worker is at the same location all the time
Dust lung retention factor (unitless)	1	Percentage of respirable dust that is small enough to reach and be retained in the lungs (NEPM 1999 amended 2013) - assumed dust is PM2.5 for inhalation
Exposure Frequency - normal conditions (EF, days/yr)	240	Number of workdays per year as per enHealth (2012)
Exposure Duration (ED, years)	30	Duration of work at any one location as per enHealth (2012)
Averaging Time - NonThreshold (Atc, hours)	613200	US EPA 2009
Averaging Time - Threshold (Atn, hours)	262800	US EPA 2009

Maximum anywhere (boundary and off-site)

Key Chemical	Toxicity Data				Concentration	Daily Exposure		Calculated Risk			
	Inhalation Unit Risk (mg/m^3)$^{-1}$	Chronic TC Air (mg/m^3)	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background) (mg/m^3)	Estimated Concentration in Air - Maximum anywhere (Ca) (mg/m^3)	Inhalation Exposure Concentration - NonThreshold (mg/m^3)	Inhalation Exposure Concentration - Threshold (mg/m^3)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Hydrogen chloride (HCl)	0.0E+00	2.6E-02	0%	2.6E-02	6.1E-04	5.8E-05	1.3E-04	--		0.0052	5%
Hydrogen fluoride (HF)	0.0E+00	2.9E-02	0%	2.9E-02	4.9E-05	4.6E-06	1.1E-05	--		0.00037	0%
Ammonia	0.0E+00	3.2E-01	0%	3.2E-01	6.1E-05	5.8E-06	1.3E-05	--		0.000042	0%
VOCs - as benzene	6.0E-03	3.0E-02	10%	2.7E-02	9.7E-05	9.1E-06	2.1E-05	5.5E-8		0.00079	1%
Antimony	0.0E+00	2.0E-04	0%	2.0E-04	1.3E-06	1.2E-07	2.7E-07	--		0.0014	1%
Arsenic	0.0E+00	6.7E-05	0%	6.7E-05	4.3E-07	4.0E-08	9.4E-08	--		0.0014	1%
Beryllium	0.0E+00	2.0E-05	0%	2.0E-05	1.1E-07	1.0E-08	2.4E-08	--		0.0012	1%
Cadmium	0.0E+00	5.0E-06	20%	4.0E-06	4.1E-07	3.9E-08	9.0E-08	--		0.023	23%
Chromium (Cr VI assumed)	0.0E+00	1.0E-04	0%	1.0E-04	2.4E-06	2.3E-07	5.3E-07	--		0.0053	5%
Copper	0.0E+00	4.9E-01	60%	2.0E-01	3.3E-07	3.1E-08	7.2E-08	--		0.00000037	0%
Cobalt	0.0E+00	1.0E-04	0%	1.0E-04	6.0E-06	5.6E-07	1.3E-06	--		0.013	13%
Lead	0.0E+00	5.0E-04	0%	5.0E-04	9.6E-06	9.0E-07	2.1E-06	--		0.0042	4%
Manganese	0.0E+00	1.5E-04	20%	1.2E-04	2.8E-06	2.6E-07	6.0E-07	--		0.0050	5%
Mercury	0.0E+00	2.0E-04	0%	2.0E-04	8.1E-07	7.7E-08	1.8E-07	--		0.00089	1%
Nickel	0.0E+00	2.0E-05	20%	1.6E-05	2.8E-06	2.6E-07	6.2E-07	--		0.038	38%
Thallium	0.0E+00	2.8E-03	0%	2.8E-03	3.5E-07	3.3E-08	7.6E-08	--		0.000027	0%
Vanadium	0.0E+00	7.0E-03	0%	7.0E-03	7.1E-07	6.7E-08	1.6E-07	--		0.000022	0%
Zinc	0.0E+00	1.8E+00	80%	3.5E-01	2.5E-05	2.4E-06	5.5E-06	--		0.000016	0%
PAHs (as BaP)	6.0E-01	0.0E+00	0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	--		--	
Dioxins and furans (WHO-TEQ)	0.0E+00	8.1E-09	54%	3.7E-09	1.2E-12	1.2E-13	2.7E-13	--		0.000073	0%
Dioxin-like PCBs (WHO-TEQ)	0.0E+00	8.1E-09	54%	3.7E-09	0.0E+00	0.0E+00	0.0E+00	--		--	
							TOTAL	5E-08		0.10	

Maximum (commercial/industrial receptors)

Key Chemical	Toxicity Data				Concentration	Daily Exposure		Calculated Risk			
	Inhalation Unit Risk (mg/m^3)$^{-1}$	Chronic TC Air (mg/m^3)	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background) (mg/m^3)	Estimated Concentration in Air - Maximum C/I receptors (Ca) (mg/m^3)	Inhalation Exposure Concentration - NonThreshold (mg/m^3)	Inhalation Exposure Concentration - Threshold (mg/m^3)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Hydrogen chloride (HCl)	0.0E+00	2.6E-02	0%	2.6E-02	5.8E-04	5.5E-05	1.3E-04	--		0.0049	5%
Hydrogen fluoride (HF)	0.0E+00	2.9E-02	0%	2.9E-02	4.7E-05	4.4E-06	1.0E-05	--		0.00035	0%
Ammonia	0.0E+00	3.2E-01	0%	3.2E-01	5.8E-05	5.5E-06	1.3E-05	--		0.000040	0%
VOCs - as benzene	6.0E-03	3.0E-02	10%	2.7E-02	9.2E-05	8.7E-06	2.0E-05	5.2E-8		0.00075	1%
Antimony	0.0E+00	2.0E-04	0%	2.0E-04	1.2E-06	1.1E-07	2.6E-07	--		0.0013	1%
Arsenic	0.0E+00	6.7E-05	0%	6.7E-05	3.5E-07	3.3E-08	7.7E-08	--		0.0011	1%
Beryllium	0.0E+00	2.0E-05	0%	2.0E-05	8.7E-08	8.2E-09	1.9E-08	--		0.0010	1%
Cadmium	0.0E+00	5.0E-06	20%	4.0E-06	4.0E-07	3.7E-08	8.7E-08	--		0.022	24%
Chromium (Cr VI assumed)	0.0E+00	1.0E-04	0%	1.0E-04	2.3E-06	2.2E-07	5.1E-07	--		0.0051	6%
Copper	0.0E+00	4.9E-01	60%	2.0E-01	3.2E-07	3.0E-08	6.9E-08	--		0.00000035	0%
Cobalt	0.0E+00	1.0E-04	0%	1.0E-04	4.0E-06	3.8E-07	8.8E-07	--		0.0088	10%
Lead	0.0E+00	5.0E-04	0%	5.0E-04	3.5E-06	3.3E-07	7.7E-07	--		0.0015	2%
Manganese	0.0E+00	1.5E-04	20%	1.2E-04	2.7E-06	2.5E-07	5.8E-07	--		0.0048	5%
Mercury	0.0E+00	2.0E-04	0%	2.0E-04	7.8E-07	7.3E-08	1.7E-07	--		0.00085	1%
Nickel	0.0E+00	2.0E-05	20%	1.6E-05	2.7E-06	2.6E-07	6.0E-07	--		0.037	42%
Thallium	0.0E+00	2.8E-03	0%	2.8E-03	3.3E-07	3.1E-08	7.3E-08	--		0.000026	0%
Vanadium	0.0E+00	7.0E-03	0%	7.0E-03	6.9E-07	6.5E-08	1.5E-07	--		0.000022	0%
Zinc	0.0E+00	1.8E+00	80%	3.5E-01	2.5E-05	2.3E-06	5.4E-06	--		0.000015	0%
PAHs (as BaP)	6.0E-01	0.0E+00	0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	--		--	
Dioxins and furans (WHO-TEQ)	0.0E+00	8.1E-09	54%	3.7E-09	1.2E-12	1.1E-13	2.6E-13	--		0.000069	0%
Dioxin-like PCBs (WHO-TEQ)	0.0E+00	8.1E-09	54%	3.7E-09	0.0E+00	0.0E+00	0.0E+00	--		--	
							Total	**5.2E-08**		**0.090**	

Inhalation - gases and particulates (Regulatory case)

$$InhalationExposureConc_V = C_a \bullet \frac{ET \bullet FI \bullet EF \bullet ED}{AT} \quad \text{(mg/m}^3\text{)}$$

Parameters Relevant to Quantification of Community Exposures - Residents		
Exposure Time at Home (ET, hr/day)	24	Assume residents at home or on property 24 hours per day
Fraction Inhaled from Source (FI, unitless)	1	Assume resident at the same property
Dust lung retention factor (unitless)	1	Percentage of respirable dust that is small enough to reach and be retained in the lungs (NEPM 1999 amended 2013) - assumed dust is PM2.5 for inhalation
Exposure Frequency - normal conditions (EF, days/yr)	365	Days at home (normal conditions), as per NEPM (1999 amended 2013)
Exposure Duration (ED, years)	70	Duration at one residence assumed for area
Averaging Time - NonThreshold (Atc, hours)	613200	US EPA 2009
Averaging Time - Threshold (Atn, hours)	613200	US EPA 2009

Maximum for sensitive receptors

Key Chemical	Toxicity Data				Concentration	Daily Exposure		Calculated Risk			
	Inhalation Unit Risk (mg/m^3)$^{-1}$	Chronic TC Air (mg/m^3)	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background) (mg/m^3)	Estimated Concentration in Air - Maximum sensitive receptors (Ca) (mg/m^3)	Inhalation Exposure Concentration - NonThreshold (mg/m^3)	Inhalation Exposure Concentration - Threshold (mg/m^3)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Hydrogen chloride (HCl)	0.0E+00	2.6E-02	0%	2.6E-02	1.1E-04	1.1E-04	1.1E-04	--		0.0043	5%
Hydrogen fluoride (HF)	0.0E+00	2.9E-02	0%	2.9E-02	8.9E-06	8.9E-06	8.9E-06	--		0.00031	0%
Ammonia	0.0E+00	3.2E-01	0%	3.2E-01	1.1E-05	1.1E-05	1.1E-05	--		0.000035	0%
VOCs - as benzene	6.0E-03	3.0E-02	10%	2.7E-02	1.1E-04	1.1E-04	1.1E-04	6.5E-7		0.0040	5%
Antimony	0.0E+00	2.0E-04	0%	2.0E-04	2.3E-07	2.3E-07	2.3E-07	--		0.0011	1%
Arsenic	0.0E+00	6.7E-05	0%	6.7E-05	6.4E-08	6.4E-08	6.4E-08	--		0.00095	1%
Beryllium	0.0E+00	2.0E-05	0%	2.0E-05	7.0E-09	7.0E-09	7.0E-09	--		0.00035	0%
Cadmium	0.0E+00	5.0E-06	20%	4.0E-06	7.5E-08	7.5E-08	7.5E-08	--		0.019	24%
Chromium (Cr VI assumed)	0.0E+00	1.0E-04	0%	1.0E-04	4.4E-07	4.4E-07	4.4E-07	--		0.0044	6%
Copper	0.0E+00	4.9E-01	60%	2.0E-01	5.9E-08	5.9E-08	5.9E-08	--		0.00000030	0%
Cobalt	0.0E+00	1.0E-04	0%	1.0E-04	7.3E-07	7.3E-07	7.3E-07	--		0.0073	9%
Lead	0.0E+00	5.0E-04	0%	5.0E-04	5.4E-07	5.4E-07	5.4E-07	--		0.0011	1%
Manganese	0.0E+00	1.5E-04	20%	1.2E-04	5.0E-07	5.0E-07	5.0E-07	--		0.0041	5%
Mercury	0.0E+00	2.0E-04	0%	2.0E-04	1.5E-07	1.5E-07	1.5E-07	--		0.00074	1%
Nickel	0.0E+00	2.0E-05	20%	1.6E-05	5.0E-07	5.0E-07	5.0E-07	--		0.031	40%
Thallium	0.0E+00	2.8E-03	0%	2.8E-03	6.3E-08	6.3E-08	6.3E-08	--		0.000022	0%
Vanadium	0.0E+00	7.0E-03	0%	7.0E-03	1.3E-07	1.3E-07	1.3E-07	--		0.000018	0%
Zinc	0.0E+00	1.8E+00	80%	3.5E-01	4.6E-06	4.6E-06	4.6E-06	--		0.000013	0%
PAHs (as BaP)	6.0E-01	0.0E+00	0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	--		--	
Dioxins and furans (WHO-TEQ)	0.0E+00	8.1E-09	54%	3.7E-09	2.2E-13	2.2E-13	2.2E-13	--		0.000060	0%
Dioxin-like PCBs (WHO-TEQ)	0.0E+00	8.1E-09	54%	3.7E-09	0.0E+00	0.0E+00	0.0E+00	--		--	
							TOTAL	6E-07		0.079	

Multi-pathway exposures for maximum sensitive receptor

Soil exposures

Calculation of Concentrations in Soil (Regulatory case)

$$C_s = \frac{DR \bullet \left[1 - e^{-k \bullet t}\right]}{d \bullet \rho \bullet k} \bullet 1000$$ **(mg/kg)** ref: Stevens B. (1991)

where:

DR=	Particle deposition rate (mg/m^2/year)
K =	Chemical-specific soil-loss constant (1/year) = ln(2)/T0.5
T0.5 =	Chemical half-life in soil (years)
t =	Accumulation time (years)
d =	Soil mixing depth (m)
ρ =	Soil bulk-density (g/m^3)
1000 =	Conversion from g to kg

General Parameters		Surface (for direct contact)	Depth (for agricultural pathways)	
Soil bulk density (p)	g/m^3	1600000	1600000	Default for fill materials
General mixing depth (d)	m	0.01	0.15	As per OEHHA (2015) guidance
Duration of deposition (T)	years	70	70	Duration of operation (conservative assumption)

Chemical-specific Inputs and calculations - maximum sensitive receptors

Chemical	Half-life in soil years	Loss constant (K) per year	Deposition Rate (DR) mg/m^2/year	Surface Concentration in Soil mg/kg	Agricultural Concentration in Soil mg/kg
Antimony	273973	2.5E-06	5.9E-02	2.6E-01	1.7E-02
Arsenic	273973	2.5E-06	5.6E-02	2.5E-01	1.6E-02
Beryllium	273973	2.5E-06	1.4E-03	6.1E-03	4.1E-04
Cadmium	273973	2.5E-06	2.6E-02	1.1E-01	7.6E-03
Chromium (Cr VI assumed)	273973	2.5E-06	1.3E-01	5.6E-01	3.7E-02
Copper	273973	2.5E-06	1.4E-02	5.9E-02	3.9E-03
Cobalt	273973	2.5E-06	7.7E-01	3.4E+00	2.2E-01
Lead	273973	2.5E-06	1.1E+00	5.0E+00	3.3E-01
Manganese	273973	2.5E-06	1.2E-01	5.4E-01	3.6E-02
Mercury	273973	2.5E-06	3.3E-02	1.5E-01	9.7E-03
Nickel	273973	2.5E-06	1.2E-01	5.3E-01	3.5E-02
Thallium	273973	2.5E-06	1.4E-02	6.2E-02	4.1E-03
Vanadium	273973	2.5E-06	2.8E-02	1.2E-01	8.3E-03
Zinc	273973	2.5E-06	2.6E+00	1.1E+01	7.6E-01
PAHs (as BaP)	1.18	5.9E-01	0.0E+00	0.0E+00	0.0E+00
Dioxins and furans (WHO-TEQ)	41	0.017	2.5E-08	6.5E-08	4.3E-09
Dioxin-like PCBs (WHO-TEQ)	41	0.017	0.0E+00	0.0E+00	0.0E+00

Half-life in soil: dioxin value from Lowe et al (1991) and metals, PAHs from OEHHA (2015)

Exposure to Chemicals via Incidental Ingestion of Soil (Regulatory case)

$$\textit{Daily Chemical Intake}_{IS} = C_S \bullet \frac{IR_S \bullet FI \bullet CF \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Adults		
Ingestion Rate (IRs, mg/day)	50	As per NEPM 2013
Fraction Ingested from Source (FI, unitless)	100%	All of daily soil intake occurs from site
Exposure Frequency (EF, days/year)	365	Days at home (normal conditions), as per NEPM (1999 amended 2013)
Exposure Duration (ED, years)	29	Time at one residence as adult as per enHealth 2002 and NEPM 1999
Body Weight (BW, kg)	70	For male and females combined (enHealth 2012)
Conversion Factor (CF)	1.00E-06	conversion from mg to kg
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	10585	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Soil Concentration (mg/kg)	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)			NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	2.6E-01	7.7E-08	1.9E-07	--		2.2E-04	4%
Arsenic		2.0E-03	50%	1.0E-03	100%	2.5E-01	7.3E-08	1.8E-07	--		1.8E-04	3%
Beryllium		2.0E-03		2.0E-03	100%	6.1E-03	1.8E-09	4.3E-09	--		2.2E-06	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	1.1E-01	3.4E-08	8.1E-08	--		2.5E-04	4%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	5.6E-01	1.6E-07	4.0E-07	--		4.9E-04	8%
Copper		1.4E-01	60%	5.6E-02	100%	5.9E-02	1.7E-08	4.2E-08	--		7.5E-07	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	3.4E+00	1.0E-06	2.4E-06	--		2.1E-03	36%
Lead		3.5E-03	50%	1.8E-03	100%	5.0E+00	1.5E-06	3.6E-06	--		2.0E-03	34%
Manganese		1.4E-01	50%	7.0E-02	100%	5.4E-01	1.6E-07	3.9E-07	--		5.5E-06	0%
Mercury		6.0E-04	40%	3.6E-04	100%	1.5E-01	4.3E-08	1.0E-07	--		2.9E-04	5%
Nickel		1.2E-02	60%	4.8E-03	100%	5.3E-01	1.6E-07	3.8E-07	--		7.9E-05	1%
Thallium		8.0E-04		8.0E-04	100%	6.2E-02	1.8E-08	4.4E-08	--		5.5E-05	1%
Vanadium		2.0E-03		2.0E-03	100%	1.2E-01	3.7E-08	8.9E-08	--		4.4E-05	1%
Zinc		5.0E-01	80%	1.0E-01	100%	1.1E+01	3.4E-06	8.2E-06	--		8.2E-05	1%
PAHs (as BaP)	2.3E-01				100%				--		--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	6.5E-08	1.9E-14	4.6E-14	--		4.4E-05	1%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%				--		--	
								TOTAL	--		5.9E-3	

Exposure to Chemicals via Incidental Ingestion of Soil (Regulatory case)

$$Daily\ Chemical\ Intake_{IS} = C_S \bullet \frac{IR_S \bullet FI \bullet CF \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Young Children		
Ingestion Rate (IRs, mg/day)	100	Assumed daily soil ingestion rate for young children, enHealth (2012)
Fraction Ingested from Source (FI, unitless)	100%	All of daily soil intake occurs from site
Exposure Frequency (EF, days/year)	365	Days at home (normal conditions), as per NEPM (1999 amended 2013)
Exposure Duration (ED, years)	6	Duration as young child
Body Weight (BW, kg)	15	Representative weight as per NEPM (2013)
Conversion Factor (CF)	1.00E-06	conversion from mg to kg
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Soil Concentration (mg/kg)	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)			NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	2.6E-01	1.5E-07	1.7E-06	--		2.0E-03	4%
Arsenic		2.0E-03	50%	1.0E-03	100%	2.5E-01	1.4E-07	1.6E-06	--		1.6E-03	3%
Beryllium		2.0E-03		2.0E-03	100%	6.1E-03	3.5E-09	4.1E-08	--		2.0E-05	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	1.1E-01	6.5E-08	7.6E-07	--		2.4E-03	4%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	5.6E-01	3.2E-07	3.7E-06	--		4.6E-03	8%
Copper		1.4E-01	60%	5.6E-02	100%	5.9E-02	3.4E-08	3.9E-07	--		7.0E-06	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	3.4E+00	1.9E-06	2.2E-05	--		2.0E-02	36%
Lead		3.5E-03	50%	1.8E-03	100%	5.0E+00	2.9E-06	3.3E-05	--		1.9E-02	34%
Manganese		1.4E-01	50%	7.0E-02	100%	5.4E-01	3.1E-07	3.6E-06	--		5.1E-05	0%
Mercury		6.0E-04	40%	3.6E-04	100%	1.5E-01	8.3E-08	9.7E-07	--		2.7E-03	5%
Nickel		1.2E-02	60%	4.8E-03	100%	5.3E-01	3.0E-07	3.5E-06	--		7.4E-04	1%
Thallium		8.0E-04		8.0E-04	100%	6.2E-02	3.5E-08	4.1E-07	--		5.1E-04	1%
Vanadium		2.0E-03		2.0E-03	100%	1.2E-01	7.1E-08	8.3E-07	--		4.1E-04	1%
Zinc		5.0E-01	80%	1.0E-01	100%	1.1E+01	6.5E-06	7.6E-05	--		7.6E-04	1%
PAHs (as BaP)	2.3E-01				100%				--		--	
Dioxins and furans (WHO-TE		2.3E-09	54%	1.1E-09	100%	6.5E-08	3.7E-14	4.3E-13	--		4.1E-04	1%
Dioxin-like PCBs (WHO-TE(		2.3E-09	54%	1.1E-09	100%				--		--	

TOTAL	--	5.5E-2

Dermal Exposure to Chemicals via Contact with Soil (Regulatory case)

$$Daily\ Chemical\ Intake_{DS} = C_S \bullet \frac{SA_S \bullet AF \bullet FE \bullet ABS \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \qquad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Adults		
Surface Area (SAs, cm^2)	6300	Exposed skin surface area for adults as per NEPM (2013)
Adherence Factor (AF, mg/cm^2)	0.5	Default as per NEPM (2013)
Fraction of Day Exposed	1	Assume skin is washed after 24 hours
Conversion Factor (CF)	1.E-06	Conversion of units
Dermal absorption (ABS, unitless)	Chemical-specific (as below)	
Exposure Frequency (EF, days/year)	365	Days at home (normal conditions), as per NEPM (1999 amended 2013)
Exposure Duration (ED, years)	29	Time at one residence as adult as per enHealth 2002 and NEPM 1999
Body Weight (BW, kg)	70	For male and females combined (enHealth 2012)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	10585	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data					Soil Concentration	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Dermal Absorption (ABS)		Non-Threshold	Threshold	Non-Threshold Risk	% Total Risk	Chronic Hazard Quotient	% Total HI
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)		(unitless)	
Antimony		8.6E-04		8.6E-04		2.6E-01			--		--	
Arsenic		2.0E-03	50%	1.0E-03		2.5E-01			--		--	
Beryllium		2.0E-03		2.0E-03		6.1E-03			--		--	
Cadmium		8.0E-04	60%	3.2E-04		1.1E-01			--		--	
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04		5.6E-01			--		--	
Copper		1.4E-01	60%	5.6E-02		5.9E-02			--		--	
Cobalt		1.4E-03	20%	1.1E-03	0.001	3.4E+00	6.3E-08	1.5E-07	--		1.4E-04	
Lead		3.5E-03	50%	1.8E-03		5.0E+00			--		--	
Manganese		1.4E-01	50%	7.0E-02		5.4E-01			--		--	
Mercury		6.0E-04	40%	3.6E-04	0.001	1.5E-01	2.7E-09	6.5E-09	--		1.8E-05	
Nickel		1.2E-02	60%	4.8E-03		5.3E-01			--		--	
Thallium		8.0E-04		8.0E-04		6.2E-02			--		--	
Vanadium		2.0E-03		2.0E-03		1.2E-01			--		--	
Zinc		5.0E-01	80%	1.0E-01	0.001	1.1E+01	2.1E-07	5.2E-07	--		5.2E-06	
PAHs (as BaP)	2.3E-01				0.06				--		--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	0.03	6.5E-08	3.6E-14	8.7E-14	--		8.2E-05	
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	0.03				--		--	
								TOTAL	--		2.4E-04	

Dermal Exposure to Chemicals via Contact with Soil (Regulatory case)

$$Daily\ Chemical\ Intake_{DS} = C_S \bullet \frac{SA_S \bullet AF \bullet FE \bullet ABS \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \qquad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Young Children		
Surface Area (SAs, cm^2)	2700	Exposed skin surface area for young children as per NEPM (2013)
Adherence Factor (AF, mg/cm^2)	0.5	Default as per NEPM (2013)
Fraction of Day Exposed	1	Assume skin is washed after 24 hours
Conversion Factor (CF)	1.E-06	Conversion of units
Dermal absorption (ABS, unitless)	Chemical-specific (as below)	
Exposure Frequency (EF, days/year)	365	Days at home (normal conditions), as per NEPM (1999 amended 2013)
Exposure Duration (ED, years)	6	Duration as young child
Body Weight (BW, kg)	15	Representative weight as per NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data					Soil Concentration	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Dermal Absorption (ABS)		Non-Threshold	Threshold	Non-Threshold Risk	% Total Risk	Chronic Hazard Quotient	% Total HI
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)		(unitless)	
Antimony		8.6E-04		8.6E-04		2.6E-01			--		--	
Arsenic		2.0E-03	50%	1.0E-03		2.5E-01			--		--	
Beryllium		2.0E-03		2.0E-03		6.1E-03			--		--	
Cadmium		8.0E-04	60%	3.2E-04		1.1E-01			--		--	
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04		5.6E-01			--		--	
Copper		1.4E-01	60%	5.6E-02		5.9E-02			--		--	
Cobalt		1.4E-03	20%	1.1E-03	0.001	3.4E+00	2.6E-08	3.0E-07	--		2.7E-04	
Lead		3.5E-03	50%	1.8E-03		5.0E+00			--		--	
Manganese		1.4E-01	50%	7.0E-02		5.4E-01			--		--	
Mercury		6.0E-04	40%	3.6E-04	0.001	1.5E-01	1.1E-09	1.3E-08	--		3.6E-05	
Nickel		1.2E-02	60%	4.8E-03		5.3E-01			--		--	
Thallium		8.0E-04		8.0E-04		6.2E-02			--		--	
Vanadium		2.0E-03		2.0E-03		1.2E-01			--		--	
Zinc		5.0E-01	80%	1.0E-01	0.001	1.1E+01	8.8E-08	1.0E-06	--		1.0E-05	
PAHs (as BaP)	2.3E-01				0.06				--		--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	0.03	6.5E-08	1.5E-14	1.7E-13	--		1.6E-04	
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	0.03				--		--	
								TOTAL	--		4.8E-04	

Homegrown fruit and vegetables and crops

Calculation of Concentrations in Plants

ref: Stevens B. (1991)

Uptake Due to Deposition in Aboveground Crops	Uptake via Roots from Soil
$C_p = \frac{DR \bullet F \bullet \left[1 - e^{-k \bullet t}\right]}{Y \bullet k}$ (mg/kg plant – wet weight)	$C_{rp} = C_s \bullet RUF$ (mg/kg plant – wet weight)
where: DR= Particle deposition rate for accidental release (mg/m^2/day) F= Fraction for the surface area of plant (unitless) k= Chemical-specific soil-loss constant (1/years) = ln(2)/$T_{0.5}$ $T_{0.5}$= Chemical half-life as particulate on plant (days) t= Deposition time (days) Y= Crop yield (kg/m^2)	**where**: Cs = Concentration of persistent chemical in soil assuming 15cm mixing depth within gardens, calculated using Soil Equation for each chemical assessed (mg/kg) RUF = Root uptake factor which differs for each Chemical (unitless)

General Parameters	Units	Value
Crop		Edible crops
Crop Yield (Y)	kg/m^2	2
Deposition Time (t)	days	70
Plant Interception fraction (F)	unitless	0.051

Chemical-specific Inputs and calculations - Maximum sensitive receptors

Chemical	Half-life in plant ($T_{0.5}$) days	Loss constant (k) per day	Deposition Rate (DR) mg/m^2/day	Aboveground Produce Concentration via Deposition mg/kg ww	Root Uptake Factor (RUF) (A) unitless	Soil Concentration (Cs) mg/kg	Below Ground Produce Concentration mg/kg ww	Uptake factor into grain crops (from soil) (B) unitless	Concetration in grain crops mg/kg ww
Antimony	14	0.05	1.6E-04	8.1E-05	0.05	1.7E-02	8.7E-04	0.03	5.2E-04
Arsenic	14	0.05	1.5E-04	7.7E-05	0.01	1.6E-02	1.6E-04	0.026	4.3E-04
Beryllium	14	0.05	3.8E-06	1.9E-06	0.0025	4.1E-04	1.0E-06	0.002	8.1E-07
Cadmium	14	0.05	7.1E-05	3.5E-05	0.125	7.6E-03	9.5E-04	0.36	2.7E-03
Chromium (Cr VI assumed)	14	0.05	3.5E-04	1.7E-04	0.00188	3.7E-02	7.0E-05	0.0045	1.7E-04
Copper	14	0.05	3.7E-05	1.8E-05	0.1	3.9E-03	3.9E-04	0.25	9.8E-04
Cobalt	14	0.05	2.1E-03	1.1E-03	0.005	2.2E-01	1.1E-03	0.0037	8.3E-04
Lead	14	0.05	3.1E-03	1.6E-03	0.0113	3.3E-01	3.8E-03	0.0047	1.6E-03
Manganese	14	0.05	3.4E-04	1.7E-04	0.0625	3.6E-02	2.2E-03	0.3	1.1E-02
Mercury	14	0.05	9.1E-05	4.5E-05	0.225	9.7E-03	2.2E-03	0.0854	8.3E-04
Nickel	14	0.05	3.3E-04	1.7E-04	0.015	3.5E-02	5.3E-04	0.01	3.5E-04
Thallium	14	0.05	3.9E-05	1.9E-05	0.001	4.1E-03	4.1E-06	0.004	1.6E-05
Vanadium	14	0.05	7.8E-05	3.9E-05	0.00138	8.3E-03	1.1E-05	0.00138	1.1E-05
Zinc	14	0.05	7.2E-03	3.6E-03	0.264	7.6E-01	2.0E-01	0.1	7.6E-02
PAHs (as BaP)	14	0.05	0.0E+00	0.0E+00	0.00214	0.0E+00	0.0E+00	0.00214	0.0E+00
Dioxins and furans (WHO-TEQ)	14	0.05	6.9E-11	3.4E-11	0.000876	4.3E-09	3.8E-12	0.000876	3.8E-12
Dioxin-like PCBs (WHO-TEQ)	14	0.05	0.0E+00	0.0E+00	0.000876	0.0E+00	0.0E+00	0.000876	0.0E+00

(A) Root uptake factors from RAIS (soil to wet weight of plant)

Note uptake into plants from soil considered insignificant as dioxins are very poorly soluble (OEHHA 2015 and USEPA 1994)

(B) Uptake factors adopted for grain based bioconcentration factors for grains and cereals (geometric mean value) from USEPA (1996) and Staven (2003)

Where no value is available the root uptake factor has been assumed to be relevant to the uptake into grains (relevant to vanadium, dioxins/furans and PAHs). Note that for PAHs the translocation from root to grain is expected to be negligible hence this approach is conservative

Exposure to Chemicals via Ingestion of Homegrown Fruit and Vegetables (Regulatory case)

$$\text{Daily chemical intake} = C_A \times \frac{IR_P \times \%A \times FI \times ME \times EF \times ED}{BW \times AT} + C_R \times \frac{IR_P \times \%R \times FI \times ME \times ED \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Adults		
Ingestion Rate of Produce (IRp) (kg/day)	0.4	Total fruit and vegetable consumption rate for adults as per NEPM (2013)
Proportion of total intake from aboveground crops (%A	73%	Proportions as per NEPM (2013)
Proportion of total intake from root crops (%R)	27%	Proportions as per NEPM (2013)
Fraction ingested that is homegrown (%)	10%	Relevant to urban areas as per NEPM (2013)
Matrix effect (unitless)	1	Assume chemicals ingested in produce is 100% bioavailable
Exposure Frequency (EF, days/year)	365	Days at home (normal conditions), as per NEPM (1999 amended 2013)
Exposure Duration (ED, years)	29	Time at one residence as adult as per enHealth 2002 and NEPM 1999
Body Weight (BW, kg)	70	For male and females combined (enHealth 2012)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	10585	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Above ground produce concentration	Root crops concentrations	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)				NonThreshold	Threshold	Non-Threshold Risk	% Total Risk	Chronic Hazard Quotient	% Total HI
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg wet weight)	(mg/kg wet weight)	(mg/kg/day)	(mg/kg/day)	(unitless)		(unitless)	
Antimony		8.6E-04		8.6E-04	100%	8.1E-05	8.7E-04	6.9E-08	1.7E-07	--		1.9E-04	6%
Arsenic		2.0E-03	50%	1.0E-03	100%	7.7E-05	1.6E-04	2.4E-08	5.7E-08	--		5.7E-05	2%
Beryllium		2.0E-03		2.0E-03	100%	1.9E-06	1.0E-06	3.9E-10	9.5E-10	--		4.7E-07	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	3.5E-05	9.5E-04	6.7E-08	1.6E-07	--		5.0E-04	14%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	1.7E-04	7.0E-05	3.4E-08	8.3E-08	--		1.0E-04	3%
Copper		1.4E-01	60%	5.6E-02	100%	1.8E-05	3.9E-04	2.8E-08	6.8E-08	--		1.2E-06	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	1.1E-03	1.1E-03	2.5E-07	6.1E-07	--		5.5E-04	16%
Lead		3.5E-03	50%	1.8E-03	100%	1.6E-03	3.8E-03	5.1E-07	1.2E-06	--		7.1E-04	20%
Manganese		1.4E-01	50%	7.0E-02	100%	1.7E-04	2.2E-03	1.7E-07	4.2E-07	--		6.0E-06	0%
Mercury		6.0E-04	40%	3.6E-04	100%	4.5E-05	2.2E-03	1.5E-07	3.6E-07	--		9.9E-04	28%
Nickel		1.2E-02	60%	4.8E-03	100%	1.7E-04	5.3E-04	6.2E-08	1.5E-07	--		3.1E-05	1%
Thallium		8.0E-04		8.0E-04	100%	1.9E-05	4.1E-06	3.6E-09	8.7E-09	--		1.1E-05	0%
Vanadium		2.0E-03		2.0E-03	100%	3.9E-05	1.1E-05	7.5E-09	1.8E-08	--		9.0E-06	0%
Zinc		5.0E-01	80%	1.0E-01	100%	3.6E-03	2.0E-01	1.4E-05	3.3E-05	--		3.3E-04	9%
PAHs (as BaP)	2.3E-01				100%					--		--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	3.4E-11	3.8E-12	6.2E-15	1.5E-14	--		1.4E-05	0%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%					--		--	
									TOTAL	--		3.5E-03	

Exposure to Chemicals via Ingestion of Homegrown Fruit and Vegetables (Regulatory case)

$$\text{Daily chemical intake} = C_A \times \frac{IR_P \times \%A \times FI \times ME \times EF \times ED}{BW \times AT} + C_R \times \frac{IR_P \times \%R \times FI \times ME \times ED \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

Scenario 2

Parameters Relevant to Quantification of Exposure by Young children		
Ingestion Rate of Produce (IRp) (kg/day)	0.28	Total fruit and vegetable consumption rate for children as per NEPM (2013)
Proportion of total intake from aboveground crops (%A	84%	Proportions as per NEPM (2013)
Proportion of total intake from root crops (%R)	16%	Proportions as per NEPM (2013)
Fraction ingested that is homegrown (%)	10%	Relevant to urban areas as per NEPM (2013)
Matrix effect (unitless)	1	Assume chemicals ingested in produce is 100% bioavailable
Exposure Frequency (EF, days/year)	365	Days at home (normal conditions), as per NEPM (1999 amended 2013)
Exposure Duration (ED, years)	6	Duration as young child
Body Weight (BW, kg)	15	Representative weight as per NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Above ground produce concentration	Root crops concentrations	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/kg wet weight)	(mg/kg wet weight)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	8.1E-05	8.7E-04	3.3E-08	3.9E-07	--		4.5E-04	5%
Arsenic		2.0E-03	50%	1.0E-03	100%	7.7E-05	1.6E-04	1.5E-08	1.7E-07	--		1.7E-04	2%
Beryllium		2.0E-03		2.0E-03	100%	1.9E-06	1.0E-06	2.8E-10	3.3E-09	--		1.6E-06	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	3.5E-05	9.5E-04	2.9E-08	3.4E-07	--		1.1E-03	12%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	1.7E-04	7.0E-05	2.5E-08	2.9E-07	--		3.6E-04	4%
Copper		1.4E-01	60%	5.6E-02	100%	1.8E-05	3.9E-04	1.3E-08	1.5E-07	--		2.6E-06	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	1.1E-03	1.1E-03	1.7E-07	2.0E-06	--		1.8E-03	20%
Lead		3.5E-03	50%	1.8E-03	100%	1.6E-03	3.8E-03	3.1E-07	3.6E-06	--		2.0E-03	23%
Manganese		1.4E-01	50%	7.0E-02	100%	1.7E-04	2.2E-03	8.0E-08	9.3E-07	--		1.3E-05	0%
Mercury		6.0E-04	40%	3.6E-04	100%	4.5E-05	2.2E-03	6.2E-08	7.2E-07	--		2.0E-03	23%
Nickel		1.2E-02	60%	4.8E-03	100%	1.7E-04	5.3E-04	3.6E-08	4.2E-07	--		8.7E-05	1%
Thallium		8.0E-04		8.0E-04	100%	1.9E-05	4.1E-06	2.7E-09	3.1E-08	--		3.9E-05	0%
Vanadium		2.0E-03		2.0E-03	100%	3.9E-05	1.1E-05	5.5E-09	6.4E-08	--		3.2E-05	0%
Zinc		5.0E-01	80%	1.0E-01	100%	3.6E-03	2.0E-01	5.6E-06	6.6E-05	--		6.6E-04	8%
PAHs (as BaP)	2.3E-01				100%					--		--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	3.4E-11	3.8E-12	4.7E-15	5.5E-14	--		5.2E-05	1%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%					--		--	

TOTAL	--	8.7E-03

Ingestion of eggs

Calculation of Concentrations in Eggs (Regulatory case)

Uptake in to chicken eggs

$$C_E=(FI \times IR_C \times C+IR_S \times C_S \times B) \times TF_E$$ (mg/kg egg – wet weight)

where:
FI = Fraction of pasture/crop ingested by chickens each day (unitless)
IRc = Ingestion rate of pasture/crop by chicken each day (kg/day)
C = Concentration of chemical in grain/crop eaten by chicken (mg/kg)
IRs = Ingestion rate of soil by chickens each day (kg/day)
Cs = Concentration in soil the chickens ingest (mg/kg)
B = Bioavailability of soil ingested by chickens (%)
TFE = Transfer factor from ingestion to eggs (day/kg)

General Parameters	Units	Value	
FI (fraction of crops ingested from property)		1	Assume pasture is grown on the site
IRc (ingestion rate of crops)	kg/day	0.12	As per OEHHA (2015)
IRs (ingestion rate of soil)	kg/day	0.01	As per OEHHA (2015) and advice from AgVIC
B (bioavailability)	%	100%	

Chemical-specific Inputs and calculations - Maximum sensitive receptors

Chemical	Concentration in crops ingested by chickens mg/kg ww	Soil Concentration - Agriculture (Cs) mg/kg	Transfer factor to eggs day/kg	Egg Concentration mg/kg ww	
Antimony	8.1E-05	1.7E-02	1.7E-01	3.1E-05	95% from Leeman et al (2007)
Arsenic	7.7E-05	1.6E-02	7.0E-02	1.2E-05	
Beryllium	1.9E-06	4.1E-04	9.0E-02	3.9E-07	
Cadmium	3.5E-05	7.6E-03	1.0E-02	8.0E-07	
Chromium (Cr VI assumed)	1.7E-04	3.7E-02	9.2E-03	3.6E-06	OEHHA (2003)
Copper	1.8E-05	3.9E-03	1.7E-01	7.1E-06	95% from Leeman et al (2007)
Cobalt	1.1E-03	2.2E-01	3.3E-03	7.8E-06	MacLachlan (2011)
Lead	1.6E-03	3.3E-01	4.0E-02	1.4E-04	
Manganese	1.7E-04	3.6E-02	1.7E-01	6.5E-05	
Mercury	4.5E-05	9.7E-03	8.0E-01	8.2E-05	
Nickel	1.7E-04	3.5E-02	2.0E-02	7.5E-06	
Thallium	1.9E-05	4.1E-03	1.7E-01	7.4E-06	95% from Leeman et al (2007)
Vanadium	3.9E-05	8.3E-03	1.7E-01	1.5E-05	95% from Leeman et al (2007)
Zinc	3.6E-03	7.6E-01	1.7E-01	1.4E-03	95% from Leeman et al (2007)
PAHs (as BaP)	0.0E+00	0.0E+00	3.0E-03	0.0E+00	
Dioxins and furans (WHO-TEQ)	3.4E-11	4.3E-09	1.0E+01	4.7E-10	
Dioxin-like PCBs (WHO-TEQ)	0.0E+00	0.0E+00	1.0E+01	0.0E+00	

Transfer factors from OEHHA 2015 unless otherwise noted

Exposure to Chemicals via Ingestion of Eggs (Regulatory case)

$$\text{Daily chemical intake} = C_E \times \frac{IR_E \times FI \times ME \times EF \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Adults		
Ingestion Rate of Eggs (IRE) (kg/day)	0.014	Ingestion rate of eggs relevant for adults as per enHealth (2012)
Fraction ingested that is homegrown (%)	100%	Assume all eggs consumed in urban area are from backyard chickens
Matrix effect (unitless)	1	Assume chemicals ingested in produce is 100% bioavailable
Exposure Frequency (EF, days/year)	365	Days at home (normal conditions), as per NEPM (1999 amended 2013)
Exposure Duration (ED, years)	29	Time at one residence as adult as per enHealth 2002 and NEPM 1999
Body Weight (BW, kg)	70	For male and females combined (enHealth 2012)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	10585	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Egg concentration	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/kg wet weight)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	3.1E-05	2.6E-09	6.2E-09	--		7.2E-06	4%
Arsenic		2.0E-03	50%	1.0E-03	100%	1.2E-05	1.0E-09	2.4E-09	--		2.4E-06	1%
Beryllium		2.0E-03		2.0E-03	100%	3.9E-07	3.2E-11	7.7E-11	--		3.9E-08	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	8.0E-07	6.6E-11	1.6E-10	--		5.0E-07	0%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	3.6E-06	3.0E-10	7.2E-10	--		8.9E-07	1%
Copper		1.4E-01	60%	5.6E-02	100%	7.1E-06	5.9E-10	1.4E-09	--		2.5E-08	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	7.8E-06	6.5E-10	1.6E-09	--		1.4E-06	1%
Lead		3.5E-03	50%	1.8E-03	100%	1.4E-04	1.2E-08	2.8E-08	--		1.6E-05	9%
Manganese		1.4E-01	50%	7.0E-02	100%	6.5E-05	5.3E-09	1.3E-08	--		1.8E-07	0%
Mercury		6.0E-04	40%	3.6E-04	100%	8.2E-05	6.8E-09	1.6E-08	--		4.5E-05	27%
Nickel		1.2E-02	60%	4.8E-03	100%	7.5E-06	6.2E-10	1.5E-09	--		3.1E-07	0%
Thallium		8.0E-04		8.0E-04	100%	7.4E-06	6.1E-10	1.5E-09	--		1.8E-06	1%
Vanadium		2.0E-03		2.0E-03	100%	1.5E-05	1.2E-09	3.0E-09	--		1.5E-06	1%
Zinc		5.0E-01	80%	1.0E-01	100%	1.4E-03	1.1E-07	2.7E-07	--		2.7E-06	2%
PAHs (as BaP)	2.3E-01				100%				--		--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	4.7E-10	3.9E-14	9.4E-14	--		8.9E-05	52%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%				--		--	
									TOTAL	**--**		**1.7E-04**

Exposure to Chemicals via Ingestion of Eggs (Regulatory case)

$$\text{Daily chemical intake} = C_E \times \frac{IR_E \times FI \times ME \times EF \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Young children		
Ingestion Rate of Eggs (IRE) (kg/day)	0.006	Ingestion rate of eggs relevant for young children as per enHealth (2012)
Fraction ingested that is homegrown (%)	100%	Assume all eggs consumed in urban area are from backyard chickens
Matrix effect (unitless)	1	Assume chemicals ingested in produce is 100% bioavailable
Exposure Frequency (EF, days/year)	365	Days at home (normal conditions), as per NEPM (1999 amended 2013)
Exposure Duration (ED, years)	6	Duration as young child
Body Weight (BW, kg)	15	Representative weight as per NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Egg concentration (mg/kg wet weight)	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)			NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	3.1E-05	1.1E-09	1.2E-08	--		1.4E-05	4%
Arsenic		2.0E-03	50%	1.0E-03	100%	1.2E-05	4.2E-10	4.9E-09	--		4.9E-06	1%
Beryllium		2.0E-03		2.0E-03	100%	3.9E-07	1.3E-11	1.5E-10	--		7.7E-08	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	8.0E-07	2.7E-11	3.2E-10	--		1.0E-06	0%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	3.6E-06	1.2E-10	1.4E-09	--		1.8E-06	1%
Copper		1.4E-01	60%	5.6E-02	100%	7.1E-06	2.4E-10	2.8E-09	--		5.1E-08	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	7.8E-06	2.7E-10	3.1E-09	--		2.8E-06	1%
Lead		3.5E-03	50%	1.8E-03	100%	1.4E-04	4.8E-09	5.6E-08	--		3.2E-05	9%
Manganese		1.4E-01	50%	7.0E-02	100%	6.5E-05	2.2E-09	2.6E-08	--		3.7E-07	0%
Mercury		6.0E-04	40%	3.6E-04	100%	8.2E-05	2.8E-09	3.3E-08	--		9.1E-05	27%
Nickel		1.2E-02	60%	4.8E-03	100%	7.5E-06	2.6E-10	3.0E-09	--		6.2E-07	0%
Thallium		8.0E-04		8.0E-04	100%	7.4E-06	2.5E-10	2.9E-09	--		3.7E-06	1%
Vanadium		2.0E-03		2.0E-03	100%	1.5E-05	5.1E-10	6.0E-09	--		3.0E-06	1%
Zinc		5.0E-01	80%	1.0E-01	100%	1.4E-03	4.7E-08	5.5E-07	--		5.5E-06	2%
PAHs (as BaP)	2.3E-01				100%				--		--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	4.7E-10	1.6E-14	1.9E-13	--		1.8E-04	52%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%				--		--	

	Non-Threshold Risk	Chronic Hazard Quotient
TOTAL	**--**	**3.4E-04**

Ingestion of beef

Calculation of Concentrations in Homegrown Beef (Regulatory case)

Uptake in to beef meat

$$C_E = (FI \times IR_C \times C + IR_S \times C_S \times B) \times TF_B$$ (mg/kg beef – wet weight)

where:
FI = Fraction of grain/crop ingested by cattle each day (unitless)
IRc = Ingestion rate of grain/crop by cattle each day (kg/day)
C = Concentration of chemical in grain/crop eaten by cattle (mg/kg)
IRs = Ingestion rate of soil by cattle each day (kg/day)
Cs = Concentration in soil the cattle ingest (mg/kg)
B = Bioavailability of soil ingested by cattle (%)
TFE = Transfer factor from ingestion to beef (day/kg)

General Parameters	Units	Value	
FI (fraction of crops ingested from property)		1	Assume 100% of pasture consumed by cattle is grown in the same soil
IRc (ingestion rate of crops)	kg/day	9	Assumed ingestion rate from OEHHA 2015 (assume concentration the same as predicted for aboveground crops)
IRs (ingestion rate of soil)	kg/day	0.45	Based on data from OEHHA 2015 (5% total produce intakes from soil from pasture)
B (bioavailability)	%	100%	

Chemical-specific Inputs and calculations - maximum sensitive receptors

Chemical	Concentration in crops ingested by cattle mg/kg ww	Soil Concentration - Agriculture (Cs) mg/kg	Transfer factor to beef day/kg	Beef Concentration mg/kg ww	
Antimony	8.1E-05	1.7E-02	1.0E-03	8.5E-06	RAIS
Arsenic	7.7E-05	1.6E-02	2.0E-03	1.6E-05	
Beryllium	1.9E-06	4.1E-04	3.0E-04	6.0E-08	
Cadmium	3.5E-05	7.6E-03	2.0E-03	7.4E-06	
Chromium (Cr VI assumed)	1.7E-04	3.7E-02	5.5E-03	1.0E-04	RAIS
Copper	1.8E-05	3.9E-03	1.0E-02	1.9E-05	RAIS
Cobalt	1.1E-03	2.2E-01	2.0E-02	2.2E-03	RAIS
Lead	1.6E-03	3.3E-01	3.0E-04	4.9E-05	
Manganese	1.7E-04	3.6E-02	4.0E-04	7.1E-06	RAIS
Mercury	4.5E-05	9.7E-03	4.0E-02	1.9E-04	
Nickel	1.7E-04	3.5E-02	3.0E-04	5.2E-06	
Thallium	1.9E-05	4.1E-03	4.0E-02	8.1E-05	RAIS
Vanadium	3.9E-05	8.3E-03	2.5E-03	1.0E-05	RAIS
Zinc	3.6E-03	7.6E-01	1.0E-01	3.8E-02	RAIS
PAHs (as BaP)	0.0E+00	0.0E+00	7.0E-02	0.0E+00	
Dioxins and furans (WHO-TEQ)	3.4E-11	4.3E-09	7.0E-01	1.6E-09	
Dioxin-like PCBs (WHO-TEQ)	0.0E+00	0.0E+00	2.0E+00	0.0E+00	

Transfer factors from OEHHA 2015 unless otherwise noted

Exposure to Chemicals via Ingestion of Beef (Regulatory case)

$$\text{Daily chemical intake} = C_B \times \frac{IR_B \times FI \times ME \times EF \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Adults		
Ingestion Rate of Beef (IRB) (kg/day)	0.16	Ingestion rate of beef for adults >19 years (enHealth 2012, noted to be the same as P90 from FSANZ 2017)
Fraction ingested that is homegrown (%)	35%	Assume 35% beef intakes from home-sourced meat
Matrix effect (unitless)	1	Assume chemicals ingested in produce is 100% bioavailable
Exposure Frequency (EF, days/year)	365	Exposure occurs every day
Exposure Duration (ED, years)	29	Time at one residence as adult as per enHealth 2002 and NEPM 1999
Body Weight (BW, kg)	70	For male and females combined (enHealth 2012)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	10585	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

	Toxicity Data						Daily Intake		Calculated Risk			
Key Chemical	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	Bioavailability (%)	Beef concentration (mg/kg wet weight)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	8.5E-06	2.8E-09	6.8E-09	--		7.9E-06	0%
Arsenic		2.0E-03	50%	1.0E-03	100%	1.6E-05	5.4E-09	1.3E-08	--		1.3E-05	0%
Beryllium		2.0E-03		2.0E-03	100%	6.0E-08	2.0E-11	4.8E-11	--		2.4E-08	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	7.4E-06	2.5E-09	6.0E-09	--		1.9E-05	0%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	1.0E-04	3.3E-08	8.0E-08	--		9.9E-05	3%
Copper		1.4E-01	60%	5.6E-02	100%	1.9E-05	6.4E-09	1.6E-08	--		2.8E-07	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	2.2E-03	7.3E-07	1.8E-06	--		1.6E-03	42%
Lead		3.5E-03	50%	1.8E-03	100%	4.9E-05	1.6E-08	3.9E-08	--		2.3E-05	1%
Manganese		1.4E-01	50%	7.0E-02	100%	7.1E-06	2.3E-09	5.7E-09	--		8.1E-08	0%
Mercury		6.0E-04	40%	3.6E-04	100%	1.9E-04	6.3E-08	1.5E-07	--		4.2E-04	11%
Nickel		1.2E-02	60%	4.8E-03	100%	5.2E-06	1.7E-09	4.2E-09	--		8.7E-07	0%
Thallium		8.0E-04		8.0E-04	100%	8.1E-05	2.7E-08	6.5E-08	--		8.1E-05	2%
Vanadium		2.0E-03		2.0E-03	100%	1.0E-05	3.4E-09	8.2E-09	--		4.1E-06	0%
Zinc		5.0E-01	80%	1.0E-01	100%	3.8E-02	1.2E-05	3.0E-05	--		3.0E-04	8%
PAHs (as BaP)	2.3E-01				100%				--		--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	1.6E-09	5.2E-13	1.3E-12	--		1.2E-03	32%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%				--		--	
								TOTAL			3.7E-03	

Exposure to Chemicals via Ingestion of Beef (Regulatory case)

$$\text{Daily chemical intake} = C_B \times \frac{IR_B \times FI \times ME \times EF \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Children		
Ingestion Rate of Beef (IRB) (kg/day)	0.085	Ingestion rate of beef by children aged 2-6 years (P90 value) FSANZ (2017)
Fraction ingested that is homegrown (%)	35%	Assume 35% beef intakes from home-sourced meat
Matrix effect (unitless)	1	Assume chemicals ingested in produce is 100% bioavailable
Exposure Frequency (EF, days/year)	365	Exposure occurs every day
Exposure Duration (ED, years)	6	Duration as young child
Body Weight (BW, kg)	15	Representative weight as per NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Beef concentration	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/kg wet weight)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	8.5E-06	1.4E-09	1.7E-08	--		2.0E-05	0%
Arsenic		2.0E-03	50%	1.0E-03	100%	1.6E-05	2.7E-09	3.2E-08	--		3.2E-05	0%
Beryllium		2.0E-03		2.0E-03	100%	6.0E-08	1.0E-11	1.2E-10	--		5.9E-08	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	7.4E-06	1.3E-09	1.5E-08	--		4.6E-05	0%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	1.0E-04	1.7E-08	2.0E-07	--		2.5E-04	3%
Copper		1.4E-01	60%	5.6E-02	100%	1.9E-05	3.3E-09	3.8E-08	--		6.9E-07	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	2.2E-03	3.8E-07	4.4E-06	--		3.9E-03	42%
Lead		3.5E-03	50%	1.8E-03	100%	4.9E-05	8.4E-09	9.8E-08	--		5.6E-05	1%
Manganese		1.4E-01	50%	7.0E-02	100%	7.1E-06	1.2E-09	1.4E-08	--		2.0E-07	0%
Mercury		6.0E-04	40%	3.6E-04	100%	1.9E-04	3.2E-08	3.8E-07	--		1.1E-03	11%
Nickel		1.2E-02	60%	4.8E-03	100%	5.2E-06	8.9E-10	1.0E-08	--		2.2E-06	0%
Thallium		8.0E-04		8.0E-04	100%	8.1E-05	1.4E-08	1.6E-07	--		2.0E-04	2%
Vanadium		2.0E-03		2.0E-03	100%	1.0E-05	1.7E-09	2.0E-08	--		1.0E-05	0%
Zinc		5.0E-01	80%	1.0E-01	100%	3.8E-02	6.4E-06	7.5E-05	--		7.5E-04	8%
PAHs (as BaP)	2.3E-01				100%				--		--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	1.6E-09	2.7E-13	3.1E-12	--		2.9E-03	32%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%				--		--	
								TOTAL			9.3E-03	

Milk ingestion

Calculation of Concentrations in Dairy Milk (Regulatory case)

Uptake in to milk (dairy cows)

$$C_E = (FI \times IR_C \times C + IR_S \times C_S \times B) \times TF_B$$ (mg/kg beef – wet weight)

where:
FI = Fraction of grain/crop ingested by cattle each day (unitless)
IRc = Ingestion rate of grain/crop by cattle each day (kg/day)
C = Concentration of chemical in grain/crop eaten by cattle (mg/kg)
IRs = Ingestion rate of soil by cattle each day (kg/day)
Cs = Concentration in soil the cattle ingest (mg/kg)
B = Bioavailability of soil ingested by cattle (%)
TFE = Transfer factor from ingestion to milk (day/kg)

General Parameters	Units	Value	
FI (fraction of crops ingested from property)		1	Assume 100% of pasture consumed by cattle is grown in the same soil
IRc (ingestion rate of crops)	kg/day	22	Assumed ingestion rate from OEHHA 2015 for lactating cattle (assume concentration the same as predicted for aboveground crops)
IRs (ingestion rate of soil)	kg/day	1.1	Based on data from OEHHA 2015 (5% total produce intakes from soil from pasture)
B (bioavailability)	%	100%	

Chemical-specific Inputs and calculations - maximum sensitive receptors

Chemical	Concentration in crops ingested by cattle mg/kg ww	Soil Concentration - Agriculture (Cs) mg/kg	Transfer factor to milk day/kg	Milk Concentration mg/kg or mg/L	
Antimony	8.1E-05	1.7E-02	1.0E-04	2.1E-06	RAIS
Arsenic	7.7E-05	1.6E-02	5.0E-05	9.9E-07	
Beryllium	1.9E-06	4.1E-04	9.0E-07	4.4E-10	
Cadmium	3.5E-05	7.6E-03	2.0E-03	1.8E-05	
Chromium (Cr VI assumed)	1.7E-04	3.7E-02	9.0E-06	4.0E-07	
Copper	1.8E-05	3.9E-03	1.5E-03	7.1E-06	RAIS
Cobalt	1.1E-03	2.2E-01	2.0E-03	5.4E-04	RAIS
Lead	1.6E-03	3.3E-01	6.0E-05	2.4E-05	
Manganese	1.7E-04	3.6E-02	3.5E-04	1.5E-05	RAIS
Mercury	4.5E-05	9.7E-03	7.0E-05	8.2E-07	
Nickel	1.7E-04	3.5E-02	3.0E-05	1.3E-06	
Thallium	1.9E-05	4.1E-03	2.0E-03	9.9E-06	RAIS
Vanadium	3.9E-05	8.3E-03	2.0E-05	2.0E-07	RAIS
Zinc	3.6E-03	7.6E-01	2.7E-09	2.5E-09	RAIS
PAHs (as BaP)	0.0E+00	0.0E+00	1.0E-02	0.0E+00	
Dioxins and furans (WHO-TEQ)	3.4E-11	4.3E-09	2.0E-02	1.1E-10	
Dioxin-like PCBs (WHO-TEQ)	0.0E+00	0.0E+00	4.0E-02	0.0E+00	

Transfer factors from OEHHA 2015 unless otherwise noted

Exposure to Chemicals via Ingestion of Milk (Regulatory case)

$$\text{Daily chemical intake} = C_M \times \frac{IR_M \times FI \times ME \times EF \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Adults		
Ingestion Rate of Milk (IRM) (L/day)	1.295	Ingestion rate of cows milk for adults (P90 value from FSANZ 2017)
Fraction ingested that is homegrown (%)	100%	Assume all milk consumed is from the dairy farm
Matrix effect (unitless)	1	Assume chemicals ingested in produce is 100% bioavailable
Exposure Frequency (EF, days/year)	365	Exposure occurs every day
Exposure Duration (ED, years)	29	Time at one residence as adult as per enHealth 2002 and NEPM 1999
Body Weight (BW, kg)	70	For male and females combined (enHealth 2012)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	10585	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Milk concentration	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/L)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	2.1E-06	1.6E-08	3.9E-08	--		4.5E-05	0%
Arsenic		2.0E-03	50%	1.0E-03	100%	9.9E-07	7.6E-09	1.8E-08	--		1.8E-05	0%
Beryllium		2.0E-03		2.0E-03	100%	4.4E-10	3.4E-12	8.1E-12	--		4.1E-09	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	1.8E-05	1.4E-07	3.4E-07	--		1.1E-03	8%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	4.0E-07	3.1E-09	7.4E-09	--		9.2E-06	0%
Copper		1.4E-01	60%	5.6E-02	100%	7.1E-06	5.4E-08	1.3E-07	--		2.3E-06	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	5.4E-04	4.1E-06	1.0E-05	--		8.9E-03	71%
Lead		3.5E-03	50%	1.8E-03	100%	2.4E-05	1.8E-07	4.5E-07	--		2.5E-04	2%
Manganese		1.4E-01	50%	7.0E-02	100%	1.5E-05	1.2E-07	2.8E-07	--		4.0E-06	0%
Mercury		6.0E-04	40%	3.6E-04	100%	8.2E-07	6.3E-09	1.5E-08	--		4.2E-05	0%
Nickel		1.2E-02	60%	4.8E-03	100%	1.3E-06	9.8E-09	2.4E-08	--		4.9E-06	0%
Thallium		8.0E-04		8.0E-04	100%	9.9E-06	7.6E-08	1.8E-07	--		2.3E-04	2%
Vanadium		2.0E-03		2.0E-03	100%	2.0E-07	1.5E-09	3.7E-09	--		1.8E-06	0%
Zinc		5.0E-01	80%	1.0E-01	100%	2.5E-09	1.9E-11	4.6E-11	--		4.6E-10	0%
PAHs (as BaP)	2.3E-01				100%				--		--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	1.1E-10	8.4E-13	2.0E-12	--		1.9E-03	15%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%				--		--	

TOTAL	**--**	**1.2E-02**

Exposure to Chemicals via Ingestion of Milk (Regulatory case)

$$\text{Daily chemical intake} = C_M \times \frac{IR_M \times FI \times ME \times EF \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Children		
Ingestion Rate of Milk (IRM) (L/day)	1.097	Ingestion rate of cows milk for children aged 2-6 years (P90 value from FSANZ 2017)
Fraction ingested that is homegrown (%)	100%	Assume all milk consumed is from the dairy farm
Matrix effect (unitless)	1	Assume chemicals ingested in produce is 100% bioavailable
Exposure Frequency (EF, days/year)	365	Exposure occurs every day
Exposure Duration (ED, years)	6	Duration as young child
Body Weight (BW, kg)	15	Representative weight as per NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Milk concentration	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	% Total Risk	Chronic Hazard Quotient	% Total HI
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/L)	(mg/kg/day)	(mg/kg/day)	(unitless)		(unitless)	
Antimony		8.6E-04		8.6E-04	100%	2.1E-06	1.3E-08	1.5E-07	--		1.8E-04	0%
Arsenic		2.0E-03	50%	1.0E-03	100%	9.9E-07	6.2E-09	7.2E-08	--		7.2E-05	0%
Beryllium		2.0E-03		2.0E-03	100%	4.4E-10	2.8E-12	3.2E-11	--		1.6E-08	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	1.8E-05	1.1E-07	1.3E-06	--		4.2E-03	8%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	4.0E-07	2.5E-09	2.9E-08	--		3.6E-05	0%
Copper		1.4E-01	60%	5.6E-02	100%	7.1E-06	4.5E-08	5.2E-07	--		9.3E-06	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	5.4E-04	3.4E-06	3.9E-05	--		3.5E-02	71%
Lead		3.5E-03	50%	1.8E-03	100%	2.4E-05	1.5E-07	1.8E-06	--		1.0E-03	2%
Manganese		1.4E-01	50%	7.0E-02	100%	1.5E-05	9.5E-08	1.1E-06	--		1.6E-05	0%
Mercury		6.0E-04	40%	3.6E-04	100%	8.2E-07	5.1E-09	6.0E-08	--		1.7E-04	0%
Nickel		1.2E-02	60%	4.8E-03	100%	1.3E-06	8.0E-09	9.3E-08	--		1.9E-05	0%
Thallium		8.0E-04		8.0E-04	100%	9.9E-06	6.2E-08	7.2E-07	--		9.0E-04	2%
Vanadium		2.0E-03		2.0E-03	100%	2.0E-07	1.3E-09	1.5E-08	--		7.3E-06	0%
Zinc		5.0E-01	80%	1.0E-01	100%	2.5E-09	1.5E-11	1.8E-10	--		1.8E-09	0%
PAHs (as BaP)	2.3E-01				100%				--		--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	1.1E-10	6.9E-13	8.0E-12	--		7.6E-03	15%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%				--		--	
								TOTAL	--		4.9E-02	

Lamb ingestion

Calculation of Concentrations in Homegrown Lamb

Uptake in to lamb meat

$$C_E = (FI \times IR_C \times C + IR_S \times C_S \times B) \times TF_B$$ (mg/kg meat – wet weight)

where:
FI = Fraction of grain/crop ingested by lambs each day (unitless)
IRc = Ingestion rate of grain/crop by lambs each day (kg/day)
C = Concentration of chemical in grain/crop eaten by lamb (mg/kg)
IRs = Ingestion rate of soil by lambs each day (kg/day)
Cs = Concentration in soil the lambs ingest (mg/kg)
B = Bioavailability of soil ingested by lambs (%)
TFE = Transfer factor from ingestion to lamb (day/kg)

General Parameters	Units	Value	
FI (fraction of crops ingested from property)		1	Assume 100% of pasture consumed by lambs is grown in the same soil
IRc (ingestion rate of crops)	kg/day	1.1088	4.2% body weight per day dry weight, then correcting for 20% moisture (assuming 22 kg weight)**
IRs (ingestion rate of soil)	kg/day	0.05544	Assumes 5% total produce intakes from soil from pasture, consistent with cattle
B (bioavailability)	%	100%	

** https://www.mla.com.au/contentassets/34ac9a74c56e4dbf8273d2a9bb2900c5/l.lsm.0022_-_production_feeding_for_lamb_growth__.pdf

Chemical-specific Inputs and calculations - maximum sensitive receptors					
Chemical	**Concentration in crops ingested by lambs mg/kg ww**	**Soil Concentration - Agriculture (Cs) mg/kg**	**Transfer factor to lambs day/kg**	**Lamb Concentration mg/kg ww**	
Antimony	8.1E-05	1.7E-02	1.0E-02	1.1E-05	MW adjustment
Arsenic	7.7E-05	1.6E-02	2.1E-02	2.1E-05	MW adjustment
Beryllium	1.9E-06	4.1E-04	3.1E-03	7.7E-08	MW adjustment
Cadmium	3.5E-05	7.6E-03	2.1E-02	9.5E-06	MW adjustment
Chromium (Cr VI assumed)	1.7E-04	3.7E-02	5.7E-02	1.3E-04	MW adjustment
Copper	1.8E-05	3.9E-03	1.0E-01	2.5E-05	MW adjustment
Cobalt	1.1E-03	2.2E-01	2.1E-01	2.8E-03	MW adjustment
Lead	1.6E-03	3.3E-01	3.1E-03	6.3E-05	MW adjustment
Manganese	1.7E-04	3.6E-02	4.2E-03	9.1E-06	MW adjustment
Mercury	4.5E-05	9.7E-03	4.2E-01	2.4E-04	MW adjustment
Nickel	1.7E-04	3.5E-02	3.1E-03	6.7E-06	MW adjustment
Thallium	1.9E-05	4.1E-03	4.2E-01	1.0E-04	MW adjustment
Vanadium	3.9E-05	8.3E-03	2.6E-02	1.3E-05	MW adjustment
Zinc	3.6E-03	7.6E-01	1.0E+00	4.8E-02	MW adjustment
PAHs (as BaP)	0.0E+00	0.0E+00	7.3E-01	0.0E+00	MW adjustment
Dioxins and furans (WHO-TEQ)	3.4E-11	4.3E-09	7.3E+00	2.0E-09	MW adjustment
Dioxin-like PCBs (WHO-TEQ)	0.0E+00	0.0E+00	2.1E+01	0.0E+00	MW adjustment

Transfer factors from OEHHA 2015 unless otherwise noted

MW weight adjustment = metabolic weight adjustmenta approach, modifying the TF for beef meet to pigs to acount for differences in tissue trasnfer due to different weights.

Approach adopted for pigs as per OEHHA (2012) to calculate transfer factors Tco as below. Approach also adopted for lambs (cattle = 500 kg and lambs = 22 kg (average for Australian lambs))

$$\text{Pig } Tco_i = (W^{0.75}{}_{cow}) / (W^{0.75}{}_{pig}) \times \text{cow } Tco_i$$

Transfer factor adjustment for lambs = 10.4

Exposure to Chemicals via Ingestion of Lamb (Regulatory case)

$$\text{Daily chemical intake} = C_B \times \frac{IR_B \times FI \times ME \times EF \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Adults		
Ingestion Rate of Beef (IRB) (kg/day)	0.085	Ingestion rate of sheep meat for adults, P90 from FSANZ 2017
Fraction ingested that is homegrown (%)	35%	Assume 35% beef intakes from home-sourced meat
Matrix effect (unitless)	1	Assume chemicals ingested in produce is 100% bioavailable
Exposure Frequency (EF, days/year)	365	Exposure occurs every day
Exposure Duration (ED, years)	29	Time at one residence as adult as per enHealth 2002 and NEPM 1999
Body Weight (BW, kg)	70	For male and females combined (enHealth 2012)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	10585	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Lamb concentration	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/kg wet weight)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	1.1E-05	1.9E-09	4.6E-09	--		5.4E-06	0%
Arsenic		2.0E-03		2.0E-03	100%	2.1E-05	3.7E-09	8.8E-09	--		4.4E-06	0%
Beryllium		2.0E-03	20%	1.6E-03	100%	7.7E-08	1.4E-11	3.3E-11	--		2.0E-08	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	9.5E-06	1.7E-09	4.1E-09	--		1.3E-05	0%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	1.3E-04	2.3E-08	5.5E-08	--		6.7E-05	3%
Copper		1.4E-01	60%	5.6E-02	100%	2.5E-05	4.4E-09	1.1E-08	--		1.9E-07	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	2.8E-03	5.0E-07	1.2E-06	--		1.1E-03	42%
Lead		3.5E-03	50%	1.8E-03	100%	6.3E-05	1.1E-08	2.7E-08	--		1.5E-05	1%
Manganese		1.4E-01	50%	7.0E-02	100%	9.1E-06	1.6E-09	3.9E-09	--		5.5E-08	0%
Mercury		6.0E-04	40%	3.6E-04	100%	2.4E-04	4.3E-08	1.0E-07	--		2.9E-04	11%
Nickel		1.2E-02	60%	4.8E-03	100%	6.7E-06	1.2E-09	2.8E-09	--		5.9E-07	0%
Thallium		8.0E-04		8.0E-04	100%	1.0E-04	1.8E-08	4.4E-08	--		5.5E-05	2%
Vanadium		2.0E-03	54%	9.2E-04	100%	1.3E-05	2.3E-09	5.6E-09	--		6.0E-06	0%
Zinc		5.0E-01	80%	1.0E-01	100%	4.8E-02	8.5E-06	2.0E-05	--		2.0E-04	8%
PAHs (as BaP)	2.3E-01				100%				--		--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	2.0E-09	3.5E-13	8.6E-13	--		8.1E-04	32%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%				--		--	
								TOTAL			2.5E-03	

Exposure to Chemicals via Ingestion of Lamb (Regulatory case)

$$\text{Daily chemical intake} = C_B \times \frac{IR_B \times FI \times ME \times EF \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure by Children		
Ingestion Rate of Beef (IRB) (kg/day)	0.036	Ingestion rate of sheep meat by children aged 2-6 years (P90 value) FSANZ (2017)
Fraction ingested that is homegrown (%)	35%	Assume 35% beef intakes from home-sourced meat
Matrix effect (unitless)	1	Assume chemicals ingested in produce is 100% bioavailable
Exposure Frequency (EF, days/year)	365	Exposure occurs every day
Exposure Duration (ED, years)	6	Duration as young child
Body Weight (BW, kg)	15	Representative weight as per NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989 and CSMS 1996

Maximum from sensitive receptors

Key Chemical	Toxicity Data				Bioavailability (%)	Lamb concentration	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/kg wet weight)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Antimony		8.6E-04		8.6E-04	100%	1.1E-05	7.9E-10	9.2E-09	--		1.1E-05	0%
Arsenic		2.0E-03		2.0E-03	100%	2.1E-05	1.5E-09	1.7E-08	--		8.7E-06	0%
Beryllium		2.0E-03	20%	1.6E-03	100%	7.7E-08	5.5E-12	6.4E-11	--		4.0E-08	0%
Cadmium		8.0E-04	60%	3.2E-04	100%	9.5E-06	6.9E-10	8.0E-09	--		2.5E-05	0%
Chromium (Cr VI assumed)		9.0E-04	10%	8.1E-04	100%	1.3E-04	9.3E-09	1.1E-07	--		1.3E-04	3%
Copper		1.4E-01	60%	5.6E-02	100%	2.5E-05	1.8E-09	2.1E-08	--		3.7E-07	0%
Cobalt		1.4E-03	20%	1.1E-03	100%	2.8E-03	2.0E-07	2.4E-06	--		2.1E-03	42%
Lead		3.5E-03	50%	1.8E-03	100%	6.3E-05	4.6E-09	5.3E-08	--		3.0E-05	1%
Manganese		1.4E-01	50%	7.0E-02	100%	9.1E-06	6.5E-10	7.6E-09	--		1.1E-07	0%
Mercury		6.0E-04	40%	3.6E-04	100%	2.4E-04	1.8E-08	2.1E-07	--		5.7E-04	11%
Nickel		1.2E-02	60%	4.8E-03	100%	6.7E-06	4.8E-10	5.6E-09	--		1.2E-06	0%
Thallium		8.0E-04		8.0E-04	100%	1.0E-04	7.5E-09	8.7E-08	--		1.1E-04	2%
Vanadium		2.0E-03	54%	9.2E-04	100%	1.3E-05	9.4E-10	1.1E-08	--		1.2E-05	0%
Zinc		5.0E-01	80%	1.0E-01	100%	4.8E-02	3.5E-06	4.1E-05	--		4.1E-04	8%
PAHs (as BaP)	2.3E-01				100%				--		--	
Dioxins and furans (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%	2.0E-09	1.5E-13	1.7E-12	--		1.6E-03	32%
Dioxin-like PCBs (WHO-TEQ)		2.3E-09	54%	1.1E-09	100%				--		--	
								TOTAL			5.0E-03	

Rainwater tanks

Calculation of Concentrations in Rainwater tank (Regulatory case)

$CW = DM/(VR*Kd*\rho)$ (mg/L)

where:

DM =	Mass of dust deposited on roof each year that enters tank (mg) = DR x Area x 0.1 x 1 year
DR =	Deposition rate from model for TSP (mg/m^2/year)
Area =	Area of roof (m^2)
VR =	Volume of water collected from roof over year (L) = (R x Area x Rc x 1000)/1000
R =	Rainfall each year (mm)
ρ =	Soil bulk-density (g/cm^3)
Rc =	Runoff coefficient (unitless)
Kd =	Soil-water partition coefficient (cm^3/g)
1000 =	Conversion from mm to m; and conversion from m^3 to L

General Parameters			
Average rainfall (R)	mm	675.8	mean for all years (1931 to 2020) for Lake Bathurst (BoM data)
Roof area (Area)	m^2	200	4 bedroom australian home
Runoff coefficient (Rc)	-	0.7	assumes 30% loss in capture into tank
Volume of rainwater (VR)	L	94612	calculated
Bulk density of deposited dust	g/cm^3	0.5	assumed for loose deposited dust on roof (similar to upper end measured for powders)

Chemical-specific Inputs and calculations - maximum sensitive receptors						
Chemical	Deposited dust entering tank		Kd	Particulate Concentration in water	Dissolved Concentration in water	Total (particulate and dissolved) - worst-case
	Deposition Rate TSP (DR)	Mass deposited each year into tank (DM)				
	mg/m^2/year	mg	(cm^3/g)	mg/L	mg/L	mg/L
Antimony	5.9E-02	1.19E+00	45	1.3E-05	5.6E-07	1.3E-05
Arsenic	5.6E-02	1.13E+00	29	1.2E-05	8.2E-07	1.3E-05
Beryllium	1.4E-03	2.78E-02	790	2.9E-07	7.4E-10	2.9E-07
Cadmium	2.6E-02	5.19E-01	75	5.5E-06	1.5E-07	5.6E-06
Chromium (Cr VI assumed)	1.3E-01	2.54E+00	1800000	2.7E-05	3.0E-11	2.7E-05
Copper	1.4E-02	2.70E-01	35	2.9E-06	1.6E-07	3.0E-06
Cobalt	7.7E-01	1.54E+01	45	1.6E-04	7.2E-06	1.7E-04
Lead	1.1E+00	2.29E+01	900	2.4E-04	5.4E-07	2.4E-04
Manganese	1.2E-01	2.46E+00	65	2.6E-05	8.0E-07	2.7E-05
Mercury	3.3E-02	6.64E-01	52	7.0E-06	2.7E-07	7.3E-06
Nickel	1.2E-01	2.42E+00	65	2.6E-05	7.9E-07	2.6E-05
Thallium	1.4E-02	2.81E-01	71	3.0E-06	8.4E-08	3.1E-06
Vanadium	2.8E-02	5.69E-01	1000	6.0E-06	1.2E-08	6.0E-06
Zinc	2.6E+00	5.24E+01	62	5.5E-04	1.8E-05	5.7E-04
PAHs (as BaP)	0.0E+00	0.00E+00	58740000	0.0E+00	0.0E+00	0.0E+00
Dioxins and furans (WHO-TEQ)	2.5E-08	5.03E-07	630957344	5.3E-12	1.7E-20	5.3E-12
Dioxin-like PCBs (WHO-TEQ)	0.0E+00	0.00E+00	630957344	0.0E+00	0.0E+00	0.0E+00