Chunxing Used Lead Acid Battery Recycling Facility: Human Health Risk Assessment

Prepared for: Ascend Waste and Environment and Chunxing Corporation Pty Ltd

28 May 2020

EnRiskS

Document History and Status

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Limitations

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Glossary of Terms and Abbreviations

Term	Definition
ABS	Australian Bureau of Statistics
Acute exposure	Contact with a substance that occurs once or for only a short time (up to 14 days)
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
ATSDR	Agency for Toxic Substances and Disease Register
AAQ	Ambient air quality
ANZECC	Australia and New Zealand Environment and Conservation Council
Background level	An average or expected amount of a substance or material in a specific environment, or typical amounts of substances that occur naturally in an environment.
BaP	Benzo(a)pyrene
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).
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.
Carcinogen	A substance that causes cancer.
CCME	Canadian Council of Ministers of the Environment
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
dB(A)	Decibels (A-weighted)
DECCW	NSW 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.
EIS	Environmental Impact Statement
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, 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.

Term	Definition
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.
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.
HIA	Health impact assessment
HI	Hazard Index
IARC	International Agency for Research on Cancer
Inhalation	The act of breathing. A hazardous substance can enter the body this way [see route of exposure].
Intermediate exposure Duration	Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].
LGA	Local Government Area
LOR	Limit of Reporting
Metabolism	The conversion or breakdown of a substance from one form to another by a living organism.
NCAs	Noise catchment areas
NCG	Noise Criteria Guideline (various, as referenced in the report)
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)
PAH	Polycyclic aromatic hydrocarbon
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

Term	Definition
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.
Roads and Maritime	NSW Roads and Maritime Services
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].
SEIFA	Socio-Economic Index for Areas
SO_2	Sulfur dioxide
TCEQ	Texas Commission on Environmental Quality
TEQ	Toxicity equivalent
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 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.
TSP	Total suspended particulates
UK	United Kingdom
US	United States
USEPA	United States Environmental Protection Agency
VOC	Volatile organic compound
WHO	World Health Organization
$\mu g/m^3$	Micrograms per cubic metre

Executive Summary

Environmental Risk Sciences Pty Ltd (enRiskS) has been engaged by Ascend Waste and Environment and Chunxing Corporation Pty Ltd to undertake a Human Health Risk Assessment (HHRA) for a Used Lead Acid Battery (ULAB) recycling facility to be located at CA 2047, Fourth Road, Hazelwood North, near Morwell in Victoria.

It is understood that the ULAB recycling facility will process approximately 50,000 tonnes per year of spent lead acid batteries and recycle these to produce approximately 28,000 tonnes of refined lead per year.

The site is located within an industrial area (zoned Industrial 2) with industrial areas (zoned Industrial 2 and Industrial 1) surrounding the site. The closest residential area is located approximately 1.1 km from the site boundary, with the closest school (Hazelwood North Primary School) located approximately 1.7 km south east of the site. Morwell South is located approximately 2.1 km to the north of the proposed site.

An assessment of air emissions from the proposed facility has been undertaken by Aubin (2019) and Ascend (2020) on the basis of emissions data from a reference facility, located in China. Potential impacts on community health associated with the predicted emissions to air are further addressed in this report.

The assessment of health impacts has considered all pollutants in the stack emissions. This includes lead, which is of key concern to the community.

The assessment of health impacts associated with emissions to air has only evaluated the one emissions scenario, which represents the facility operating at the maximum measured emission rate from the reference facility. Impacts associated with lower emissions, including the average emission rate will be lower than presented in the HHRA.

The HHRA has assessed the maximum impacts that may occur anywhere (which is on the plant site or on the site boundary) as well as at a number of sensitive receptors, which are the closest residential and school properties.

The assessment has considered the surrounding areas and how people may be exposed in these areas. More specifically the following has been undertaken and concluded:

<u>Industrial areas</u>

- The site is located in an industrial area, with industrial facilities located adjacent to and surrounding the site.
- Exposures may occur in these areas via the inhalation of gases and particulates (which will also comprise metals and organics).
- In these areas, it is assumed that workers and visitors are present outdoors for 24 hours per day, 365 days of the year for at least 35 years.
- The assessment of potential acute and chronic inhalation exposures in these areas has concluded that there are no risks to the health of workers or visitors. This conclusion relates to lead exposures as well as exposure to all pollutants.

Residential areas

- The assessment has considered potential exposures that may occur in residential areas, focusing on the closest residential and rural residential areas, where maximum impacts may occur. The assessment has also considered a worst-case scenario where these exposures may also occur at the maximum impacted location (which is onsite or on the site boundary). This worst-case scenario is unrealistic for the assessment of residential exposures.
- Exposures may occur in these areas via the inhalation of gases and particulates (which will also comprise metals and organics). In addition particulates may settle out of the air and deposit onto the ground, accumulating in soil (and dust indoors) with metals and organics present on these particulates potentially being further accumulated into homegrown produce, specifically fruit and vegetables and chicken eggs (permitted within the urban zoning of the residential area). In a rural residential area other homegrown produce may include the consumption of meat and milk. These additional exposures are termed multi-pathway exposures
- In these residential and rural residential areas (and for the worst-case scenario), it is assumed that people are at home 24 hours per day, 365 days of the year for 35 years.
- The assessment of potential acute inhalation and chronic inhalation and multi-pathway exposures in the residential and rural residential areas has concluded that there are no risks to the health of residents. This conclusion relates to lead exposures as well as exposure to all pollutants.

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Section 1. Introduction

1.1 Background

Environmental Risk Sciences Pty Ltd (enRiskS) has been engaged by Ascend Waste and Environment and Chunxing Corporation Pty Ltd to undertake a Human Health Risk Assessment (HHRA) for a Used Lead Acid Battery (ULAB) recycling facility to be located at CA 2047, Fourth Road, Hazelwood North, near Morwell in Victoria.

It is understood that the ULAB recycling facility will process approximately 50,000 tonnes per year of spent lead acid batteries and recycle these to produce approximately 28,000 tonnes of refined lead per year. The process proposed involves:

- Physical breakdown of the batteries into its components
- Further processing of the plastics and spent acids to convert them to value added products
- Melting and smelting of lead components recovered to produce a refined lead product.

Air emissions from the facility will be treated using desulfurisation (which has multiple stages including a scrubber), a baghouse and additional scrubber prior to discharge to air via a stack.

The proposed site is zoned industrial 2, and the closest sensitive receptor, residential, is located more than 1 km from the site. The site is proposed to operate 24 hours per day, 7 days per week.

A Works Approval Application relating to this project has been submitted in December 2019. As part of the community consultation phase of work, EPA Victoria identified that a HHRA would be required to address community concerns in relation to risks to health in the surrounding community. The key concerns identified relate to emissions to air from the proposed facility.

This report presents a HHRA specifically related to changes in air quality associated with the operation of the proposed ULAB recycling facility.

1.2 Objectives

The objective of the HHRA presented in this report is to assess potential impacts to community health in relation to the operation of a proposed ULAB recycling facility.

The focus of the HHRA relates to impacts on community health associated with changes in air quality. The HHRA has incorporated current information on the proposed operation of the ULAB recycling facility, and the modelling of air emissions that has been prepared as part of the Works Approval Application.

1.3 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 2012a);
- enHealth, 2012. Australian Exposure Factor Guidance – Guidelines for Assessing Human Health Risks from Environmental Hazards (enHealth 2012b); and

- Guidance and guidelines available from the National Environment Protection Council in relation to ambient air quality (NEPC 2016) and contaminated land (NEPC 1999 amended 2013b)
- Victorian State Environment Protection Policies relevant to the assessment of air quality (EPA Victoria 2001) and others as relevant to the assessment.

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 2007).

In addition, guidance available from international agencies such as the US EPA and WHO have been utilised, where relevant, as referenced in this report.

1.4 Available information

In relation to the proposed project, the HHRA has been undertaken on the basis of existing information which is available in the following reports:

- Ascend 2019, Works Approval Application, Chunxing Used Lead Acid Battery (ULAB) recycling facility, December 2020.
- Aubin 2019, Air Quality Impact Assessment, Appendix G of the Works Approval Application.
- Ascend 2020, Chunxing S22(1) Notice (technical) – response. Draft dated 1 April 2020, along with tabulated results from the air modelling as required for use in the HHRA.

Section 2. Project description

2.1 Site description and location

The proposal is to establish a state-of-the-art technology ULAB recycling plant at Crown Allotment (CAQ) 2047 Fourth Road, Hazelwood North, near Morwell, Victoria (the '**site**') (refer to **Figure 1.1**).

The site is located within Industrial 2-zoned land, surrounded by related recycling activities and heavy industries also located on land zoned Industrial 2 (refer to **Figure 1.1**). Outside of these areas, land is zoned Industrial 1.

The larger industrial area is surrounded by agricultural, industrial (including power generation and supply) and residential areas. Morwell Power Station is located to the west of the site and Jeeralang Power Stations are located to the south of the site. The closest residential area is located approximately 1.1 km from the site boundary, with the closest school (Hazelwood North Primary School) located approximately 1.7 km south east of the site. Morwell South is located approximately 2.1 km to the north of the proposed site (refer to **Figure 1.1**).

The proposed project will occupy 50% of the site with the remainder providing landscaping and a buffer (refer to **Figure 1.2**).

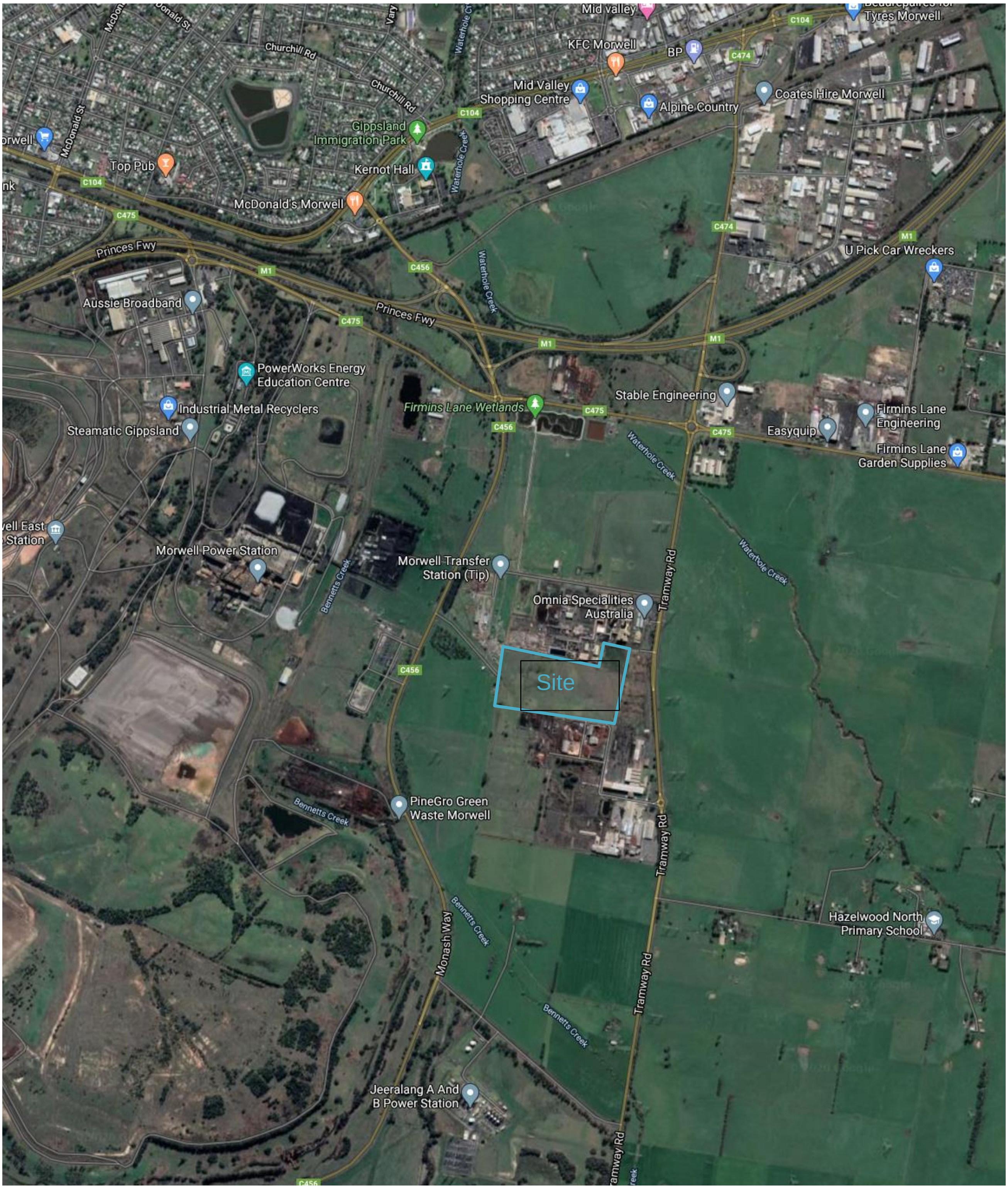

Figure 1.1: General site location

Figure 1.2: Artist's impression of the Hazelwood North facility (view from the east)

2.2 Project description

The Works Approval Application (Ascend 2019) provides a detailed description of the proposed process.

In summary the proposed process involves the recycling of lead, plastic and electrolyte (i.e. sulfiric acid) from lead acid batteries. It is proposed that around 98% of the material in each battery will be recycled at the plant. The process involves the following:

First stage: physical breakdown of the batteries into its components, i.e. metallic lead grid, lead oxide paste, plastics and spent acids

Second stage: further processing of the plastics and spent acids to convert them into value added products, such as chipped plastic for further recycling and fertiliser grade zinc sulfate

Third stage: melting and smelting of lead components recovered into refined lead products.

Products from the proposed project include plastic chips, ammonium sulfate which is used as a soil fertiliser, gypsum which can be used in agriculture or in cement kilns, fertiliser grade zinc sulfate, lead allow and pure lead. Some waste (which include slag) will require disposal to landfill.

Emissions to air from the facility, specifically from the smelting operation (and also vent gases from other areas in the plant) are treated in a baghouse (which removes particles) and desulfurisation scrubber (which removes sulfur dioxide). These processes are further illustrated in **Figure 1.4**.

Figure 1.3 shows the key areas of the plant and processes.

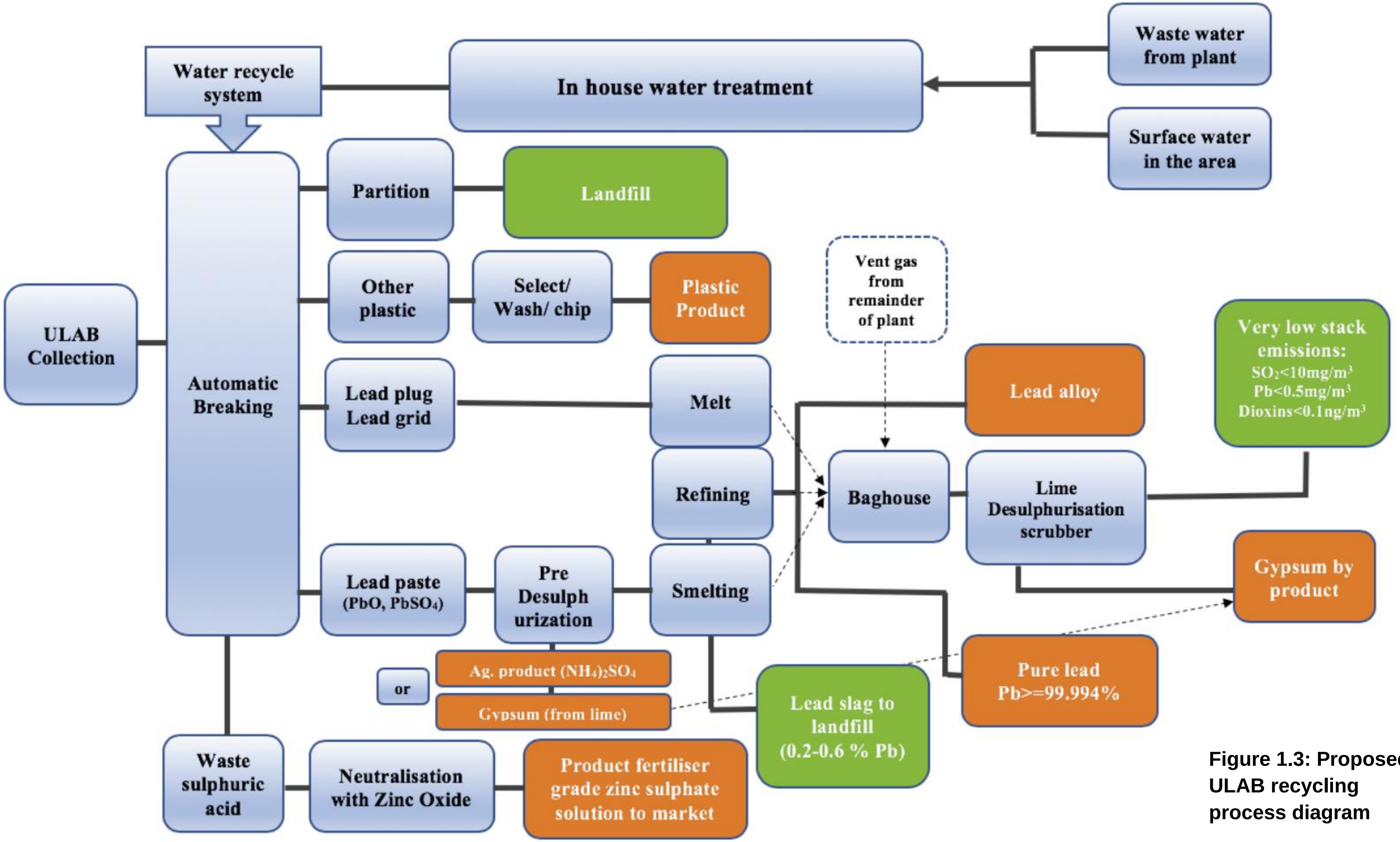

Figure 1.3: Proposed ULAB recycling process diagram

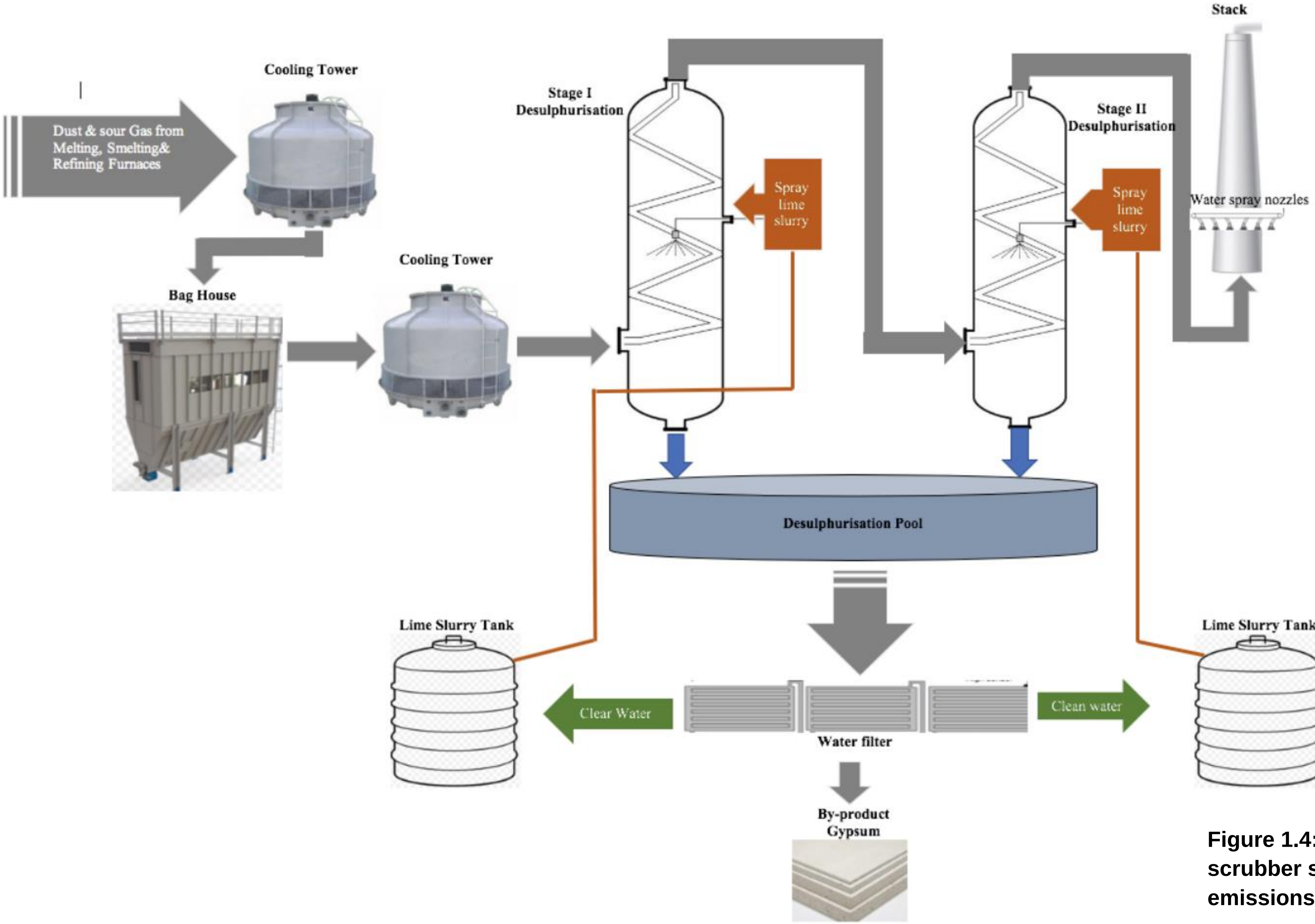

Figure 1.4: Baghouse and scrubber system to treat air emissions from facility

Emissions to air are discharged via a stack which is 30 m tall. At the top pf the stack, where emissions are discharged to air, the stack is 1m in diameter and the gas is discharged at 46 ^{o}C.

The proposed project will operate 24 hours per day, 7 days per week with 30 to 40 days expected for maintenance per year.

2.3 Emissions to air

Emissions to air via the stack, have been modelled (Aubin 2019) based on measured emissions from a reference facility in China. The reference plant is operated by Chenxing and located in Jiangsu Province. The reference plant has the same processes and control technology as proposed at North Hazelwood, however the reference plant is much larger than the proposed plant. As a result the emissions to air, via the stack, have been scaled based on the different operating capacities of the plants.

The modelling has quantified the following pollutants in the air emissions:

- Sulfur dioxide;
- Nitrogen oxides – from a health perspective only nitrogen dioxide is important. As there is no separate assessment of nitrogen dioxide, 100% of the nitrogen oxides is assumed to be nitrogen dioxide;
- Total dust – from a health perspective it is the fine particle sizes that are important as these are small enough to penetrate into the lungs. For the purpose of this assessment 100% of the total dust is assumed to be PM_{10} (i.e. particles with an aerodynamic diameter of 10 microns and smaller) and 100% of total dust is $PM_{2.5}$ (i.e. particles with an aerodynamic diameter of 2.5 microns and smaller);
- Sulfuric acid mist – from a health perspective there are no long-term public health guidelines for this pollutant, as should term exposures are of most importance for this pollutant. Hence the risk assessment has only considered short duration exposures to this pollutant;
- Lead- this is of key concern to the community;
- Chromium;
- Arsenic;
- Cadmium;
- Tin;
- Antimony; and
- Dioxins and Furans *as TCDD I-TEQs, which is assumed to be essentially equal to WHO_{05} TEQs).

The assessment of health impacts has considered all the above pollutants (noting the assumptions also listed above).

Section 3. Community profile

This section provides an overview of the community potentially impacted by the proposed project. It is noted that the key focus of this assessment is the local community surrounding the site.

The site is located in the Latrobe City Council Local Government Area, within an industrial land use zone and surrounded by industrial premises, power generation and supply premises as well as agricultural and residential areas (refer to **Figure 1.1**). The closest resident is approximately 1.1 kilometres away, with the town of Morwell South is approximately 2.1 kilometres from the site.

Table 3.1 presents a summary of the populations in the town of Morwell (based on 2016 Census and 2016 Socio-Economic data from the Australian Bureau of Statistics) in comparison to the Victorian and Australian populations.

Table 3.1: Summary of populations surrounding the proposed project site

Indicator	Morwell suburb	Victoria	Australia
Total population	13771	5926624	23401892
Population 0 - 4 years	6.0% (828)	6.3% (371220)	6.3% (1464779)
Population 5 - 19 years	16.7% (2298)	18.0% (1066042)	18.5% (4321427)
Population 20 - 64 years	55.7% (7669)	60.2% (3566775)	59.6% (13938918)
Population 65 years and over	21.6% (2976)	15.6% (922598)	15.7% (3676758)
Median age	43	37	38
Household size	2.1	2.6	2.6
Unemployment	14.5%	6.6%	6.9%
Tertiary education	36.1%	50.4%	49.6%
SEIFA IRSAD	830	--	--
SEIFA rank	1	--	--
SEIFA IRSD	829	--	--
SEIFA rank	1	--	--
Indigenous	2.6%	0.8%	2.8%
Born overseas	15.4%	28.4%	26.3%
Speak other language at home	10.2%	26.0%	20.8%

SEIFA IRSAD = index of socioeconomic advantage and disadvantage, rank relates to rank in Australia that ranges from 1 = most disadvantaged to 10 = least disadvantaged

SEIFA IRSD = index of socioeconomic disadvantage, rank relates to rank in Australia that ranges from 1 = most disadvantaged to 10 = least disadvantaged

Shading relates to comparison against Victoria: more vulnerable; less vulnerable.

Sources of information:
http://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2016/communityprofile/SSC21757?opendocument **(for Morwell, Vic)**
http://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2016/communityprofile/SSC22556?opendocument **(for Traralgon, Vic)**

Based on the population data available and presented in **Table 3.1**, the community of Morwell is older, has higher unemployment, less tertiary education and a high socioeconomic disadvantage when compared to the general Victorian and Australian population. The indicators outlined in **Table 3.1** reflect the vulnerability of the population, its ability to adapt to environmental stresses, and are important to highlight from an equity point of view. The project will be implemented within a community with higher age profile and socially disadvantage relative to the rest of the state, so the population surrounding the project may be more vulnerable to impacts from the proposed facility.

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 3.2**) generally reflect a wide range of these factors.

The population adjacent to the proposed site is relatively small and health data is not available that specifically relates to this population. However, it is assumed that the health of the local community is consistent with that reported in the larger Latrobe City Council Local Government Area. The Latrobe City Council local government area has been selected as it contained the town of Morwell and surrounding areas and is the smallest unit for which health data is publicly available.

Table 3.2 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 Victoria.

Table 3.2: Summary of health indicators/data

Health indicator/data	Latrobe City Council LGA	Victoria
Health behaviours (rate with 95% confidence limits)		
Adults - compliance with fruit consumption guidelines (2017)[1]	37.1% (31.1% - 43.6%)	43.2% (42.3% - 44.1%)
Adults - compliance with vegetable consumption guidelines (2017)[1]	4.3% (2.7% - 6.9%)	5.4% (5.0% - 5.8%)
Children adequate consumption of fruit and vegetables (2009) [2]	35.4%	34.7%
Adults - increased lifetime risk of alcohol related harm (2017) [1]	63.5% (57.4% - 69.2%)	59.5% (58.63% - 60.4%)
Adults - body weight (preobese) (2017) [1]	34.1% (27.8% to 40.9%)	31.5% (30.7% - 32.4%)
Adults - body weight (obese) (2017) [1]	20.4% (16.5% - 25.0%)	19.3% (18.6 – 20.0%)
Adults – insufficient physical activity (2017) [1]	38.1% (31.9% - 44.8%)	44.1% (43.2 – 45.0%)
Children – adequate physical activity (2009) [2]	70.4%	60.3%
Current smoker (2017) [1]	21.6% (16.3% – 27.9%)	16.7% (16.0% - 17.5%)
Burden of disease		
Morbidity - cardiovascular disease hospitalisations (2016/17)[3]	2225.4*	2229.4*
Morbidity – respiratory disease hospitalisations (2016/17)[3]	1908.5*	1913.4*
Morbidity - prevalence of hypertension ≥18 years (2016/17)[3]	23800 (22200 – 25400)*	22700 (22500 – 22900)*
Adolescent (12 -17 years) – prevalence of asthma (2009)[3]	12.1%	11.6%
Children (school entrant) – prevalence of asthma (2019)[4]	14.0%	10.6%

* Rate per 100,000 population

1 Data from Victorian Population Health Survey 2017: https://www2.health.vic.gov.au/public-health/population-health-systems/health-status-of-victorians/survey-data-and-reports/victorian-population-health-survey/victorian-population-health-survey-2017

2 Data from the City of Latrobe Early Childhood Community Profile (2010) and City of Latrobe Adolescent Community Profile (2010) (Gippsland region)

3 Age standardised ratio - data relevant to the years 2016-2017 from the Social Health Atlas of Australia, Victoria: http://phidu.torrens.edu.au/social-health-atlases

4 Data available from School Entrant Health Questionnaire, 2019 https://www.education.vic.gov.au/about/research/Pages/reportdatahealth.aspx

Shading relates to comparison against Victoria: more vulnerable, less vulnerable.

In general, the key indicators of health for the population in the Latrobe local government area are similar to those of Victoria with the exception of physical activity for children (LGA has more active children than Victorian average) and proportion of adult smokers (LGA has more smokers than Victorian average), which are statistically significant. In relation to health burden there are some indicators suggesting the population may be less vulnerable (cardiovascular and respiratory hospitalisations), however the prevalence of asthma in children is higher (compared with Victoria) suggesting a higher vulnerability.

It is noted that the life expectancy for Latrobe LGA (male = 76.9 years, female = 82.2 years) is lower than other local government areas in the Gippsland region and lower than the Victorian average (male = 80.3 years, female = 84.4 years) (Department of Health 2013).

This data, along with data presented in **Table 3.1**, suggest the population in the areas surrounding the site may be more susceptible to health-related impacts associated with the project, than the general population of Victoria.

Section 4. Health impacts: Air emissions

4.1 Approach

This section presents a review of impacts on health associated with predicted air emissions, relevant to the operation of the facility. The assessment presented has relied on the modelling of emissions to air as presented by Aubin (2019) and Ascend (2020).

The estimation of risk follows the general principles outlined in the enHealth document Environmental Health Risk Assessment: Guidelines for Assessing Human Health Risks from Environmental Hazards (enHealth 2012a).

4.2 Modelled air impacts

4.2.1 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; and
- Information about the terrain in the surrounding areas.

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

Figures 4.1 and 4.2 illustrate the processes which govern how the emissions get mixed into the atmosphere.

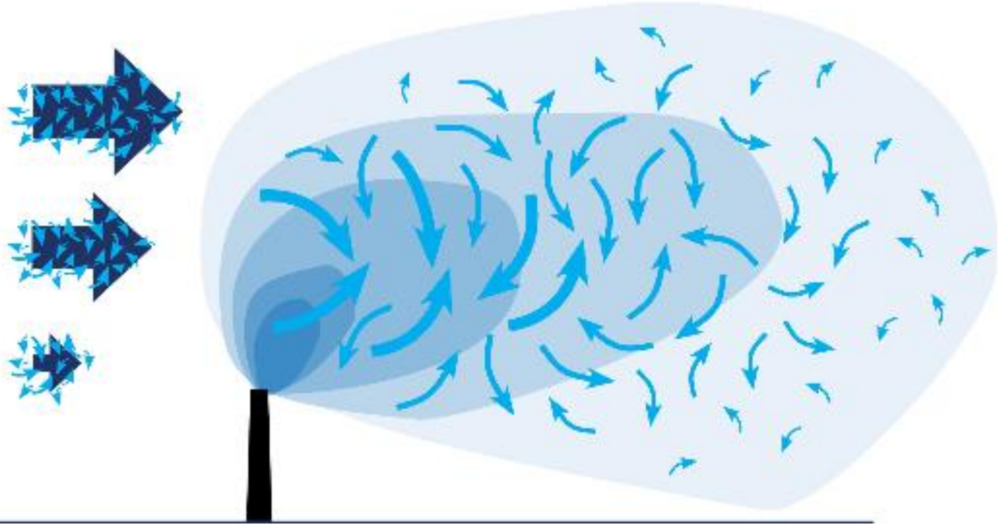

Figure 4.1: Turbulence in the air, how it mixes and dilutes pollutants emitted from a stack (NSW Chief Scientist 2018)

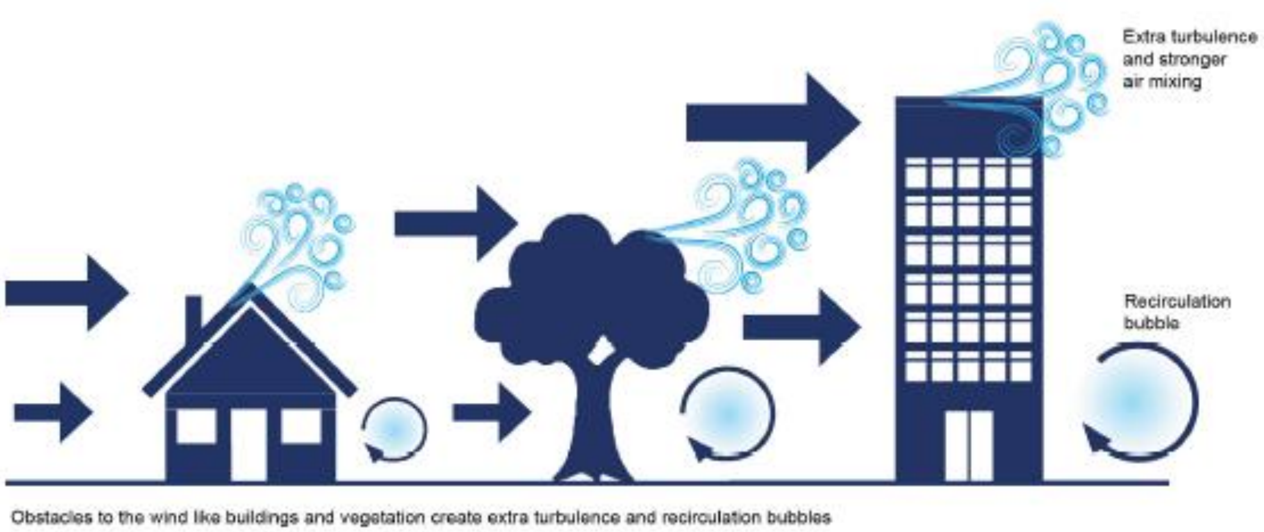

Figure 4.2: Turbulence in the air and how it is affected by buildings and vegetation (NSW Chief Scientist 2018)

Gases (and any fine particles that remain) are emitted at around 46ºC from the stack and they 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 gases are travelling at a faster speed than the air surrounding the stack. You can see this in the figures.

As the gases (and fine particles) cool and slow down a bit they begin to interact with the wind above the stack (i.e. well above the 30 m high stack). This mixes the gases (and fine particles) into the atmosphere decreasing the actual concentration present in any one particular place.

Figure 4.1 shows that most of the pollutants remain up in the atmosphere away from where people 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 sky (due to gravity) or get washed out of the sky (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 around the facility.

4.2.2 Overview of air modelling

The air modelling was undertaken and presented by Aubin (2019).

To predict the concentration of emissions from the energy from waste plant, a study area was defined (**Figure 4.3**) and predicted emissions from the stack were modelled using the AEROMOD air dispersion model. The AEROMOD air dispersion model is the regulatory air pollution model prescribed by EPA Victoria for the assessment of air quality impacts from all industrial developments including energy from waste facilities. This model uses air emissions estimates the proposed process, plant design (for example stack height), local terrain and meteorological data to predict the ground level concentrations of emissions within the defined study area. The modelling utilised 5 years of meteorological data (from 2012 to 2016) with the maximum impacts predicted from all these years presented and considered in this HHRA.

Background air concentrations are also used to determine the total emissions exposure in the study area. Background air data were obtained from EPA Victoria monitoring data acquired in the Latrobe Valley between 2012 and 2016, with the monitoring stations at Morwell East and Morwell South the closest to the site. Background data from Morwell East has been adopted in the Air quality Impact Assessment (Aubin 2019). These estimated background concentrations are likely to be an overestimate of the current background concentrations because the historical data includes facilities that have since closed (Hazelwood Power Station, Morwell Power Station and Briquette Factory).

The assessment of air quality impacts within the off-site community considered impacts within the study area that is 5 km x 5 km in size. Impacts were modelled within this study area based on a grid with 50 m spacing.

In addition, a number of individual sensitive receptors have been evaluated. These are the closest residential or school properties to the site. These are shown in **Figure 4.3** and summarised in **Table 4.1**.

Figure 4.3: Location of sensitive receptors – the closest residential or school premises

Table 4.1: Sensitive receptors

Receptor name	Description
SR1	Residential premises
SR2	Residential premises
SR3	Residential premises
SR4	Hazelwood North Primary School
SR5	Residential premises
SR6	Residential premises
SR7	Residential premises
SR8	Residential premises
SR9	Residential premises

This assessment, of risks to human health, has considered the maximum predicted impacts at any location across the study area (regardless of the land use and presence (or otherwise) of a residential home), as well as each of the sensitive receptors.

4.3 Conceptual site model

Understanding how a community member may come into contact with pollutants released in air emissions from the proposed energy from waste 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 (breathing it in)
- ingestion (eating or drinking it) or
- dermally (absorbing it through the skin).

For some of the emissions from the proposed plant, inhalation is considered the only route of exposure. This is due to the substance's chemical properties, which make the other pathways inconsequential. In this instance, gases such as NO_2, SO_2 (and associated sulfur acid mists) as well as fine particulate matter as particulates less than 10 micrometres (PM_{10}) and particulate matter less than 2.5 micrometres ($PM_{2.5}$) that are so small they remain suspended in air could be considered in this class (i.e. inhalation only exposure pathway).

Other emissions may be inhaled, but also may be deposited on the ground. These emissions can then be ingested either directly through accidental consumption of soil or indirectly through food grown or raised in the soil (fruit, vegetables and eggs). Skin contact with the soil is also possible. Therefore, it is important with these emissions that all three exposure pathways are considered. In this instance, metals and dioxins that are bound to the heavier particulate matter that may fall out and deposit onto the ground could be considered in this class.

Table 4.2 lists the substances considered in the plant emissions and the exposure pathway/s of potential concern. **Figure 4.4** provides a diagrammatical representation of the community exposures to emissions from the facility (conceptual site model).

Table 4.2: Substances and routes of exposure

Substance	Route of exposure
Nitrogen dioxide (NO_2)	**Inhalation only** as these are gases
Sulfur dioxide (SO_2)	
Sulfuric acid gases	
PM_{10}	**Inhalation only** 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. These other pathways relate to the individual chemical substances, rather than the physical size of the particulates.
$PM_{2.5}$	
Cadmium	**Inhalation** of these pollutants adhered to fine particulates **Ingestion and dermal contact** with these pollutants deposited to soil **Ingestion** of produce grown in soil potentially impacted by these pollutants (i.e. homegrown fruit and vegetables, eggs, milk and meat products – where the pollutants can be taken up/bioaccumulated into plants and animals)
Arsenic	
Antimony	
Lead	
Chromium	
Tin	
Dioxins / furans	

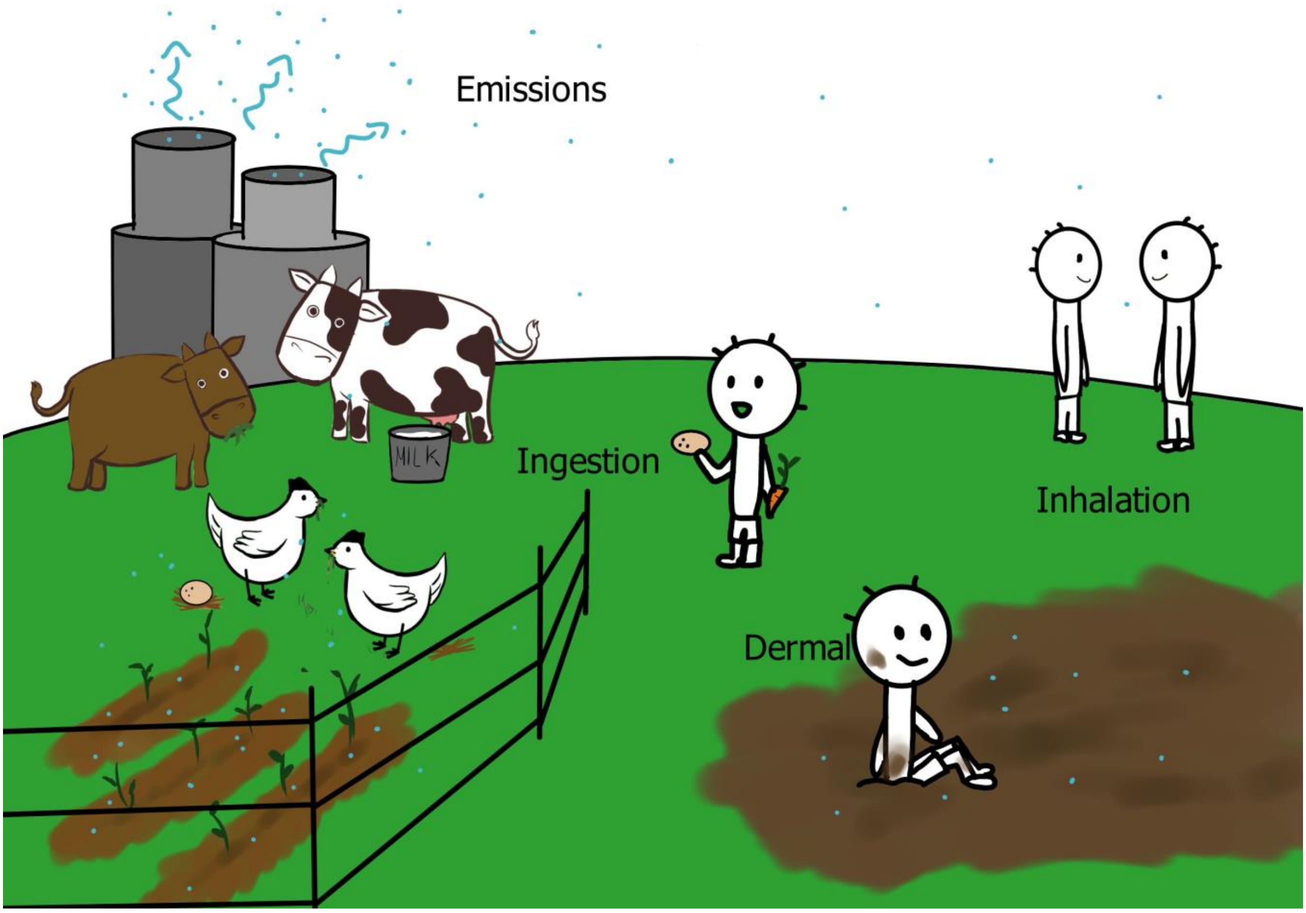

Figure 4.4: Conceptual site model (illustrative only)

4.4 Use of air modelling data in HHRA

The air dispersion modelling has predicted ground level concentrations based on three different emissions scenarios, all of which relate to the measured data from the reference plant:

- Lowest emissions
- Highest emissions
- Average emissions

This assessment has focused on the most conservative scenario, where the highest emissions occur all of the time.

In addition, the HHRA has adopted the maximum predicted concentration for the representative year of 2016. There is little difference between the predicted air concentrations over the years 2012 to 2016, hence 2016 has been selected for use in the HHRA as most data is provided for this year.

It is noted that the modelling has presented results for averaging times relevant to the Victorian EPA Ambient Air Quality SEPP (EPA Victoria 1999 as varied to 2016), which include 3 minute averages and 1 hour averages. Further, the additional information provided by Ascend (2020) presents the annual average concentrations.

The HHRA requires consideration of 1 hour averages for the assessment of short-term exposures, 24-hour averages for the assessment of exposure to particulates, and annual averages for the assessment of chronic, or long term exposures.

To be able to obtain consistent data for these averaging time, the modelled data for 2016 (where 1 hour average, 3 minute average and annual average data is available) has been reviewed to determine an averaging time conversion ratio. Based on this review the following equation (Duffee, O'Brien & Ostojic 1991) can be used to convert the averaging times:

$$C_1 = C_0 \times \left(\frac{t_0}{t_1}\right)^n$$

Where:

t_1 = the longer averaging time, which relates to concentration C_0

t_0 = the shorter averaging time, which relates to concentration C_1

n = exponent – for this data set an exponent of 0.224 can be applied (as this best matches the data provided for 2016)

Based on the above the following conversions have been used (with the values rounded):

- Annual average = 1-hour average/7.6
- Annual average = 3-minute average/15
- 1-hour average = 3-minute average/2
- 24-hour average = 1-hour average/2

The modelling undertaken has provided estimated ground level concentrations. The HHRA also utilises a deposition rate. Dust deposition was not specifically modelled by Aubin (2019), however guidance on the assessment of multi-pathway exposures (OEHHA 2015) indicates that for facilities where particulate matter control devices are implemented (as is the case for the proposed facility), a default deposition velocity of 0.02 m/s can be adopted. This has been adopted in this assessment. Pollutant specific deposition rates have then been calculated based on the annual average air concentration and the particle deposition rate of 0.02 m/s.

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

- **Maximum impacted location anywhere** within the modelling area (5 km x 5 km) regardless of location and land use – this is a location on the site or on the site boundary, however for the purpose of this assessment exposures that may occur 24 hours per day, every day have been assumed
- **Maximum impacted sensitive receptor** – this is the maximum impacted receptor from the individual sensitive receptors listed in **Table 4.1** and shown on **Figure 4.3**. Based on the modelling undertaken, the maximum impacted receptor is SR6, a residential property located to the east of the site.

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

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 Air Quality Impact Assessment. The 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 2013). These health effects were considered in the derivation of the NEPM air guideline for $PM_{2.5}$ (NEPC 2016), which are consistent with the SEPP (AAQ).

The modelling undertaken has not specifically modelled $PM_{2.5}$, hence the modelled total dust concentration has been conservatively assumed to comprise 100% $PM_{2.5}$.

The NEPM/SEPP criteria relate to total exposures to $PM_{2.5}$, that is background or existing levels as well as the additional impact from the proposed facility. Background levels of $PM_{2.5}$ relevant to the local area have been considered and are noted to be influenced by the Hazelwood Coal Mine Fire and prescribed burns as the existing data includes results for these periods. As a result, depending on the meteorological data year assessed and meteorological monitoring location, total exposures to $PM_{2.5}$ have the potential to exceed the NEPM/SEPP air criteria. These exceedances occur regardless of the project – i.e. they relate to background levels.

Table 4.3 provides a summary of the contribution of the project to the total $PM_{2.5}$ concentrations, and the NEPM/SEPP air criteria. This table shows that the worst-case $PM_{2.5}$ derived from the facility makes a small contribution to existing concentrations and only makes up a small fraction of the NEPM/SEPP guideline.

Table 4.3: $PM_{2.5}$ impacts from the project – maximum impacts (at any location)**

Parameter	$PM_{2.5}$ – as 24-hour average (µg/m^3)	$PM_{2.5}$ – as annual average (µg/m^3)
Maximum from all grid receptors		
Guideline (NEPM 2016)	25	8
Background*	33	6.8
Contribution from project	1.3	0.33
% contribution of project to NEPM	5.2%	4.1%
% contribution of project to background	4%	4.8%

* Maximum 24-hour average and annual average for Morwell East for 2015 (most recent data publicly available): https://www.epa.vic.gov.au/for-community/monitoring-your-environment/monitoring-victorias-air-quality

**In parallel with the development of this assessment, further analysis of background data in the Latrobe Valley was undertaken by Aubin, via hourly variable background data modelling for the 2016 year. Results of that modelling indicate that a '% contribution of project to background' for $PM_{2.5}$ may be more accurately estimated as 0.5% (rather than 4.8%), and similar for PM_{10}. These differences are likely to be attributable to this report's approach to simple (and therefore more conservative) assumptions, such as $PM_{2.5}$ = total dust, using the maximum emission value and using a background number from 2015 data (as opposed to 2016 by Aubin). These background estimates have been left unchanged in this table so as to support the most conservative assessment

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 for males in the Latrobe Valley LGA (which is higher than for females) from 2010 to 2014 (all ages and all causes), 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 facility for 24 hours a day, every day of the year.

For a maximum annual increase of $PM_{2.5}$ of 0.33 µg/m^3, this results in a maximum individual risk of $1x10^{-5}$. This risk level is considered to be to be low and equal to the mortality risk criteria outlined by NEPM (NEPC 2011). Risks relevant to other areas in the community will be lower than this maximum. The maximum individual risk, at the maximum impacted sensitive receptor is much lower, at $1x10^{-6}$.

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

4.5.3 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 an 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:

$$HI = \frac{\text{Exposure concentration (maximum 1-hour average)}}{\text{(Acute health based guideline)}}$$

Where:
Exposure concentration = calculated from the concentration in air derived from the air modelling, as per **Appendix B** (mg/m^3)
Acute health based guideline = health based guideline that is protective of short-duration exposures (mg/m^3)

The above calculation relates to acute exposures from the proposed facility only. The assessment of acute exposures has not included background intakes. It should be noted that in relation to the NEPM pollutants, background data is available as outlined by Aubin (2019) and has been considered in this review.

The acute health based guidelines adopted in this assessment have been adopted on the basis of the approach detailed in **Appendix B**.

Table 4.4 presents a summary of the relevant health-based guideline, the predicted maximum 1-hour average concentration from all locations, and the maximum impacted receptor, and the calculated HI for each pollutant. Exposures at all other locations, including the other sensitive receptors will be lower than presented in **Table 4.4**.

The assessment of exposures to nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) has utilised the NEPM guidelines that are protective of health. Risks associated with these pollutants are not considered to be additive. However, potential exposures to all other gases and chemical substances attached to fine particulates have been assumed to be additive and the total HI (the sum of all individual HI's) is also presented.

Risks associated with acute exposures are considered to be acceptable where the individual and total HI's are less than or equal to 1. Based on the assessment presented in **Table 4.4**, all the individual and total HI's are less than 1. For NO_2 and SO_2, the calculated acute exposure risks remain acceptable even where the limited background concentrations are considered (as discussed above, which would result in a total HI of 0.7 for NO_2 and 0.1 for SO_2).

On this basis there are no acute risk issues of concern in relation to inhalation exposures.

Table 4.4: Review of acute exposures and risks

Pollutants	Acute air guideline (1-hour average) (mg/m^3)	1-hour average concentration (mg/m^3)		Calculated HI	
		Maximum anywhere	Maximum receptors	Maximum anywhere	Maximum receptors
NEPM pollutants*					
Nitrogen dioxide (NO_2)	0.22[1]	3.0E-02	1.2E-02	1.4E-01	5.7E-02
Sulfur dioxide (SO_2)	0.5[1]	3.7E-03	2.9E-03	7.3E-03	5.7E-03
Other Pollutants					
Sulfuric acid mist	0.5[4]	6.2E-04	2.8E-05	3.1E-03	1.4E-04
Cadmium	0.0054[2]	1.5E-07	2.1E-08	1.0E-05	1.4E-06
Antimony	1.5[4]	1.1E-06	1.5E-07	2.6E-07	3.7E-08
Arsenic	0.003[2]	3.3E-06	8.5E-07	4.1E-04	1.1E-04
Lead	0.15[4]	2.9E-05	2.4E-06	7.3E-05	6.1E-06
Chromium (Cr VI assumed)	0.0013[2]	4.0E-06	5.6E-07	1.2E-03	1.6E-04
Tin	0.7[5]	4.9E-07	6.9E-08	2.6E-07	3.7E-08
Dioxin	0.00013[4]	8.9E-12	1.2E-12	2.6E-08	3.6E-09
			Total HI (for other pollutants)	**0.0047**	**0.00042**
			Target (acceptable/negligible HI)	**≤1**	**≤1**

0.11 = Values in table relate to the assessment of inhalation exposures for gases (or the equivalent of gases). All other pollutants are assessed on the basis of particulate inhalation exposures (refer to **Appendix B** for details in the calculations undertaken)

* = NEPM pollutants are assessed separately from the other pollutants (includes background for NO_2 and SO_2)

References for health-based acute air guidelines (1-hour average, refer to Appendix B):

1 = NEPM health based guideline (NEPC 2016) – include background

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

3 = 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

4 = Guideline available from the USEPA as Protective Action Criteria (PAC), where the most conservative value has been adopted https://www.energy.gov/ehss/protective-action-criteria-pac-aegls-erpgs-teels-rev-29-chemicals-concern-may-2016

5 = No acute guideline available, hence the chronic inhalation guideline has been adopted (which is conservative)

Chronic exposures

For the assessment of chronic exposures, all the pollutants 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 HI is calculated as follows (enHealth 2012a):

$$\text{HI}= \frac{\text{Exposure Concentration}}{\left(\text{Health based criteria or Tolerable Concentration (TC)}\right)\text{x(100\%-Background)}}$$

Where:
Exposure concentration = concentration in air relevant to the exposure period – annual average (mg/m^3)
Health based criteria or TC = health-based threshold protective of all health effects for all members of the community (mg/m^3) (refer to **Appendix B**)
Background = proportion of the TC that may be derived from other sources/exposures such as water, soil or products (%) (refer to **Appendix B**)

For this assessment, it is assumed that a resident or rural resident spend 24 hours per day at home or working on the property, every day of the year, and that the maximum predicted concentration in air is present at the residence and on the property.

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. **Appendix C** presents the calculations undertaken for residential and industrial inhalation exposures.

Table 4.5 presents the calculated individual HI relevant to the assessment of chronic inhalation exposures. The table presents the calculations relevant to the maximum annual average concentration predicted across all the grid receptors (i.e. anywhere) as well as the maximum predicted at the sensitive receptors.

The assessment of exposures to nitrogen dioxide and sulfur dioxide has utilised the NEPM guidelines that are protective of health. Risks associated with these pollutants are not considered to be additive. However, potential exposures to all other gases and chemical substances attached to fine particulates have been assumed to be additive and the total HI (the sum of all individual HI's) is also presented.

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.

Based on the assessment presented in **Table 4.5**, all the individual and total HI's are less than 1.

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

Table 4.5: Calculated chronic risks*

Pollutant	Annual average concentration (mg/m^3)		Calculated HI#	
	Maximum anywhere	Maximum receptors	Maximum anywhere	Maximum receptors
NEPM pollutants**				
Nitrogen dioxide (NO_2)	1.2E-02	1.0E-02	0.22	0.18
Sulfur dioxide (SO_2)	2.1E-03	2.0E-03	0.042	0.040
Other pollutants				
Cadmium	2.0E-08	2.8E-09	0.0043	0.00060
Antimony	1.4E-07	2.0E-08	0.00028	0.000039
Arsenic	4.4E-07	1.1E-07	0.00037	0.000094
Lead	3.7E-06	3.2E-07	0.028	0.0024
Chromium (Cr VI assumed)	5.4E-07	7.5E-08	0.0036	0.00050
Tin	6.6E-08	9.2E-09	0.000000035	0.0000000049
Dioxin	1.2E-12	1.7E-13	0.00012	0.000017
		Total HI (other pollutants)	**0.036**	**0.0036**
		Negligible risk	**≤1**	**≤1**

* Refer to **Appendix B** for the equations adopted, and **Appendix C** for the calculations

** Includes background annual average concentrations reported at Morwell East for most recent year (2015)

\# Inhalation exposures calculated on the basis of exposures that occur at the same location 24 hours per day, 365 days per year for 35 years

It is noted that the margin of safety relevant to inhalation exposures ranges from 30 to 300 for the total HI, with the MOS higher than this for many individual pollutants. 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 depositing to the environment where a range of other exposures may then occur. These include:

- 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 particulates may deposit onto the plants and is also present in the soil where the plants are grown, and where pollutants bound to these particles are taken up into these plants;
- Ingestion of eggs, meat (beef) and milk (cows) where particulates may deposit onto pasture and be present in soil (which the pasture/feed grows in and animals also ingest when feeding), and the pollutants bound to these particles are taken up into the edible produce.

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 residential or rural residential properties where people live and where homegrown produce or other agricultural activities can be undertaken. The maximum impacts predicted from the plant are located on the site, or on the site boundary, where exposures evaluated for residential and agricultural type exposures cannot occur. Hence risks associated with multiple pathway exposures are of most relevance to the assessment of impacts at the off-site sensitive receptors.

However, a conservative scenario has also been assessed where the maximum impacts anywhere are assumed to also be relevant to multi-pathway exposures. This worst-case assessment is not realistic, however it has been included to provide an indication of the maximum impacts regardless of location.

The calculation of risks posed by multiple pathway exposures only relates to pollutants that are bound to the particulates. The calculations undertaken has utilised a deposition rate, which is derived from the air modelling as detailed in **Section 4.4**.

Appendix B 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 **Appendix C**.

As discussed in **Section 4.4.3**, the following criteria have been adopted for determining when risks are considered to be negligible or acceptable.

- **HI:** the individual and total HI, where calculated as the sum over all relevant exposure pathways and pollutants ≤ 1 = negligible/acceptable risk to human health.

4.6.3 Calculated risks

Table 4.6 presents the calculated risks associated with these multiple pathway exposures relevant to both adults and children. These risks have been calculated on the basis of the maximum predicted deposition rate for all of the sensitive receptors in the surrounding community, as well as a worst-case scenario where the maximum impacts anywhere (regardless of landuse). The table presents the total HI for each exposure pathway, calculated as the sum over all the pollutants evaluated. The table also includes the calculated risks associated with inhalation exposures, as these exposures are additive to the other exposure pathways for residential/rural residential properties.

Depending on the use of the property, the types 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 may occur. The sum of risks associated with these multiple exposures is presented in **Table 4.6**.

Table 4.6: Summary of risks for multiple pathway exposures

Exposure pathway	Maximum impacts at sensitive receptors (most relevant for multi-pathway exposures)		Maximum impacts at any location (worst-case assessment of maximum impacts which are likely to occur on-site or on the site boundary)	
	Calculated HI - Adults	Calculated HI - Children	Calculated HI - Adults	Calculated HI - Children
Individual exposure pathways				
Inhalation (I)	0.0036	0.0036	0.036	0.036
Soil ingestion (SI)	0.0024	0.023	0.024	0.23
Soil dermal contact (SD)	0.00020	0.00039	0.0012	0.0023
Ingestion of homegrown fruit and vegetables (F&V)	0.0035	0.0099	0.032	0.093
Ingestion of homegrown eggs (E)	0.00034	0.00068	0.0025	0.0050
Ingestion of homegrown beef (B)	0.0023	0.0056	0.016	0.040
Ingestion of homegrown dairy milk (at property) (M)	0.0039	0.015	0.029	0.11
Multiple pathways (i.e. combined exposure pathways)				
I + SI + SD	0.0063	0.027	0.062	0.27
I + SI + SD + F&V	0.0098	0.037	0.094	0.36
I + SI + SD + E	0.0066	0.027	0.064	0.27
I + SI + SD + F&V + E	0.010	0.037	0.097	0.37
I + SI + SD + B	0.0086	0.032	0.078	0.31
I + SI + SD + M	0.010	0.042	0.090	0.38
I + SI + SD + F&V + E + B	0.012	0.043	0.11	0.41
I + SI + SD + F&V + E + M	0.014	0.053	0.13	0.48
Negligible risk	**≤1**	**≤1**	**≤1**	**≤1**

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

Review of **Table 4.6** 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 risks. The calculated HI relates to the sum of risks calculated for all pollutants assessed, including lead. The margin of safety relevant to the calculated risks range from 40 to 150 for the maximum impacted sensitive receptor, which is the most reasonable calculation for multi-pathway exposures.

Community exposures to lead have been identified as a key concern for the local community. Individual calculations for lead are included in **Appendix C**. **Table 4.7** presents a summary of the calculated HIs relevant to exposure to lead only.

Table 4.7: Summary of risks for multiple pathway exposures – Exposure to lead emissions only

Exposure pathway	**Maximum impacts at sensitive receptors** (most relevant for multi-pathway exposures)		**Maximum impacts at any** location (worst-case assessment of maximum impacts which are likely to occur on-site or on the site boundary)	
	Calculated HI - Adults	**Calculated HI - Children**	**Calculated HI - Adults**	**Calculated HI - Children**
Individual exposure pathways				
Inhalation (I)	0.0024	0.0024	0.028	0.028
Soil ingestion (SI)	0.0018	0.017	0.021	0.19
Soil dermal contact (SD)	--	--	--	--
Ingestion of homegrown fruit and vegetables (F&V)	0.0022	0.0063	0.025	0.072
Ingestion of homegrown eggs (E)	0.000028	0.000057	0.00033	0.00065
Ingestion of homegrown beef (B)	0.000020	0.000049	0.00023	0.00057
Ingestion of homegrown dairy milk (at property) (M)	0.00022	0.00089	0.0026	0.010
Multiple pathways (i.e. combined exposure pathways)				
I + SI + SD	0.0042	0.019	0.048	0.22
I + SI + SD + F&V	0.0064	0.025	0.073	0.29
I + SI + SD + E	0.0042	0.019	0.049	0.22
I + SI + SD + F&V + E	0.0064	0.026	0.074	0.29
I + SI + SD + B	0.0042	0.019	0.049	0.22
I + SI + SD + M	0.0044	0.020	0.051	0.23
I + SI + SD + F&V + E + B	0.0064	0.026	0.074	0.29
I + SI + SD + F&V + E + M	0.0066	0.026	0.076	0.30
Negligible risk	**≤1**	**≤1**	**≤1**	**≤1**

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

Review of the **Table 4.7** indicates that all calculated His are below 1. In addition comparison of the two tables indicates that in relation to the total HI, lead is a significant contributor where exposures occur via inhalation and soil ingestion. Lead is a mor minor contributor to other exposure pathways such as the ingestion of produce.

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 rural residential use of the surrounding areas. This conclusion remains unchanged even when the maximum off-site impacts are considered (not in an existing or proposed rural or residential area).

It should also be noted that in relation to inhalation exposures, **Table 4.6** relates to inhalation exposures all day every day. Where the maximum impacts occur in an existing industrial areas, these exposures would be lower, occurring for 8 to 12 hours per day for 240 days of the year. As a result the calculated inhalation HI in these industrial areas will be lower than presented above.

4.7 Uncertainties

The characterisation of potential health risks related to exposures to emissions to air from the proposed facility has utilised data from the air quality modelling as well as a number of assumptions. The following presents further discussion on these data and parameters, the level of uncertainty in these values and whether changes in these values will change the outcome of the assessment presented.

Air modelling

The modelling of air emissions has been undertaken by Aubin (2019) using a regulatory approved model, utilising meteorological and terrain data for the local area. The emissions data used in the assessment was derived from a reference plant in China that operates using the same technology. A range of measured emissions data are available for the reference plant. The HHRA has utilised the modelled impacts that relate to the maximum measured emissions from the reference plant. Where average emission rates are used, the calculated risks will be lower than presented in this assessment.

The air modelling has not considered upset operating conditions. Where these occur, there is the potential for elevated emissions to occur. Operation of the facility is expected to appropriately manage the plant to ensure these conditions do not occur, and where they do, that these conditions only occur for a short period of time. On an annual average basis, a short duration of upset conditions may increase the annual average exposure concentrations slightly. For the assessment of acute exposures, there is >30 fold margin of safety in the risk calculations which is more than sufficient to allow for such events to occur, without causing any health impacts.

Inhalation exposures

It is assumed that residents are home 24 hours per day, every day of the year for as long as they live at their home. This is overly conservative as most people attend childcare, school, work or other activities and holidays away from the home. This will be overly conservative for workers in the surrounding industrial areas where exposures will be lower, for 8 to 12 hours per day, 240 days of the year.

In addition to the above, it is assumed that indoor air concentrations are equal to concentrations outdoors.

As a result, the risks calculated for inhalation exposures will be an overestimate.

Multi-pathway exposures

These have been calculated on the basis of an assumed dust deposition rate of 0.02 m/s. Experience on other projects indicates that this default deposition rate is conservative for facilities with pollution control equipment. The default deposition rate from OEHHA (2015) for uncontrolled sources is higher, at 0.05 m/s. Where this is used in the risk calculations the maximum total HI (for the maximum sensitive receptor) increases from 0.053 for children (as per **Table 4.6**) to 0.13, still well below the criteria of 1.

The quantification of potential intakes via ingestion of soil, fruit and vegetables, eggs, meat and milk, and dermal contact with soil, has adopted a number of assumptions relating to how the dust mixes in with soil, how much accumulates in edible produce, and how people may be exposed. These assumptions have used conservative models and uptake factors that are likely to overestimate the accumulation of pollutants in soil and edible produce. In addition, default exposure parameters have been adopted assuming exposures occur all day every day, which is conservative.

Future changes in guidelines

Consistent with enHealth guidance (enHealth 2012a) this assessment has considered guidelines and toxicity reference values that are based on current science.

However, it should be noted that should guidelines and toxicity values change in the future, there is a significant margin of safety between the calculated risks and the thresholds/values adopted as representative of where risks are considered to be unacceptable. The margin of safety in the calculated risks are discussed below **Table 4.5** for inhalation exposures and below **Table 4.6** for multi-pathway exposures. It is unlikely that changes in guidelines and criteria for any individual contaminant would be more than 2-5 fold as the chemicals evaluated are those where there are already a large number of studies and information available. The margin of safety is >40 fold which is more than sufficient to address any changes in guidance or toxicity, should these changes result in more conservative criteria. Should future changes in guidance and toxicity result in less conservative criteria then the margin of safety would be higher. In addition, the contribution emissions to air from the proposed facility to $PM_{2.5}$ concentration is low, hence any change in these guidelines in the future would not significantly change this outcome.

Overall

Overall, the approach taken will have overestimated actual exposures and risks. Changes in the assumptions to those more representative of actual exposures will result in lower levels of risk, rather than higher levels of risk.

Section 5. Conclusions

Based on the evaluation presented in relation to potential health impacts of air emissions from the proposed ULAB recycling facility, the following is concluded:

- Inhalation exposures: Risks to human health associated with acute or chronic exposures are negligible. This includes risks to pollutants presents as gases, particulate matter and pollutants bound to particulates.
- Multiple pathway exposures: Risks to human health associated with chronic exposures to pollutants, bound to particulates, that may deposit to surfaces and taken up into produce for home consumption relevant to all surrounding areas, including all rural residential and low-density residential properties, are negligible.

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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[1]. The calculation of a relative risk based on the change in relative risk exposure concentration from baseline/existing (i.e. 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:

1 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)[2] 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 ΔX 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 (e.g. 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 (i.e. incremental impacts) due to the project for the relevant modelled scenarios – these have been modelled for the proposed project, with the maximum change from all locations (grid receptors). 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 0.33 µg/m³
- 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 Latrobe Valley (with the highest rate for males, all ages, all causes adopted). The data has been obtained from the Gippsland PHN Population Health Planning Hub, with the mortality

2 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).

rate for males (based on data from 2010 to 2014) for the Latrobe LGA being 774 as an age standardised rate (per 100,000), or 0.00774. The rate for females is reported to be 556. This calculation has used the higher value for males in the Latrobe area

- 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 10µg/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 10µg/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):

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

$$= 0.33 \times 0.00774 \times 0.0058$$

$$= 1 \times 10^{-5}$$

Appendix B Methodology and assumptions

B1 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.

B2 Identification of toxicity reference values

Approach

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**.

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.

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. NEPM Ambient Air Quality guideline, relevant to 1-hour average exposures (NEPC 2016)
    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 2012a; NEPC 1999 amended 2013a, 2004) by the WHO (WHO 2000a, 2000b, 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. USEPA Protective Action Criteria (PAC) values, which are all based on a target HI of 1. PACs threshold values that the public may be exposed, with varying levels of protection, as a result of elevated exposure. For this assessment the most conservative PAC value has been adopted, PAC-1, which is the concentration above which the public, including sensitive individuals, may be exposed to for 1 hour and may experience discomfort, irritation or other non-sensory effects that are not disabling and transient (i.e. reversible upon cessation of exposure). Exposures below these thresholds are considered protective of these effects. These values have only been adopted where no acute guidelines are available from the above (or any other reliable source).

Based on the above the following acute TRVs have been adopted in this assessment:

Table B1: Review of acute exposures and risks (maximum receptor anywhere)

Pollutants	Acute air guideline (1-hour average) (mg/m^3)
NEPM pollutants	
Nitrogen dioxide (NO_2)	0.22[1]
Sulfur dioxide (SO_2)	0.5[1]
Other pollutants	
Sulfuric acid mist	0.5[4]
Cadmium	0.0054[2]
Antimony	1.5[4]
Arsenic	0.003[2]
Lead	0.15[4]
Chromium (Cr VI assumed)	0.0013[2]
Tin	0.7[5]
Dioxins and furans	0.00013[4]

References
1 = NEPM health based guideline (NEPC 2016)
2 = Guideline available from the Texas Commission on Environmental Quality (TCEQ), https://www.tceq.texas.gov/toxicology/dsd/final.html
3 = 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
4 = Guideline available from the USEPA as Protective Action Criteria (PAC), where the most conservative value has been adopted https://www.energy.gov/ehss/protective-action-criteria-pac-aegls-erpgs-teels-rev-29-chemicals-concern-may-2016
5 = No acute guideline is available for tin, hence the chronic guideline has been adopted for the purpose of screening acute exposures, which will be conservative.

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 2012a).

For the gaseous pollutants 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 pollutants have been estimated on the basis of existing available information.

The assessment of chronic exposures has considered pollutants that are listed under the NEPM (NEPC 2016), namely NO_2 and SO_2, where the assessment requires comparison of the total intake (background plus the project) to the NEPM air criteria, relevant to an annual average. This has been undertaken separately to the other pollutants, and these pollutants have only been assessed on the basis of inhalation exposures.

Table B2 presents the threshold TRVs adopted for the assessment of chronic health effects associated with exposure to most of the other pollutants considered in this assessment.

It is noted that cadmium and chromium VI are classified by IARC as Class I carcinogens and this normally triggers a non-threshold type approach. For these metals, detailed review of their toxicology was undertaken for the ASC NEPM (i.e. National Environment Protection (Assessment of Site Contamination) Measure) (See Schedule B7 Appendix B1) (NEPC 1999 amended 2013a). This review found that the mechanism by which they are thought to cause cancer is non-genotoxic. As a result, it is appropriate to assess hazards associated with exposure to cadmium and chromium VI using a threshold-based approach. The toxicity reference values for each of these metals listed in **Table B2** are, therefore, based on relevant reference doses/concentrations.

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

Pollutant	Inhalation TRV (mg/m³)	Oral/dermal TRV (mg/kg/day)	GI absorption factor*	Dermal absorption*	Background intakes (as percentage of TRV)	
					Other sources**	Including natural soil***
Cadmium	0.000005 W	0.0008 W	100%	0	60%	66%
Antimony	0.0002 U	0.00086 NH	15%	0	0%	4%
Arsenic	0.001 D	0.002 N	100%	0.005	50%	55%
Lead	0.0005 N	0.0035 NH	100%	0	50%	90%
Chromium (Cr VI assumed)	0.0001 U	0.001 A	100%	0	10%	43%
Tin	0.7 R	0.2 D	100%	0	0%	0%
Dioxins and furans	8.05E-09 R	2.3E-09 NH	100%	0.03	54%	54%

Notes for Table B2:

* GI factor and dermal absorption values adopted from RAIS (accessed in 2020) (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 2013a) and relevant sources as noted for the TRVs. Gaseous pollutant background intakes are not known and hence for this assessment they have been assumed to be negligible

*** As the background intakes of inorganics as provided within the ASC-NEPM does not include natural soil, calculated intakes associated with ingestion of soil, adopting background concentrations of inorganics in soil from Morwell (maximum value from sites assessed by EPA Victoria in 2014, https://www.epa.vic.gov.au/our-work/monitoring-the-environment/hazelwood-recovery-effort/testing-during-the-hazelwood-fire/soil-testing-data-during-the-fire), has been included. Calculations relevant to these intakes are presented in **Appendix C**

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 2012)

D = TRV available from RIVM (Baars et al. 2001; Tiesjema & Baars 2009; van Vlaardingen, Posthumus & Posthuma-Doodeman 2005)

N = Inhalation guideline adopted for lead from the NEPM (NEPC 2016), and arsenic oral/dermal value as adopted in ASC-NEPM (NEPC 1999 amended 2013a).

NH = Dioxin value (and background intakes, which includes natural soil) adopted from NHMRC (NHMRC 2002) and Environment Australia (DEH 2005; EPHC 2005), and antimony and lead value consistent with that adopted by NHMRC to assess intakes in drinking water (NHMRC 2011 updated 2018)

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

W = TRV available from the WHO, relevant to chronic inhalation exposures (WHO 1999, 2000b, 2006b, 2017)

B3 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 2012a; NEPC 1999 amended 2013a; 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 B3** provides details on the assumptions adopted in this assessment:

$$\text{Inhalation Exposure Concentration} = C_{air} \times \frac{ET \times FI \times RF \times EF \times ED}{AT} \quad (mg/m^3)$$

Table B3: Inhalation exposure assumptions

Parameter		Value adopted	Basis
Ca	Concentration of chemical substance in air (mg/m^3)	Modelled from facility, adopting the maximum predicted anywhere (all grid receptors) and the maximum from all discrete receptors	Calculations undertaken on the basis of the maximum predicted impacts
FI	Fraction inhaled from site	100%	All exposures occur at the same location
RF	Dust lung retention factor (unitless)	0.375 for pollutants bound to particles 1 for gasses	Percentage of respirable dust that is small enough to reach and be retained in the lungs (NEPC 1999 amended 2013a)
ET	Exposure time (dependant on activity) (hours/day)	24 hours/day	Assume someone is exposed at the maximum location all day, every day of the year
EF	Exposure frequency (days/year)	365 days	
ED	Exposure duration (years)	35 years	Duration of residency as per enHealth (enHealth 2012b)
AT	Averaging time (hours)	Threshold = ED x 365 days/year x 24 hours/day Non-threshold = 70 years x 365 days/year x 24 hours/day	As per enHealth (enHealth 2012a) guidance

B4 Multiple pathway exposures

B4.1 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 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 2012a; USEPA 1989). This approach is presented in the following equation, and parameters adopted in this assessment are presented in **Table B4**:

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

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 B4**:

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

Table B4: 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, beef or milk) (mg/kg)	Modelled based on deposition of particulates to soil (refer to **Section 4.2**), adopting the maximum from all discrete 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 2012b)
	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 2013a)
	Eggs (kg/day)	0.006 kg/day	0.014 kg/day	Ingestion rate of eggs per day as per enHealth (enHealth 2012b), also consistent with P90 intakes from FSANZ (FSANZ 2017)
	Beef (kg/day)	0.085	0.16 kg/day	Ingestion rate for adults aged 19 years and older (enHealth 2012b), also consistent with P90 intakes from FSANZ (FSANZ 2017), Values for children from FSANZ (2017)
	Milk (kg/day)	1.097 kg/day	1.295 kg/day	Ingestion rate P90 intakes from FSANZ (FSANZ 2017)
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%	Rate assumed for rural area (higher than the default of 10% for urban areas)
	Eggs	200%	200%	Assume higher intake of home-produced eggs in rural areas (SAHC 1998)
	Beef	35%	35%	Rate assumed for rural area (higher than the default of 10% for urban areas)

Parameter		Value adopted		Basis
		Young children	Adults	
	Milk	100%	100%	Assume all milk consumed each day is from the property
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 2013a)
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 2013a)
ABSd	Dermal absorption fraction (unitless)	Chemical specific		Refer to **Tables B1 and B2**
CF	Conversion factor			
	Soil	$1x10^{-6}$ 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	70	15	As per enHealth (enHealth 2012b) and ASC NEPM (NEPC 1999 amended 2013a)
EF	Exposure frequency (days/year)	365	365	Assume residents exposed every day
ED	Exposure duration (years)	6 years	29	Duration of residency as per enHealth (enHealth 2012b) and split between young children and adults as per ASC NEPM (NEPC 1999 amended 2013a)
AT	Averaging time (days)	Threshold = ED x 365 days/year Non-threshold = 70 years x 365 days/year		As per enHealth (enHealth 2012a) guidance

B4.2 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, with assumptions adopted in this assessment presented in **Table B5**.

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

Table B5: 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 facility. Adopted maximum deposition rate for discrete receptors		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)
t	Accumulation time (years)	70 years	70 years	Default value (OEHHA 2015)
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 and meat/milk 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 B6**:

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

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 B6:**

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

Table B6: 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 facility. Adopted maximum deposition rate for discrete receptors	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 B5**
RUF	Root uptake factor (unitless)	Chemical specific value adopted	Root uptake factors from RAIS (RAIS) (soil to wet weight of plant)

Eggs, beef and milk

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

The concentration (C_P) calculated in eggs, beef or milk is calculated using the following equation (OEHHA 2015), with parameters and assumptions adopted presented in **Table B7**:

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

Table B7: 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 all pasture/crops ingested by chickens and cows are grown on the property
IR_C	Ingestion rate of pasture/crops by each animal considered (kg/day)		
	Chickens	0.12 kg/day	Ingestion rate from OEHHA (2015)
	Beef cattle	9 kg/day	Ingestion rate from OEHHA (2015)
	Lactating cattle	22 kg/day	Ingestion rate for lactating cattle from OEHHA (2015)
C	Concentration of pollutant in crops consumed by animals (mg/kg)	Assume equal to that calculated in aboveground produce	Calculated as described above with assumptions in **Table B6**
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)
Cs	Concentration of pollutant in soil (mg/kg)	Calculated value for agricultural soil	Calculated as described above and assumptions in **Table B5**
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. Values for antimony and tin are the mean values for the transfer of heavy metals into eggs (Leeman, Van Den Berg & Houben 2007)
	Beef	Chemical specific	Transfer factors adopted from OEHHA (2015) and RAIS
	Milk	Chemical specific	Transfer factors adopted from OEHHA (2015) and RAIS

All calculations relevant to the estimation of pollutant concentrations in soil, fruit and vegetables as well as animal products are presented in **Appendix C**.

Appendix C Risk calculations

Calculation of background intakes from natural soil

Exposure to Chemicals via Incidental Ingestion of Soil

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

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%	Compound-specific as noted below
Exposure Frequency (EF, days/year)	365	Exposure occurs every day
Exposure Duration (ED, years)	5	Duration as young child
Body Weight (BW, kg)	15	As per enHealth 2012 - mean for children aged 2-3 years
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)	1825	USEPA 1989 and CSMS 1996

Key Chemical	Toxicity Data				Bioavailability (%)	Background soil concnetration - Morwell	Daily Intake			
	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)	Chronic Hazard Quotient (unitless)	Intake as % TDI
Cadmium		8.0E-04		8.0E-04	100%	6.8	3.2E-06	4.5E-05	0.057	5.7%
Antimony		8.6E-04		8.6E-04	100%	5	2.4E-06	3.3E-05	0.039	3.9%
Arsenic		2.0E-03		2.0E-03	100%	14	6.7E-06	9.3E-05	0.047	4.7%
Lead		3.5E-03		3.5E-03	100%	210	1.0E-04	1.4E-03	0.40	40.0%
Chromium (Cr VI assumed)		1.0E-03		1.0E-03	100%	50	2.4E-05	3.3E-04	0.33	33.3%

Soil concentrations are maximum reported by EPA Victoria for locations in Morwell (sampled after the Hazelwood fire). Values in red are the analytical limit of reporting as the analyte was not detected

Inhalation exposures

Air concentrations used in HHRA

Pollutant	Maximum GLC at any location (mg/m^3)			Maximum GLC from all receptors (SR6) (mg/m^3)		
	Annual average	1 hour average	3 minute average	Annual average	1 hour average	3-minute average
	Ascend (2020), Table 8 for 2016	Aubin (2019) for 2016	Aubin (2019) for 2016	Calculated	Aubin (2019) for 2016	Aubin (2019) for 2016
Nitrogen dioxide (NO2)	2.4E-03	1.9E-02		1.3E-04	9.8E-04	
Sulfur dioxide (SO2)	1.2E-04	9.7E-04		2.1E-05	1.6E-04	
Sulfuric acid mist	8.3E-05	6.2E-04	1.2E-03	3.8E-06	2.8E-05	5.7E-05
PM10	3.3E-04	2.6E-03		2.8E-05	2.2E-04	
PM2.5	3.3E-04	2.6E-03		2.8E-05	2.2E-04	
Cadmium	2.0E-08	1.5E-07	3.0E-07	2.8E-09	2.1E-08	4.1E-08
Antimony	1.4E-07	1.1E-06	2.1E-06	2.0E-08	1.5E-07	3.0E-07
Arsenic	4.4E-07	3.3E-06	6.6E-06	1.1E-07	8.5E-07	1.7E-06
Lead	3.7E-06	2.9E-05		3.2E-07	2.4E-06	
Chromium (Cr VI assumed)	5.4E-07	4.0E-06	8.0E-06	7.5E-08	5.6E-07	1.1E-06
Tin	6.6E-08	4.9E-07	9.9E-07	9.2E-09	6.9E-08	1.4E-07
Dioxin	1.2E-12	8.9E-12	1.8E-11	1.7E-13	1.2E-12	2.5E-12

1.0E-06 Concentration calculated based on conversion of averaging times from data provided

Inhalation - gases and fine particulates

$$\text{Inhalation Exposure Concentration} = C_{air} \times \frac{ET \times FI \times RF \times EF \times ED}{AT} \quad (mg/m^3)$$

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 (RF, unitless)	0.375	Percentage of respirable dust that is small enough to reach and be retained in the lungs (NEPM 1999 amended 2013) - NA for gasses
Exposure Frequency (EF, days/yr)	365	Days at home, as per NEPM (1999 amended 2013)
Exposure Duration (ED, years)	35	As per NEPM (1999 amended 2013)
Averaging Time - NonThreshold (Atc, hours)	613200	US EPA 2009
Averaging Time - Threshold (Atn, hours)	306600	US EPA 2009

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
Nitrogen dioxide (NO2)	0.0E+00	5.6E-02	0%	5.6E-02	1.2E-02	6.2E-03	1.2E-02	--		0.22	
Sulfur dioxide (SO2)	0.0E+00	5.0E-02	0%	5.0E-02	2.1E-03	1.1E-03	2.1E-03	--		0.042	
Cadmium	0.0E+00	5.0E-06	66%	1.7E-06	2.0E-08	3.7E-09	7.4E-09	--		0.0043	12%
Antimony	0.0E+00	2.0E-04	4%	1.9E-04	1.4E-07	2.7E-08	5.3E-08	--		0.00028	1%
Arsenic	0.0E+00	1.0E-03	55%	4.5E-04	4.4E-07	8.3E-08	1.7E-07	--		0.00037	1%
Lead	0.0E+00	5.0E-04	90%	5.0E-05	3.7E-06	6.9E-07	1.4E-06	--		0.028	76%
Chromium (Cr VI assumed)	0.0E+00	1.0E-04	43%	5.7E-05	5.4E-07	1.0E-07	2.0E-07	--		0.0036	10%
Tin	0.0E+00	7.0E-01	0%	7.0E-01	6.6E-08	1.2E-08	2.5E-08	--		0.000000035	0%
Dioxin	0.0E+00	8.1E-09	54%	3.7E-09	1.2E-12	2.2E-13	4.5E-13	--		0.00012	0%
							TOTAL	**0.0E+00**		**0.036**	

Key Chemical	Toxicity Data				Concentration	Daily Exposure		Calculated Risk			
	Inhalation Unit Risk (mg/m³)⁻¹	Chronic TC Air (mg/m³)	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background) (mg/m³)	Estimated Concentration in Air - Maximum receptors (Ca) (mg/m³)	Inhalation Exposure Concentration - NonThreshold (mg/m³)	Inhalation Exposure Concentration - Threshold (mg/m³)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Nitrogen dioxide (NO2)	0.0E+00	5.6E-02	0%	5.6E-02	1.0E-02	5.0E-03	1.0E-02	--		0.18	
Sulfur dioxide (SO2)	0.0E+00	5.0E-02	0%	5.0E-02	2.0E-03	1.0E-03	2.0E-03	--		0.040	
Cadmium	0.0E+00	5.0E-06	66%	1.7E-06	2.8E-09	5.2E-10	1.0E-09	--		0.00060	17%
Antimony	0.0E+00	2.0E-04	4%	1.9E-04	2.0E-08	3.7E-09	7.4E-09	--		0.000039	1%
Arsenic	0.0E+00	1.0E-03	55%	4.5E-04	1.1E-07	2.1E-08	4.2E-08	--		0.000094	3%
Lead	0.0E+00	5.0E-04	90%	5.0E-05	3.2E-07	6.0E-08	1.2E-07	--		0.0024	66%
Chromium (Cr VI assumed)	0.0E+00	1.0E-04	43%	5.7E-05	7.5E-08	1.4E-08	2.8E-08	--		0.00050	14%
Tin	0.0E+00	7.0E-01	0%	7.0E-01	9.2E-09	1.7E-09	3.5E-09	--		0.0000000049	0%
Dioxin	0.0E+00	8.1E-09	54%	3.7E-09	1.7E-13	3.1E-14	6.2E-14	--		0.000017	0%
							TOTAL	**0.0E+00**		**0.0036**	

Soil exposures

Calculation of Concentrations in Soil

$$C_s = \frac{DR \bullet \left[1 - e^{-k \bullet t}\right]}{d \bullet \rho \bullet k} \bullet 1000$$ **(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	As per OEHHA (2015) guidance

Chemical-specific Inputs and calculations - maximum anywhere

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
Cadmium	273973	2.5E-06	1.25E-02	5.5E-02	3.6E-03
Antimony	273973	2.5E-06	8.92E-02	3.9E-01	2.6E-02
Arsenic	273973	2.5E-06	2.78E-01	1.2E+00	8.1E-02
Lead	273973	2.5E-06	2.32E+00	1.0E+01	6.8E-01
Chromium (Cr VI assumed)	273973	2.5E-06	3.39E-01	1.5E+00	9.9E-02
Tin	273973	2.5E-06	4.16E-02	1.8E-01	1.2E-02
Dioxin		0.069	7.51E-07	6.7E-07	4.5E-08

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
Cadmium	273973	2.5E-06	1.74E-03	7.6E-03	5.1E-04
Antimony	273973	2.5E-06	1.25E-02	5.5E-02	3.6E-03
Arsenic	273973	2.5E-06	7.15E-02	3.1E-01	2.1E-02
Lead	273973	2.5E-06	2.02E-01	8.8E-01	5.9E-02
Chromium (Cr VI assumed)	273973	2.5E-06	4.74E-02	2.1E-01	1.4E-02
Tin	273973	2.5E-06	5.82E-03	2.5E-02	1.7E-03
Dioxin		0.069	1.05E-07	9.4E-08	6.3E-09

Half-life in soil: dioxin loss constant from Lowe et al (1991) and half-life for remainder from OEHHA (2015)

Exposure to Chemicals via Incidental Ingestion of Soil

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

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	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)
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 anywhere

Key Chemical	Toxicity Data: Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Toxicity Data: Threshold TDI (mg/kg/day)	Toxicity Data: Background Intake (% TDI)	Toxicity Data: TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	Bioavailability (%)	Soil Concentration (mg/kg)	Daily Intake: NonThreshold (mg/kg/day)	Daily Intake: Threshold (mg/kg/day)	Calculated Risk: Non-Threshold Risk (unitless)	Calculated Risk: % Total Risk	Calculated Risk: Chronic Hazard Quotient (unitless)	Calculated Risk: % Total HI
Cadmium		8.0E-04	66%	2.7E-04	100%	5.5E-02	1.6E-08	3.9E-08	--		0.00014	1%
Antimony		8.6E-04	4%	8.3E-04	100%	3.9E-01	1.2E-07	2.8E-07	--		0.00034	1%
Arsenic		2.0E-03	55%	9.1E-04	100%	1.2E+00	3.6E-07	8.7E-07	--		0.00096	4%
Lead		3.5E-03	90%	3.5E-04	100%	1.0E+01	3.0E-06	7.3E-06	--		0.021	85%
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04	100%	1.5E+00	4.4E-07	1.1E-06	--		0.0019	8%
Tin		2.0E-01		2.0E-01	100%	1.8E-01	5.4E-08	1.3E-07	--		6.5E-07	0%
Dioxin		2.3E-09	54%	1.1E-09	100%	6.7E-07	2.0E-13	4.8E-13	--		0.00045	2%
								TOTAL			0.024	

Maximum from sensitive receptors

Key Chemical	Toxicity Data: Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Toxicity Data: Threshold TDI (mg/kg/day)	Toxicity Data: Background Intake (% TDI)	Toxicity Data: TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	Bioavailability (%)	Soil Concentration (mg/kg)	Daily Intake: NonThreshold (mg/kg/day)	Daily Intake: Threshold (mg/kg/day)	Calculated Risk: Non-Threshold Risk (unitless)	Calculated Risk: % Total Risk	Calculated Risk: Chronic Hazard Quotient (unitless)	Calculated Risk: % Total HI
Cadmium		8.0E-04	66%	2.7E-04	100%	7.6E-03	2.3E-09	5.5E-09	--		0.000020	1%
Antimony		8.6E-04	4%	8.3E-04	100%	5.5E-02	1.6E-08	3.9E-08	--		0.000047	2%
Arsenic		2.0E-03	55%	9.1E-04	100%	3.1E-01	9.3E-08	2.2E-07	--		0.00025	10%
Lead		3.5E-03	90%	3.5E-04	100%	8.8E-01	2.6E-07	6.3E-07	--		0.0018	74%
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04	100%	2.1E-01	6.1E-08	1.5E-07	--		0.00026	11%
Tin		2.0E-01		2.0E-01	100%	2.5E-02	7.5E-09	1.8E-08	--		9.1E-08	0%
Dioxin		2.3E-09	54%	1.1E-09	100%	9.4E-08	2.8E-14	6.7E-14	--		0.000063	3%
								TOTAL			0.0024	

Exposure to Chemicals via Incidental Ingestion of Soil

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

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%	Compound-specific as noted below
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)
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 anywhere

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
Cadmium		8.0E-04	66%	2.7E-04	100%	5.5E-02	3.1E-08	3.6E-07	--		0.0013	1%
Antimony		8.6E-04	4%	8.3E-04	100%	3.9E-01	2.2E-07	2.6E-06	--		0.0031	1%
Arsenic		2.0E-03	55%	9.1E-04	100%	1.2E+00	7.0E-07	8.1E-06	--		0.0090	4%
Lead		3.5E-03	90%	3.5E-04	100%	1.0E+01	5.8E-06	6.8E-05	--		0.19	85%
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04	100%	1.5E+00	8.5E-07	9.9E-06	--		0.017	8%
Tin		2.0E-01		2.0E-01	100%	1.8E-01	1.0E-07	1.2E-06	--		6.1E-06	0%
Dioxin		2.3E-09	54%	1.1E-09	100%	6.7E-07	3.8E-13	4.5E-12	--		0.0042	2%
								TOTAL			0.23	

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
Cadmium		8.0E-04	66%	2.7E-04	100%	7.6E-03	4.4E-09	5.1E-08	--		0.00019	1%
Antimony		8.6E-04	4%	8.3E-04	100%	5.5E-02	3.1E-08	3.6E-07	--		0.00044	2%
Arsenic		2.0E-03	55%	9.1E-04	100%	3.1E-01	1.8E-07	2.1E-06	--		0.0023	10%
Lead		3.5E-03	90%	3.5E-04	100%	8.8E-01	5.0E-07	5.9E-06	--		0.017	74%
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04	100%	2.1E-01	1.2E-07	1.4E-06	--		0.0024	11%
Tin		2.0E-01		2.0E-01	100%	2.5E-02	1.5E-08	1.7E-07	--		8.5E-07	0%
Dioxin		2.3E-09	54%	1.1E-09	100%	9.4E-08	5.4E-14	6.3E-13	--		0.00059	3%
								TOTAL			0.023	

Dermal Exposure to Chemicals via Contact with Soil

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

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/yr)	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 anywhere

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)	
Cadmium		8.0E-04	66%	2.7E-04		5.5E-02			--		--	
Antimony		1.3E-04	4%	1.2E-04		3.9E-01			--		--	
Arsenic		2.0E-03	55%	9.1E-04	0.005	1.2E+00	1.1E-07	2.7E-07	--		0.00030	26%
Lead		3.5E-03	90%	3.5E-04		1.0E+01			--		--	
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04		1.5E+00			--		--	
Tin		2.0E-01		2.0E-01		1.8E-01			--		--	
Dioxin		2.3E-09	54%	1.1E-09	0.03	6.7E-07	3.8E-13	9.1E-13	--		0.00086	74%
								TOTAL			0.0012	

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)	
Cadmium		8.0E-04	66%	2.7E-04		7.6E-03			--		--	
Antimony		1.3E-04	4%	1.2E-04		5.5E-02			--		--	
Arsenic		2.0E-03	55%	9.1E-04	0.005	3.1E-01	2.9E-08	7.0E-08	--		0.000078	39%
Lead		3.5E-03	90%	3.5E-04		8.8E-01			--		--	
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04		2.1E-01			--		--	
Tin		2.0E-01		2.0E-01		2.5E-02			--		--	
Dioxin		2.3E-09	54%	1.1E-09	0.03	9.4E-08	5.3E-14	1.3E-13	--		0.00012	61%
								TOTAL			0.00020	

Dermal Exposure to Chemicals via Contact with Soil

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

Parameters Relevant to Quantification of Exposure by 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/yr)	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 anywhere

Key Chemical	Toxicity Data					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)	Dermal Absorption (ABS)	(mg/kg)	Non-Threshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Cadmium		8.0E-04	66%	2.7E-04		5.5E-02			--		--	
Antimony		1.3E-04	4%	1.2E-04		3.9E-01			--		--	
Arsenic		2.0E-03	55%	9.1E-04	0.005	1.2E+00	4.7E-08	5.5E-07	--		0.00060	26%
Lead		3.5E-03	90%	3.5E-04		1.0E+01			--		--	
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04		1.5E+00			--		--	
Tin		2.0E-01		2.0E-01		1.8E-01			--		--	
Dioxin		2.3E-09	54%	1.1E-09	0.03	6.7E-07	1.6E-13	1.8E-12	--		0.0017	74%
								TOTAL			**0.0023**	

Maximum from sensitive receptors

Key Chemical	Toxicity Data					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)	Dermal Absorption (ABS)	(mg/kg)	Non-Threshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Cadmium		8.0E-04	66%	2.7E-04		7.6E-03			--		--	
Antimony		1.3E-04	4%	1.2E-04		5.5E-02			--		--	
Arsenic		2.0E-03	55%	9.1E-04	0.005	3.1E-01	1.2E-08	1.4E-07	--		0.00016	39%
Lead		3.5E-03	90%	3.5E-04		8.8E-01			--		--	
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04		2.1E-01			--		--	
Tin		2.0E-01		2.0E-01		2.5E-02			--		--	
Dioxin		2.3E-09	54%	1.1E-09	0.03	9.4E-08	2.2E-14	2.5E-13	--		0.00024	61%
								TOTAL			**0.00039**	

Homegrown fruit and vegetables

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 anywhere

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) unitless	Soil Concentration (Cs) mg/kg	Below Ground Produce Concentration mg/kg ww
Cadmium	14	0.05	3.4E-05	1.7E-05	0.125	3.6E-03	4.5E-04
Antimony	14	0.05	2.4E-04	1.2E-04	0.05	2.6E-02	1.3E-03
Arsenic	14	0.05	7.6E-04	3.8E-04	0.04	8.1E-02	3.2E-03
Lead	14	0.05	6.4E-03	3.2E-03	0.0112	6.8E-01	7.6E-03
Chromium (Cr VI assumed)	14	0.05	9.3E-04	4.6E-04	0.00188	9.9E-02	1.9E-04
Tin	14	0.05	1.1E-04	5.7E-05	0.0075	1.2E-02	9.1E-05
Dioxin	14	0.05	2.1E-09	1.0E-09	0.000876	4.5E-08	3.9E-11

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

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) unitless	Soil Concentration (Cs) mg/kg	Below Ground Produce Concentration mg/kg ww
Cadmium	14	0.05	4.78E-06	2.4E-06	0.125	5.1E-04	6.4E-05
Antimony	14	0.05	3.42E-05	1.7E-05	0.05	3.6E-03	1.8E-04
Arsenic	14	0.05	1.96E-04	9.8E-05	0.04	2.1E-02	8.3E-04
Lead	14	0.05	5.52E-04	2.8E-04	0.0112	5.9E-02	6.6E-04
Chromium (Cr VI assumed)	14	0.05	1.30E-04	6.5E-05	0.00188	1.4E-02	2.6E-05
Tin	14	0.05	1.59E-05	8.0E-06	0.0075	1.7E-03	1.3E-05
Dioxin	14	0.05	2.87E-10	1.4E-10	0.000876	6.3E-09	5.5E-12

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

Exposure to Chemicals via Ingestion of Homegrown Fruit and Vegetables

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

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 (%)	35%	Assumed for rural areas (higher than typical default)
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 anywhere

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
Cadmium		8.0E-04	66%	2.7E-04	100%	1.71E-05	4.55E-04	1.1E-07	2.7E-07	--		0.00099	3%
Antimony		8.6E-04	4%	8.3E-04	100%	1.22E-04	1.30E-03	3.6E-07	8.8E-07	--		0.0011	3%
Arsenic		2.0E-03	55%	9.1E-04	100%	3.81E-04	3.25E-03	9.6E-07	2.3E-06	--		0.0025	8%
Lead		3.5E-03	90%	3.5E-04	100%	3.17E-03	7.59E-03	3.6E-06	8.7E-06	--		0.025	77%
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04	100%	4.64E-04	1.86E-04	3.2E-07	7.8E-07	--		0.0014	4%
Tin		2.0E-01		2.0E-01	100%	5.69E-05	9.10E-05	5.5E-08	1.3E-07	--		6.6E-07	0%
Dioxin		2.3E-09	54%	1.1E-09	100%	1.03E-09	3.92E-11	6.3E-13	1.5E-12	--		0.0014	4%
									TOTAL			**0.032**	

Maximum at 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
Cadmium		8.0E-04	66%	2.7E-04	100%	2.4E-06	6.4E-05	1.6E-08	3.8E-08	--		0.00014	4%
Antimony		8.6E-04	4%	8.3E-04	100%	1.7E-05	1.8E-04	5.1E-08	1.2E-07	--		0.00015	4%
Arsenic		2.0E-03	55%	9.1E-04	100%	9.8E-05	8.3E-04	2.5E-07	5.9E-07	--		0.00065	19%
Lead		3.5E-03	90%	3.5E-04	100%	2.8E-04	6.6E-04	3.1E-07	7.6E-07	--		0.0022	62%
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04	100%	6.5E-05	2.6E-05	4.5E-08	1.1E-07	--		0.00019	5%
Tin		2.0E-01		2.0E-01	100%	8.0E-06	1.3E-05	7.7E-09	1.8E-08	--		9.2E-08	0%
Dioxin		2.3E-09	54%	1.1E-09	100%	1.4E-10	5.5E-12	8.8E-14	2.1E-13	--		0.00020	6%
									TOTAL			**0.0035**	

Exposure to Chemicals via Ingestion of Homegrown Fruit and Vegetables

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

Parameters Relevant to Quantification of Exposure by 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 (%)	35%	Assumed for rural areas (higher than typical default)
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 anywhere

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)	
Cadmium		8.0E-04	66%	2.7E-04	100%	1.71E-05	4.55E-04	4.9E-08	5.7E-07	--		0.0021	2%
Antimony		8.6E-04	4%	8.3E-04	100%	1.22E-04	1.30E-03	1.7E-07	2.0E-06	--		0.0025	3%
Arsenic		2.0E-03	55%	9.1E-04	100%	3.81E-04	3.25E-03	4.7E-07	5.5E-06	--		0.0060	6%
Lead		3.5E-03	90%	3.5E-04	100%	3.17E-03	7.59E-03	2.2E-06	2.5E-05	--		0.072	78%
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04	100%	4.64E-04	1.86E-04	2.3E-07	2.7E-06	--		0.0048	5%
Tin		2.0E-01		2.0E-01	100%	5.69E-05	9.10E-05	3.5E-08	4.1E-07	--		2.0E-06	0%
Dioxin		2.3E-09	54%	1.1E-09	100%	1.03E-09	3.92E-11	4.9E-13	5.7E-12	--		0.0054	6%
									TOTAL			**0.093**	

Maximum at 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)	
Cadmium		8.0E-04	66%	2.7E-04	100%	2.4E-06	6.4E-05	6.8E-09	8.0E-08	--		0.00029	3%
Antimony		8.6E-04	4%	8.3E-04	100%	1.7E-05	1.8E-04	2.4E-08	2.8E-07	--		0.00034	3%
Arsenic		2.0E-03	55%	9.1E-04	100%	9.8E-05	8.3E-04	1.2E-07	1.4E-06	--		0.0016	16%
Lead		3.5E-03	90%	3.5E-04	100%	2.8E-04	6.6E-04	1.9E-07	2.2E-06	--		0.0063	64%
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04	100%	6.5E-05	2.6E-05	3.3E-08	3.8E-07	--		0.00068	7%
Tin		2.0E-01		2.0E-01	100%	8.0E-06	1.3E-05	4.9E-09	5.7E-08	--		2.8E-07	0%
Dioxin		2.3E-09	54%	1.1E-09	100%	1.4E-10	5.5E-12	6.8E-14	7.9E-13	--		0.00075	8%
									TOTAL			**0.0099**	

Ingestion of eggs, beef and milk

Calculation of Concentrations in Eggs

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 100% of crops consumed by chickens is grown in the same soil
IRc (ingestion rate of crops)	kg/day	0.12	Assumed ingestion rate from OEHHA 2015 (assume concentration the same as predicted for aboveground crops)
IRs (ingestion rate of soil)	kg/day	0.01	Based on OEHHA (2015) and advice from Ag Vic
B (bioavailability)	%	100%	

Chemical-specific Inputs and calculations - Maximum

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	
Cadmium	1.7E-05	3.6E-03	1.0E-02	3.8E-07	
Antimony	1.2E-04	2.6E-02	3.8E-02	1.0E-05	Mean value for heavy metals into eggs - Leeman et al 2007
Arsenic	3.8E-04	8.1E-02	7.0E-02	6.0E-05	
Lead	3.2E-03	6.8E-01	4.0E-02	2.9E-04	
Chromium (Cr VI assumed)	4.6E-04	9.9E-02	9.2E-03	9.6E-06	OEHHA (2003)
Tin	5.7E-05	1.2E-02	3.8E-02	4.9E-06	Mean value for heavy metals into eggs - Leeman et al 2007
Dioxin	1.0E-09	4.5E-08	1.0E+01	5.7E-09	

Transfer factors from OEHHA 2015 unless otherwise noted

Chemical-specific Inputs and calculations - Maximum discrete 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	
Cadmium	2.4E-06	5.1E-04	1.0E-02	5.4E-08	
Antimony	1.7E-05	3.6E-03	3.8E-02	1.5E-06	Mean value for heavy metals into eggs - Leeman et al 2007
Arsenic	9.8E-05	2.1E-02	7.0E-02	1.5E-05	
Lead	2.8E-04	5.9E-02	4.0E-02	2.5E-05	
Chromium (Cr VI assumed)	6.5E-05	1.4E-02	9.2E-03	1.3E-06	OEHHA (2003)
Tin	8.0E-06	1.7E-03	3.8E-02	6.8E-07	Mean value for heavy metals into eggs - Leeman et al 2007
Dioxin	1.4E-10	6.3E-09	1.0E+01	8.0E-10	

Transfer factors from OEHHA 2015 unless otherwise noted

Exposure to Chemicals via Ingestion of Eggs

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

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 (%)	200%	Assumed for rural areas where a higher rate of egg ingestion expected
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 anywhere

Key Chemical	Toxicity Data				Bioavailability (%)	Egg 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
Cadmium		8.0E-04	66%	2.7E-04	100%	3.84E-07	6.4E-11	1.5E-10	--		5.6E-07	0%
Antimony		8.6E-04	4%	8.3E-04	100%	1.04E-05	1.7E-09	4.2E-09	--		5.1E-06	0%
Arsenic		2.0E-03	55%	9.1E-04	100%	6.00E-05	9.9E-09	2.4E-08	--		2.6E-05	1%
Lead		3.5E-03	90%	3.5E-04	100%	2.86E-04	4.7E-08	1.1E-07	--		3.3E-04	13%
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04	100%	9.62E-06	1.6E-09	3.8E-09	--		6.8E-06	0%
Tin		2.0E-01		2.0E-01	100%	4.87E-06	8.1E-10	1.9E-09	--		9.7E-09	0%
Dioxin		2.3E-09	54%	1.1E-09	100%	5.71E-09	9.5E-13	2.3E-12	--		2.2E-03	86%

TOTAL		**2.5E-3**

Maximum from sensitive receptor

Key Chemical	Toxicity Data				Bioavailability (%)	Egg 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
Cadmium		8.0E-04	66%	2.7E-04	100%	5.4E-08	8.9E-12	2.1E-11	--		7.8E-08	0%
Antimony		8.6E-04	4%	8.3E-04	100%	1.5E-06	2.4E-10	5.8E-10	--		7.1E-07	0%
Arsenic		2.0E-03	55%	9.1E-04	100%	1.5E-05	2.6E-09	6.2E-09	--		6.8E-06	2%
Lead		3.5E-03	90%	3.5E-04	100%	2.5E-05	4.1E-09	9.9E-09	--		2.8E-05	8%
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04	100%	1.3E-06	2.2E-10	5.4E-10	--		9.5E-07	0%
Tin		2.0E-01		2.0E-01	100%	6.8E-07	1.1E-10	2.7E-10	--		1.4E-09	0%
Dioxin		2.3E-09	54%	1.1E-09	100%	8.0E-10	1.3E-13	3.2E-13	--		3.0E-04	89%

TOTAL		**3.4E-04**

Exposure to Chemicals via Ingestion of Eggs

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

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 (%)	200%	Assumed for rural areas where a higher rate of egg ingestion expected
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 anywhere

Key Chemical	Toxicity Data: Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Toxicity Data: Threshold TDI (mg/kg/day)	Toxicity Data: Background Intake (% TDI)	Toxicity Data: TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	Bioavailability (%)	Egg concentration (mg/kg wet weight)	Daily Intake: NonThreshold (mg/kg/day)	Daily Intake: Threshold (mg/kg/day)	Calculated Risk: Non-Threshold Risk (unitless)	Calculated Risk: % Total Risk	Calculated Risk: Chronic Hazard Quotient (unitless)	Calculated Risk: % Total HI
Cadmium		8.0E-04	66%	2.7E-04	100%	3.84E-07	2.6E-11	3.1E-10	--		1.1E-06	0%
Antimony		8.6E-04	4%	8.3E-04	100%	1.04E-05	7.2E-10	8.4E-09	--		1.0E-05	0%
Arsenic		2.0E-03	55%	9.1E-04	100%	6.00E-05	4.1E-09	4.8E-08	--		5.3E-05	1%
Lead		3.5E-03	90%	3.5E-04	100%	2.86E-04	2.0E-08	2.3E-07	--		6.5E-04	13%
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04	100%	9.62E-06	6.6E-10	7.7E-09	--		1.4E-05	0%
Tin		2.0E-01		2.0E-01	100%	4.87E-06	3.3E-10	3.9E-09	--		1.9E-08	0%
Dioxin		2.3E-09	54%	1.1E-09	100%	5.71E-09	3.9E-13	4.6E-12	--		4.3E-03	86%
								TOTAL			**5.0E-3**	

Maximum from sensitive receptor

Key Chemical	Toxicity Data: Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Toxicity Data: Threshold TDI (mg/kg/day)	Toxicity Data: Background Intake (% TDI)	Toxicity Data: TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	Bioavailability (%)	Egg concentration (mg/kg wet weight)	Daily Intake: NonThreshold (mg/kg/day)	Daily Intake: Threshold (mg/kg/day)	Calculated Risk: Non-Threshold Risk (unitless)	Calculated Risk: % Total Risk	Calculated Risk: Chronic Hazard Quotient (unitless)	Calculated Risk: % Total HI
Cadmium		8.0E-04	66%	2.7E-04	100%	5.4E-08	3.7E-12	4.3E-11	--		1.6E-07	0%
Antimony		8.6E-04	4%	8.3E-04	100%	1.5E-06	1.0E-10	1.2E-09	--		1.4E-06	0%
Arsenic		2.0E-03	55%	9.1E-04	100%	1.5E-05	1.1E-09	1.2E-08	--		1.4E-05	2%
Lead		3.5E-03	90%	3.5E-04	100%	2.5E-05	1.7E-09	2.0E-08	--		5.7E-05	8%
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04	100%	1.3E-06	9.2E-11	1.1E-09	--		1.9E-06	0%
Tin		2.0E-01		2.0E-01	100%	6.8E-07	4.7E-11	5.4E-10	--		2.7E-09	0%
Dioxin		2.3E-09	54%	1.1E-09	100%	8.0E-10	5.5E-14	6.4E-13	--		6.0E-04	89%
								TOTAL			**6.8E-04**	

Calculation of Concentrations in Homegrown Beef

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

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	
Cadmium	1.7E-05	3.6E-03	2.0E-03	3.6E-06	
Antimony	1.2E-04	2.6E-02	1.0E-03	1.3E-05	RAIS
Arsenic	3.8E-04	8.1E-02	2.0E-03	8.0E-05	
Lead	3.2E-03	6.8E-01	3.0E-04	1.0E-04	
Chromium (Cr VI assumed)	4.6E-04	9.9E-02	5.5E-03	2.7E-04	RAIS
Tin	5.7E-05	1.2E-02	1.0E-03	6.0E-06	RAIS
Dioxin	1.0E-09	4.5E-08	7.0E-01	2.1E-08	

Transfer factors from OEHHA 2015 unless otherwise noted

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	
Cadmium	2.4E-06	5.1E-04	2.0E-03	5.0E-07	
Antimony	1.7E-05	3.6E-03	1.0E-03	1.8E-06	RAIS
Arsenic	9.8E-05	2.1E-02	2.0E-03	2.1E-05	
Lead	2.8E-04	5.9E-02	3.0E-04	8.7E-06	
Chromium (Cr VI assumed)	6.5E-05	1.4E-02	5.5E-03	3.7E-05	RAIS
Tin	8.0E-06	1.7E-03	1.0E-03	8.4E-07	RAIS
Dioxin	1.4E-10	6.3E-09	7.0E-01	2.9E-09	

Transfer factors from OEHHA 2015 unless otherwise noted

Exposure to Chemicals via Ingestion of Beef

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

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 anywhere

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
Cadmium		8.0E-04	66%	2.7E-04	100%	3.6E-06	1.2E-09	2.9E-09	--		1.0E-05	0%
Antimony		8.6E-04	4%	8.3E-04	100%	1.3E-05	4.2E-09	1.0E-08	--		1.2E-05	0%
Arsenic		2.0E-03	55%	9.1E-04	100%	8.0E-05	2.6E-08	6.4E-08	--		7.1E-05	0%
Lead		3.5E-03	90%	3.5E-04	100%	1.0E-04	3.3E-08	8.0E-08	--		2.3E-04	1%
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04	100%	2.7E-04	8.9E-08	2.1E-07	--		3.8E-04	2%
Tin		2.0E-01		2.0E-01	100%	6.0E-06	2.0E-09	4.8E-09	--		2.4E-08	0%
Dioxin		2.3E-09	54%	1.1E-09	100%	2.1E-08	6.8E-12	1.6E-11	--		1.6E-02	96%
								TOTAL			1.6E-02	

Maximum for 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
Cadmium		8.0E-04	66%	2.7E-04	100%	5.0E-07	1.7E-10	4.0E-10	--		1.5E-06	0%
Antimony		8.6E-04	4%	8.3E-04	100%	1.8E-06	5.9E-10	1.4E-09	--		1.7E-06	0%
Arsenic		2.0E-03	55%	9.1E-04	100%	2.1E-05	6.8E-09	1.6E-08	--		1.8E-05	1%
Lead		3.5E-03	90%	3.5E-04	100%	8.7E-06	2.9E-09	6.9E-09	--		2.0E-05	1%
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04	100%	3.7E-05	1.2E-08	3.0E-08	--		5.3E-05	2%
Tin		2.0E-01		2.0E-01	100%	8.4E-07	2.8E-10	6.7E-10	--		3.3E-09	0%
Dioxin		2.3E-09	54%	1.1E-09	100%	2.9E-09	9.5E-13	2.3E-12	--		2.2E-03	96%
								TOTAL			2.3E-03	

Exposure to Chemicals via Ingestion of Beef

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

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 anywhere

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
Cadmium		8.0E-04	66%	2.7E-04	100%	3.58E-06	6.1E-10	7.1E-09	--		2.6E-05	0%
Antimony		8.6E-04	4%	8.3E-04	100%	1.28E-05	2.2E-09	2.5E-08	--		3.1E-05	0%
Arsenic		2.0E-03	55%	9.1E-04	100%	7.99E-05	1.4E-08	1.6E-07	--		1.7E-04	0%
Lead		3.5E-03	90%	3.5E-04	100%	1.00E-04	1.7E-08	2.0E-07	--		5.7E-04	1%
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04	100%	2.68E-04	4.6E-08	5.3E-07	--		9.4E-04	2%
Tin		2.0E-01		2.0E-01	100%	5.97E-06	1.0E-09	1.2E-08	--		5.9E-08	0%
Dioxin		2.3E-09	54%	1.1E-09	100%	2.06E-08	3.5E-12	4.1E-11	--		3.9E-02	96%
								TOTAL			**4.0E-02**	

Maximum - Discrete receptors

Maximum for 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
Cadmium		8.0E-04	66%	2.7E-04	100%	5.0E-07	8.5E-11	9.9E-10	--		3.6E-06	0%
Antimony		8.6E-04	4%	8.3E-04	100%	1.8E-06	3.0E-10	3.6E-09	--		4.3E-06	0%
Arsenic		2.0E-03	55%	9.1E-04	100%	2.1E-05	3.5E-09	4.1E-08	--		4.5E-05	1%
Lead		3.5E-03	90%	3.5E-04	100%	8.7E-06	1.5E-09	1.7E-08	--		4.9E-05	1%
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04	100%	3.7E-05	6.4E-09	7.4E-08	--		1.3E-04	2%
Tin		2.0E-01		2.0E-01	100%	8.4E-07	1.4E-10	1.7E-09	--		8.3E-09	0%
Dioxin		2.3E-09	54%	1.1E-09	100%	2.9E-09	4.9E-13	5.7E-12	--		5.4E-03	96%
								TOTAL			**5.6E-03**	

Calculation of Concentrations in Dairy Milk

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

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 ww	
Cadmium	1.7E-05	3.6E-03	2.0E-03	8.8E-06	
Antimony	1.2E-04	2.6E-02	1.0E-04	3.1E-06	RAIS
Arsenic	3.8E-04	8.1E-02	5.0E-05	4.9E-06	
Lead	3.2E-03	6.8E-01	6.0E-05	4.9E-05	
Chromium (Cr VI assumed)	4.6E-04	9.9E-02	9.0E-06	1.1E-06	
Tin	5.7E-05	1.2E-02	1.0E-03	1.5E-05	RAIS
Dioxin	1.0E-09	4.5E-08	2.0E-02	1.4E-09	

Transfer factors from OEHHA 2015 unless otherwise noted

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 ww	
Cadmium	2.4E-06	5.1E-04	2.0E-03	1.2E-06	
Antimony	1.7E-05	3.6E-03	1.0E-04	4.4E-07	RAIS
Arsenic	9.8E-05	2.1E-02	5.0E-05	1.3E-06	
Lead	2.8E-04	5.9E-02	6.0E-05	4.2E-06	
Chromium (Cr VI assumed)	6.5E-05	1.4E-02	9.0E-06	1.5E-07	
Tin	8.0E-06	1.7E-03	1.0E-03	2.0E-06	RAIS
Dioxin	1.4E-10	6.3E-09	2.0E-02	2.0E-10	

Transfer factors from OEHHA 2015 unless otherwise noted

Exposure to Chemicals via Ingestion of Milk

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

Parameters Relevant to Quantification of Exposure by Adults		
Ingestion Rate of Milk (IRM) (kg/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 anywhere

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/kg wet weight)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Cadmium		8.0E-04	66%	2.7E-04	100%	8.76E-06	6.7E-08	1.6E-07	--		5.9E-04	2%
Antimony		8.6E-04	4%	8.3E-04	100%	3.13E-06	2.4E-08	5.8E-08	--		7.0E-05	0%
Arsenic		2.0E-03	55%	9.1E-04	100%	4.88E-06	3.7E-08	9.0E-08	--		1.0E-04	0%
Lead		3.5E-03	90%	3.5E-04	100%	4.89E-05	3.7E-07	9.0E-07	--		2.6E-03	9%
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04	100%	1.07E-06	8.2E-09	2.0E-08	--		3.5E-05	0%
Tin		2.0E-01		2.0E-01	100%	1.46E-05	1.1E-07	2.7E-07	--		1.4E-06	0%
Dioxin		2.3E-09	54%	1.1E-09	100%	1.44E-09	1.1E-11	2.7E-11	--		2.5E-02	88%
								TOTAL			2.9E-02	

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/kg wet weight)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Cadmium		8.0E-04	66%	2.7E-04	100%	1.2E-06	9.4E-09	2.3E-08	--		8.2E-05	2%
Antimony		8.6E-04	4%	8.3E-04	100%	4.4E-07	3.4E-09	8.1E-09	--		9.8E-06	0%
Arsenic		2.0E-03	55%	9.1E-04	100%	1.3E-06	9.6E-09	2.3E-08	--		2.6E-05	1%
Lead		3.5E-03	90%	3.5E-04	100%	4.2E-06	3.3E-08	7.9E-08	--		2.2E-04	6%
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04	100%	1.5E-07	1.1E-09	2.8E-09	--		4.9E-06	0%
Tin		2.0E-01		2.0E-01	100%	2.0E-06	1.6E-08	3.8E-08	--		1.9E-07	0%
Dioxin		2.3E-09	54%	1.1E-09	100%	2.0E-10	1.5E-12	3.7E-12	--		3.5E-03	91%
								TOTAL			3.9E-03	

Exposure to Chemicals via Ingestion of Milk

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

Parameters Relevant to Quantification of Exposure by Children		
Ingestion Rate of Milk (IRM) (kg/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 anywhere

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/kg wet weight)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Cadmium		8.0E-04	66%	2.7E-04	100%	8.76E-06	5.5E-08	6.4E-07	--		2.3E-03	2%
Antimony		8.6E-04	4%	8.3E-04	100%	3.13E-06	2.0E-08	2.3E-07	--		2.8E-04	0%
Arsenic		2.0E-03	55%	9.1E-04	100%	4.88E-06	3.1E-08	3.6E-07	--		3.9E-04	0%
Lead		3.5E-03	90%	3.5E-04	100%	4.89E-05	3.1E-07	3.6E-06	--		1.0E-02	9%
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04	100%	1.07E-06	6.7E-09	7.8E-08	--		1.4E-04	0%
Tin		2.0E-01		2.0E-01	100%	1.46E-05	9.2E-08	1.1E-06	--		5.3E-06	0%
Dioxin		2.3E-09	54%	1.1E-09	100%	1.44E-09	9.0E-12	1.1E-10	--		9.9E-02	88%
								TOTAL			1.1E-01	

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/kg wet weight)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Cadmium		8.0E-04	66%	2.7E-04	100%	1.2E-06	7.7E-09	9.0E-08	--		3.3E-04	2%
Antimony		8.6E-04	4%	8.3E-04	100%	4.4E-07	2.7E-09	3.2E-08	--		3.9E-05	0%
Arsenic		2.0E-03	55%	9.1E-04	100%	1.3E-06	7.9E-09	9.2E-08	--		1.0E-04	1%
Lead		3.5E-03	90%	3.5E-04	100%	4.2E-06	2.7E-08	3.1E-07	--		8.9E-04	6%
Chromium (Cr VI assumed)		1.0E-03	43%	5.7E-04	100%	1.5E-07	9.4E-10	1.1E-08	--		1.9E-05	0%
Tin		2.0E-01		2.0E-01	100%	2.0E-06	1.3E-08	1.5E-07	--		7.5E-07	0%
Dioxin		2.3E-09	54%	1.1E-09	100%	2.0E-10	1.3E-12	1.5E-11	--		1.4E-02	91%
								TOTAL			1.5E-02	