7 April 2016

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| **Submitted to:** |
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| Number. | 1413212-032-R-Rev0 | GA Logo Small_RGB from Phil |
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COSTERFIELD, VICTORIA

HEALTH RISK ASSESSMENT

Key Points

* This health risk assessment (HRA) confirms the key conclusion of the Rapid Health Assessment conducted in June 2014 that antimony is not likely to cause adverse health effects in Costerfield.
* This report provides results of a tank water monitoring program conducted over six months of the year both in tanks that were cleaned and those that were not. The program identified that the levels of antimony in tank water remained higher than the drinking water guideline despite tank cleaning and refilling. For this reason as previously advised in June 2014 the tank water should not be used as a drinking water source.
* This report provides an in-depth analysis of environmental data collected over an 18 month period. Of the many metals investigated three metals (antimony, arsenic and lead) were identified to be elevated above background levels in the environment and also above trigger levels for further health investigation.
* In Costerfield, antimony and arsenic levels in soil, water and air are typically elevated when compared to other parts of Victoria that have not been mined for gold. This is consistent with the natural geology of Costerfield and the mining legacy in the Costerfield Area. The current mining operations are not a major contributor to antimony, arsenic or lead in tank water, dust or soil.
* Whilst lead is also a naturally occurring metal in the Costerfield formation, the concentrations found in soil within the Dome are higher than expected if the lead was all due to the local geology, therefore it is likely that there are other anthropogenic (man made) sources of lead in the Costerfield environment. For this reason lead is different to antimony and arsenic.
* The HRA was done on a regional basis (i.e. it is not a property specific assessment). It was done in a conservative manner and according to national and international guidelines. It looked at many factors that can change exposure between different people. Two sets of estimates were made: average; and reasonable worst case. It is concluded:
  + that there is no concern for adverse health effects from average exposures to multiple metals at Costerfield (i.e. for the average person it is safe to live in Costerfield).
  + For reasonable worst case exposures (i.e. this estimate applies to a small minority of people (particularly young children) within Costerfield) the HRA found that there is some concern for adverse health effects. The main reason for the conclusion of some concern is because a small proportion of tanks and soil had lead contamination, noting that this pattern of lead contamination are typical of urban/rural Victoria. Residents with high lead contamination have been provided with soil and tank water results during the monitoring program together risk management advice.
  + For both average and reasonable worst case weekend residents there is no concern for adverse health effects. This conclusion also applies to occasional visitors (up to 104 days per year).
* The air monitoring results for dust (PM10 and PM2.5), metals, and crystalline silica found that levels are lower than health guidelines. For this reason the chemicals in dust measured in air are not harmful to health.
* The HRA considered antimony, arsenic and lead levels with respect to bathing / showering in tank water and ingestion of homegrown food (eggs and lamb). These activities were minor contributors to antimony, arsenic and lead exposure and can be continued without concern for adverse health effects.
* Dust levels in air from the current mining operations were found to be within compliance levels and national standards on practically all days. The antimony, arsenic and lead in dust levels were well below health based air guideline values. However dust from the mining operations is expected to contribute a small level (less than 15%) to soil loads over an extended period of time (10 years).

Executive Summary

Introduction

This independent report by Golder Associates Pty Ltd (Golder) commissioned by a Government of Victoria Reference Group (GVRG) details a health risk assessment (HRA) to inform the Costerfield community, Government and the current mining operations on two important questions:

* Do the environmental levels of antimony and other metals present a health risk to people living in Costerfield? This question could also be expressed as – “Is it safe to live in Costerfield?”
* What strategies can be put in place to manage environmental levels of antimony and associated metals in Costerfield? This question could also be expressed as – “What can be done to manage exposure within Costerfield?”

Additional questions that are important to the Costerfield stakeholders (community, government and mining operations) are also addressed within the body of this report.

Background

Health risk assessment (referred to as HRA in this report) is an objective, scientifically-based tool used to provide answers to the above questions. The HRA conducted in this report is consistent with Australian and International guidelines. It has been designed by experienced health risk and toxicology experts in consultation with experts within the Victorian Department of Health and Human Services and the Victorian Environment Protection Authority (EPA).

This HRA assists in the development of strategies and procedures to address health concerns for chemical exposures. However management and planning are separate pieces of work that require consideration of economic, social, and political factors, as well as technical feasibility of any proposed management strategies. This HRA informs such strategies but these strategies are not detailed in this report.

Golder conducted a rapid health assessment in June 2014 and concluded that adverse health effects were unlikely. This assessment focussed on the likelihood of adverse health effects due to antimony exposure. They were not intended to address other metals nor the details of how best to manage exposure.

The HRA was needed to answer the above questions because the field program (described below) identified that environmental levels of three metals (antimony, arsenic and lead) were elevated out of 18 metals evaluated in Costerfield. Elevated in this context means that the concentrations of these three metals were occasionally above normal background levels in the environment (soil, water and air samples) and/or they were above health based screening guidelines used to indicate the need for further investigation.

Field Program

A field program to collect data and information was undertaken over a fifteen month period (June 2014 – December 2015). The program was designed and reviewed by experienced environmental scientists and engineers, and meets guidelines and standards for the conduct of such programs. The scientific and technical details of this program are described within this HRA report. The elements of the program included:

* An air quality analysis program, including dust in homes and outdoor locations.
* A soil sampling and analysis program.
* A tank water monitoring program.
* Lamb and egg sampling program.

Field Program Findings

In Costerfield, antimony is a naturally occurring compound in soil and rock. Mining activities over the past 100 years have created tailings and leftover material such as rock, sand and earth which may contain antimony at concentrations higher than the surrounding soil and rock. A range of metals and inorganic chemicals were measured during the field program based on the natural history, mining legacy and current mining operations in Costerfield.

The field program found that antimony and arsenic in Costerfield (particularly in soil and water) are generally higher than in other parts of Australia. It also identified occasional instances where lead contamination was present. Lead contamination in soil and water is common in urban/rural Victoria. The pattern of lead concentrations in soil and tank water was not found to be unique to Costerfield.

HRA Approach

The HRA estimated risks due to individual metal exposure to antimony, arsenic and lead, and cumulative exposure (i.e. combined health risk). That is, health risks were assessed for each of the three metals, and then the combined health risk of these metals was assessed.

In this HRA the amount of chemical entering the body (the intake) is referred to as the estimated daily intake (EDI).

The EDI combines many estimates (soil, tank water concentrations) with many factors (human activities and behaviours). As a consequence it is necessary to consider a range of environmental concentrations and a range of human activities and behaviours to make the EDI representative and relevant to different people and different circumstances. This is done in a statistical manner so that the variation between estimates and uncertainties in the factors can be understood.

The first question above (“Is it safe to live in Costerfield?”) was addressed by using a range of exposure estimates that are most applicable to residents of Costerfield. The EDI estimation relies on many factors. The selection of a value for each of these factors is described in Appendix E of this HRA report. The combination of factors to calculate an EDI errs on the side of caution, yet avoids over-estimation.

The exposure estimates are not property specific and utilise the data across the Costerfield dome (i.e. it is a regional assessment).

Two estimates of the EDI have been provided:

* Average Estimate of EDI. Combining the averages in soil, tank water and air with average circumstances of exposure results in an EDI that is relevant to most people in Costerfield.
* Upper Estimate of EDI. Combining a range of upper statistical estimates for many inputs such as the soil concentration and the amount of soil ingested each day by a person results in what is known as a “reasonable worst case”. These two terms (upper and reasonable worst case) are equivalent and interchangeable. The reasonable worst case, or upper estimate is intended to exceed the EDI for most people in Costerfield. It is intended as a plausible yet unlikely estimate of upper end exposure.

Both EDI estimates have been provided as it is important to describe a range of different circumstances and also to account for uncertainties in the information available on which to make estimates.

The second question (“What can be done to manage exposure within Costerfield?”) requires a more detailed evaluation of the Upper Estimate. The upper estimates are not likely estimates of exposure but are plausible. For instance, the upper estimate assumes that a person spends two hours a day, each day of the year in a spot where the highest soil concentrations of all three metals anywhere in Costerfield co-occur. In addition, this person ingests every day of the year two litres of tank water containing one of the highest tank water results reported in Costerfield for each metal. This unlikely occurrence is included in the HRA to understand the uncertainties in the EDI.

To assist stakeholders to understand the key ways to manage exposure, the HRA contains a total of sixteen estimates of the EDI.

| Type of Resident | Resident Age Groups | Exposed Each Day Via | Use of Tank Water |
| --- | --- | --- | --- |
| **Permanent Residents**  Stays in Costerfield  365 days per year. | * Infant (1 year old) * Young child  (2 year old) * Older Child  (10 year old) * Adult | * Soil ingestion * Home-grown food (egg meat), * Breathing in dust in air * Bathing using tank water | * Use tank water as their primary drinking water source. |
| * Do not use tank water for drinking purposes (but do bathe in tank water) |
| **Weekend Residents**  Stays in Costerfield  104 days per year  (2 days per week). | * Infant  (1 year old) * Young child  (2 year old) * Older Child  (10 year old) * Adult | * Soil ingestion * Home-grown food (egg meat), * Breathing in dust in air * Bathing using tank water | * Use tank water as their primary drinking water source. |
| * Do not use tank water for drinking purposes (but do bathe in tank water) |

Once the EDI is estimated for each age group and exposure combination, it is then compared to a health benchmark called a tolerable daily intake (TDI) for each metal. The TDI is the amount of chemical that can be ingested over a lifetime without appreciable health risk. Because the TDI is a lifetime average daily intake, the estimated lifetime EDI is calculated and used for assessing health risk for a community.

The EDI is divided by the TDI. The ratio of the EDI to the TDI (this ratio is called the ‘hazard quotient’ or ‘HQ’) is then used to make decisions about the risk of adverse health effects. When the EDI is less than the TDI (i.e. a margin of less than 1) this means health risks are unlikely. When the EDI is greater than the TDI (i.e. a margin of greater than 1) then the magnitude of the margin is further considered to provide context to what that means. For example, there may be uncertainty in the EDI estimate that could be reduced with additional data. Alternatively, actions may be required to address the health risk.

To consider health risks due to the combined exposure of each metal, each of the HQs is added up. That is, the total health risk is assumed to be the sum of the health risk due to each metal. The sum of HQ’s is referred to as the hazard index (HI). This is a conservative assumption that in reality is likely to overestimate the health risk. However it is done to err on the side of caution.

Given the multiple levels of conservatism built into a HRA, there is generally a high level of confidence that risks are not under-estimated. The following key[[1]](#footnote-1) is used to interpret the HI.

Conclusions Specific to Living with Antimony and Arsenic within the Costerfield Dome

Antimony and arsenic soil concentrations are different in Costerfield than other parts of Victoria because of the geological and mining legacy in Costerfield. The results are summarised in Table ES1 using the key described above.

Table ES1 concludes that it is safe to live in Costerfield. Table ES1 is specific to mining legacy in Costerfield. That is it includes consideration of metals (antimony and arsenic) that are different to other parts of Victoria.

Table ES1 Conclusion for health risk to Costerfield Permanent Residents (Antimony and Arsenic)

| Estimate Type | **Key Assumption** | **Conclusion** |
| --- | --- | --- |
| Upper Estimate  Permanent Residents | **Use tank water** as their primary drinking water source. | Minimal Concern for adverse health effects |
| **Do not use tank water** for drinking purposes (but do bathe in tank water) | Negligible Concern for adverse health effects |
| **Average Estimate**  Permanent Residents | **Use tank water** as their primary drinking water source. | Negligible Concern for adverse health effects |
| **Do not use tank water** for drinking purposes (but do bathe in tank water) | Negligible Concern for adverse health effects |

Table ES2 provides the results for weekend residents either including or excluding tank water use. The results show a negligible concern for adverse health effects. Results for permanent residents using tank water as a drinking water source show a minimal concern for adverse health effects.

Table ES2 Conclusion for health risk to Costerfield Weekend Residents (Antimony and Arsenic)

| Estimate Type | **Key Assumption** | **Conclusion** |
| --- | --- | --- |
| Upper Estimate  Permanent Residents | **Use tank water** as their primary drinking water source. | Negligible Concern for adverse health effects |
| **Do not use tank water** for drinking purposes (but do bathe in tank water) | Negligible Concern for adverse health effects |
| **Average Estimate**  Permanent Residents | **Use tank water** as their primary drinking water source. | Negligible Concern for adverse health effects |
| **Do not use tank water** for drinking purposes (but do bathe in tank water) | Negligible Concern for adverse health effects |

Conclusions Including Lead

Occasionally in Costerfield, as is in many other parts of Victoria, high levels of lead in tank water and soil are encountered. It is most likely that these high levels are due to widespread historical anthropogenic (man made) uses of lead. Table ES3 summarises the results for permanent residents using the key described above.

Because the conclusions in Table ES3 are based on occasional circumstances of high lead concentrations in soil and tank water and these do not co-occur at the same property, these results are considered unlikely to be representative of most Costerfield residents.

However lead exposure from soil and tank water is plausible and the results in Table ES3 emphasise the need for careful management of exposure.

Table ES3: Conclusion for health risk - Costerfield Permanent Residents (Antimony, Arsenic and Lead)

| Estimate Type | Key Assumption | Conclusion |
| --- | --- | --- |
| Upper Estimate  Permanent Residents | * **Use tank water** as their primary drinking water source. | Some Concern for adverse health effects |
| * **Do not use tank water** for drinking purposes (but do bathe in tank water) | Minimal Concern for adverse health effects |
| **Average Estimate**  Permanent Residents | * **Use tank water** as their primary drinking water source. | Negligible Concern for adverse health effects |
| * **Do not use tank water** for drinking purposes (but do bathe in tank water) | Negligible Concern for adverse health effects |

Table ES4 provides the results for weekend residents either including or excluding tank water use. The results show a negligible concern for adverse health effects. Results for permanent residents using tank water as a drinking water source show a minimal concern for adverse health effects.

Table ES4: Conclusion for health risk to Costerfield Weekend Residents (Antimony, Arsenic and Lead)

| Estimate Type | Key Assumption | Conclusion |
| --- | --- | --- |
| Upper Estimate  Weekend Residents | * **Use tank water** as their primary drinking water source. | Minimal Concern for adverse health effects |
| * **Do not use tank water** for drinking purposes (but do bathe in tank water) | Negligible Concern for adverse health effects |
| **Average Estimate**  Weekend Residents | * **Use tank water** as their primary drinking water source. | Negligible Concern for adverse health effects |
| * **Do not use tank water** for drinking purposes (but do bathe in tank water) | Negligible Concern for adverse health effects |

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Important Information Relating to this Report

User Note: This Table of Contents section acts as a reference point for the Record of Issue, Executive Summary and Study Limitations sections as and when they might be required. Therefore, the structure of this section must not be altered in any way.

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**Acronyms and Abbreviations**

| ADI | Acceptable Daily Intake |
| --- | --- |
| AGV | Air Guideline Value |
| As | Arsenic |
| ADWG | Australian Drinking Water Guideline |
| BMD | Benchmark Dose |
| BMDL | Benchmark Dose upper confidence limit |
| Cd | Cadmium |
| CSM | Conceptual site model |
| CoC | Chain of Custody |
| COI | Chemicals of Interest |
| COPC | Chemicals of Potential Concern |
| Cu | Copper |
| DEDJTR | Victorian Department of Economic Development, Jobs, Transport and Resources |
| DEPI | Former Victorian Department of Environment and Primary Industries |
| DHHS | Victorian Department of Health & Human Services |
| DQIs | Data Quality Indicators |
| DQOS | Data Quality Objectives |
| EDI | Estimated Daily Intake |
| EPA | Environment Protection Authority Victoria |
| Fe | Iron |
| FSANZ | Food Standards Australia and New Zealand |
| Hg | Mercury |
| HI | Hazard Index |
| HQ | Hazard Quotient |
| HRA | Health Risk Assessment |
| IARC | International Agency for Research on Cancer |
| JECFA | Joint FAO/WHO Expert Committee on Food Additives |
| LOAEL | Low Observed Adverse Effect Level |
| LOR | Limit of Reporting |
| Mining PEM | Mining and Extractive Industries Protocol for Environmental Management |
| Mn | Manganese |
| N/A | Not applicable |
| NATA | National Association of Testing Authority |
| NEPC | National Environment Protection Council |
| NEPM (2013) | National Environment Protection (Assessment of Site Contamination) Measure 1999, as amended 2013 |
| NEPM (AAQ) | National Environment Protection (Ambient Air Quality) Measure 2003 |
| NHMRC | National Health and Medical Research Council |
| Ni | Nickel |
| NMI | National Measurement Institute |
| NOAEL | No Observed Adverse Effect Level |
| NOEL | No Observed Effect Level |
| NTP | National Toxicology Program (U.S.) |
| Pb | Lead |
| PCR | Primary Contact Recreation |
| PM2.5 | Particulate Matter less than 2.5µm in size |
| PM10 | Particulate Matter less than 10µm in size |
| RPD | Relative Percentage Difference |
| SEPP | State Environment Protection Policy |
| SEPP (AQM) | SEPP (Air Quality Management) |
| Sb | Antimony |
| TDI | Tolerable Daily Intake |
| TRV | Toxicity Reference Value (TDI is an equivalent term) |
| UF | Uncertainty Factor |
| US EPA | United States Environment Protection Authority |
| WHO | World Health Organization |
| Zn | Zinc |

# Introduction

## Background

Golder Associates Pty Ltd (Golder) was engaged as an independent expert by the Victorian Department of Economic Development, Jobs, Transport and Resources (DEDJTR) and Department of Health & Human Services (DHHS) to undertake a Health Risk Assessment (HRA) at Costerfield, Victoria, Australia.

Golder was engaged to undertake environmental monitoring at Costerfield, and an assessment of human health risks.

The assessment was undertaken over three stages:

* Rapid Health Assessment, June 2014. This work involved ambient air monitoring, and soil and tank water sampling. The rapid health assessment is discussed further in Section 1.5.1.
* Further site assessment to support the HRA, September 2014 to September 2015. This work involved stock sampling (lamb and eggs), air modelling, desktop study, tank water and soil sampling and ambient air monitoring.
* HRA, as documented in this report.

## Issue Identification

In early 2014, the Costerfield community voiced concern with the former Department of State Development, Business and Innovation (DSDBI)[[2]](#footnote-2) that the mining operations in the Costerfield area may be a source of elevated antimony detected in biological samples collected from a local resident, and water samples collected from local water tanks and nearby Tin Pot creek.

## Project Location

Costerfield is located in rural Victoria, approximately 100 km north-west of Melbourne and 50 km south- east of Bendigo. The largest township within close proximity of Costerfield is Heathcote. The population of the Heathcote District (including the Costerfield area), during 2011, was less than 4000 residents.

The desktop review considered a study area including the broader Costerfield area with particular focus on geological conditions and related mining activities. For the purposes of the HRA, the study area is considered to be the area within the Costerfield Dome, as shown in Figure 1.

Further details on the historical and current mining activities are presented in the Desktop Review (Golder 2015, Appendix A).

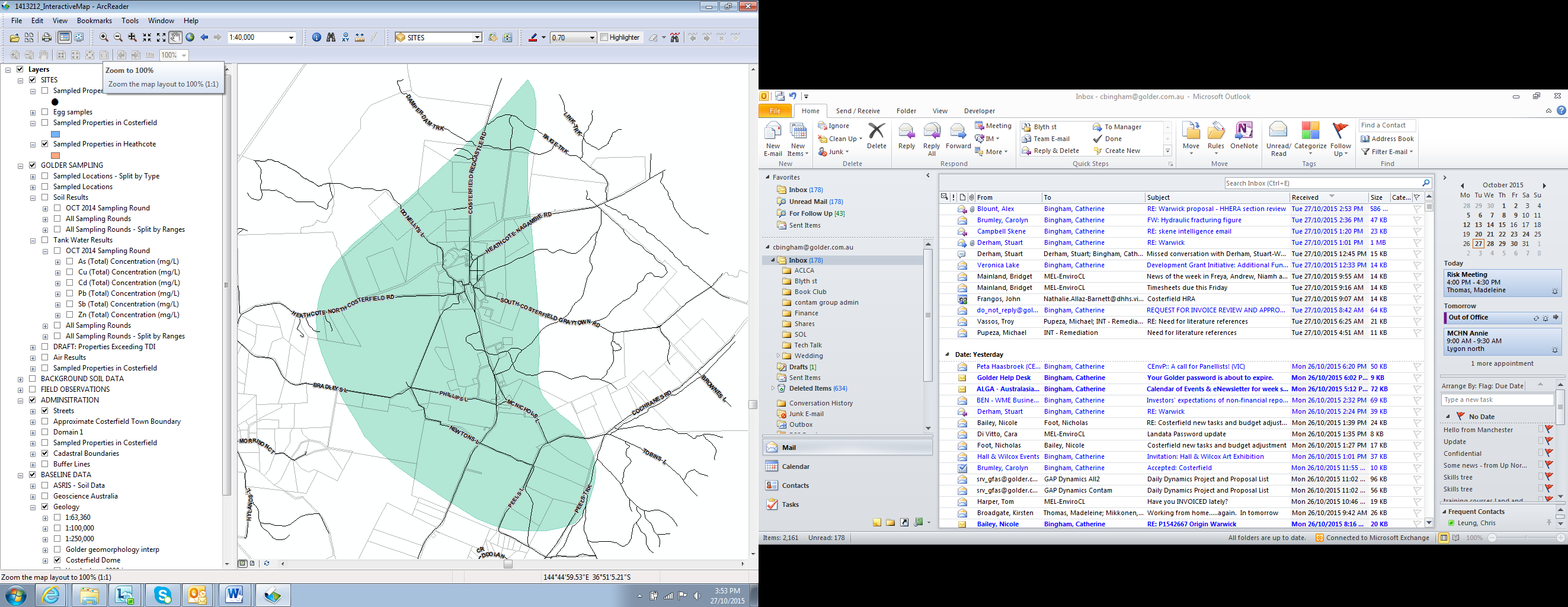


Figure 1: Costerfield Township, showing Costerfield Dome (HRA Study Area)

## Structure of the HRA Report

This HRA is a technical report. However to make the report more accessible to all stakeholders it is reported at three layers of detail:

* Overall Summary. A summary of key outcomes of the HRA are provided in the Sections titled “Key Points” and “Executive Summary”.
* Body of report. The body of this report provides more detail on the environmental assessments at Costerfield than that provided in the Key Points and Executive Summary. To make the report more readable and user friendly, detailed technical discussions supporting a particular aspect of the assessment or presentation of scientific information have been confined to Appendix A to I to this report.
* Appendices A to I in this HRA report. The appendices detail the technical HRA undertaken. The appendices are reported in a scientific manner to allow accurate description of a large collection of data. They transparently describe the objective manner in which the assessment is undertaken. Equations and factors used in equations are provided, as well as the results of the HRA. The content of the technical HRA (Appendices) is outlined in Table 1.

Table 1: Technical HRA - Report Structure

| Appendix | Title | Content |
| --- | --- | --- |
| A | Desktop Review - Antimony in the Costerfield Area | A copy of the Golder (2015) background report on the nature, transport and distribution of antimony in the environment, for the Costerfield area, Victoria. |
| B | Risk Assessment Methodology | An outline of the HRA approach, and summary of the document structure. |
| C | Problem Formulation | This is the first part of the issue identification stage. Includes the development of the Conceptual Site Model (CSM) to describe the sources, receptors and pathway(s) by which stressors (e.g., chemicals) can move from the source to the receptor, and identifies the complete pathways that have been assessed in further stages of the HRA. |
| D | Environmental Data Review & Selection of COPC | This is the second part of the issue identification stage and is often referred to as a Tier 1 risk assessment. The available environmental data is reviewed and screened against published environmental guidelines (relevant to the pathways and receptors to be assessed) to select the chemicals of potential concern (COPC) that have been assessed in further stages of the HRA. |
| E | Exposure Assessment | An outline of the equations and exposure parameters used to calculate the estimated daily intakes of the COPC for children and adults in Costerfield. |
| F | Toxicity Assessment and Interaction Profile | This appendix presents a review of toxicity information and an interaction profile for the COPC. This section is referred to as the ‘hazard assessment’ in the Australian Risk Assessment Framework. |
| G | Risk Characterisation | Details of the model used to calculate the estimated daily intakes and the hazard quotients, and a summary of the results. |
| H | Variability Assessment | An analysis of the uncertainties and sensitivities in the risk characterisation results. |
| I | Sources of Metals in the Environment | A review of various data sets to assist in understanding the key sources of the metals modelled in the HRA. |

## Previous Reports Relevant to the HRA

### Golder Rapid Assessment

The Golder rapid assessment was based on data collected in a two week period during June 2014. Samples were collected from shallow soils and tank water. Ambient air monitoring was undertaken from one measuring station. The results of the rapid risk assessment were reported in *Rapid Health Assessment and Preliminary Report on Monitoring Program Based on Information and Data Available to 15 June 2014* (Golder 2014).

The key findings of the rapid assessment were as follows:

* Regional soil antimony levels are naturally elevated. This is the reason antimony is mined in Costerfield. The rapid assessment did not attribute antimony concentrations in urine, soil, water or any other media to any source natural, historical or current.
* Antimony was the key metal measured above guideline levels.  At 33 of 34 residential properties, antimony concentrations in tank water were greater than the Australian Drinking Water Guideline. For soil, 13 of 34 residential properties reported an exceedance of the provisional antimony investigation level.
* The preliminary air monitoring results indicated low particulate levels (PM10 and PM2.5).  Antimony was measured within these particulates with a maximum ambient air concentration of 0.011 µg/m3 [[3]](#footnote-3).

Using conservative assumptions the rapid assessment found that for both adults and children adverse health effects were unlikely. The assessment did conclude that further investigations and a comprehensive risk assessment were warranted to inform ways to reduce antimony exposures to residents.

The rapid assessment found that, although most residences within Costerfield are likely to have low exposures, there are a small number of residences that if children were present every day there would be a need to reduce exposure levels. The rapid assessment recommended implementation of precautionary mitigation measures in the interim between the rapid assessment and completion of the HRA. The following measures were recommended to reduce exposure:

* Using drinking water that complies with the drinking water standard
* Reducing indoor dust
* Reducing soil exposures (e.g. replace soil in play areas and garden beds).

The rapid health assessment fulfilled the purpose of addressing the immediate health concerns of the Costerfield community. The outcomes and recommendation of the rapid health assessment are essentially superseded by the results of the HRA.

# Why is a HRA Needed for Costerfield ?

Monash University (Monash 2014) conducted an independent assessment of urinary antimony levels reported to the Victorian Department of Health from Costerfield and other parts of Victoria. Monash state “*The creatinine-corrected values from Costerfield from 1 to >35 nmole Sb/mmole cr were substantially higher than most reference values in unexposed populations from the literature (generally < 1 nmole Sb/mmole cr)*”. The Monash University (2014) report also states that the high levels may be due to antimony contamination from the urinary collection/storage in PET bottles or tubes. It is Golder’s understanding that a subsequent investigation of the collection and storage procedures identified that collection/storage bottles and tubes contained antimony and some of this was leachable into urine.

Monash University (2014)[[4]](#footnote-4) commented that the following general exposure pathways were relevant for Costerfield residents:

* Ingestion of contaminated food and water. This is the pathway that generally accounts for most of the exposure in non-occupationally exposed groups.
* Direct ingestion of soil. This pathway is not normally a significant source for adults, although there can be some hand-to-mouth and food preparation transfer from household dusts. Direct ingestion of soil and dusts by hand-to-mouth transfer can be a more significant exposure source in children (enHealth 2012 a, b).
* Inhalation of dusts, including those of local geochemical origin from soils in the region and possibly from dusts drifting across from mine operations.
* Contamination of drinking water, sourced mainly from rainwater tanks collecting water from contaminated surfaces on individual properties.

Subsequent public meetings and consultation[[5]](#footnote-5) with the community indicated that there was also a concern about health effects resulting from not only antimony but other metals that might interact with antimony to cause adverse health effects. In particular the community were concerned about interactions between antimony and arsenic.

Golder was commissioned to prepare a desktop review with the objective of providing information to support the understanding of the nature, transport and distribution of antimony and related chemicals in the Costerfield area. This review was necessary to understand the source contributions of antimony and related metals in Costerfield. The main source of antimony in the Costerfield area is mineralised zones of sulphide minerals such as stibnite and adjacent altered host rocks of the Costerfield Formation. Historical mining activities have resulted in the relocation (and in some cases) concentration of antimony in the Costerfield environment. Distinguishing the natural, historical and current mining operations is difficult, but is important for the stakeholders. The desktop review[[6]](#footnote-6) is provided as Appendix A of this report.

Minister D’Ambrosio, the Minister for Industry, and Minister for Energy and Resources, engaged RM Consulting Group (RMCG) to consult with the Costerfield community to seek a greater understanding of community concerns and advise on appropriate responses to those concerns (RMCG 2015)[[7]](#footnote-7).

The Costerfield Community identified potential health concerns associated with current mining operations. In particular the Community identified that dust from a mobile crusher installed at the Brunswick Processing Plant, had increased volumes of dust production (RMCG 2015).

Given that HRA helps answer common questions for people who might be exposed to chemicals in the environment, it is a suitable tool to assist addressing community concerns, assessing the current mining operations contribution and providing clarity on the uncertainties in interpreting the significance of exposure to antimony and other mining related metals in Costerfield.

# What is a Health risk assessment (hra)

HRA helps to answer common questions for people who might be exposed to chemicals in the environment, in this case antimony and other metals that are found at relatively high concentrations in the Costerfield area. This HRA is used to answer questions such as:

* Under what circumstances might I and my family and neighbours be exposed to antimony and other metals?
* Is it possible we might be exposed to antimony and other metals at levels higher than those determined to be safe?
* If the levels of antimony and other metals are higher than regulatory standards, what are the health effects that might occur?
* What can be done to reduce exposure to antimony and other metals?

A conceptual site model (CSM) describes three elements: sources, receptors and pathway(s) by which stressors (e.g., chemicals) can move from the source to the receptor. These three elements need to be integrated to characterise the risk, as described in Figure 2. This figure illustrates that unless there is a pathway from the chemical source to the receptor, a risk cannot occur.

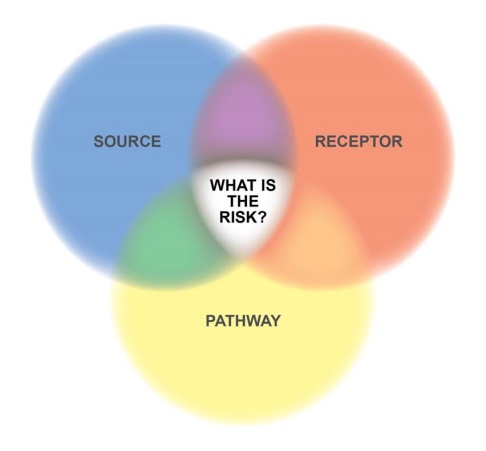


Figure 2: Risk Assessment Fundamentals

The CSM for the Costerfield HRA is presented in Appendix C. This CSM considers the potential sources of antimony and associated metals in the environment and the pathways of exposure for the residents of Costerfield.

The fundamental concept of risk assessment is that there should be an exposure pathway linking the source of contamination and the exposed population. Where this linkage exists, an assessment of the nature and significance of the exposure pathway is required to assess the level of risk (NEPC 2013). The pathways of exposure potentially relevant to the residents of Costerfield are as follows:

* Soil – incidental ingestion during outside activities (e.g. gardening, children playing)
* Soil – dermal contact during outside activities (e.g. gardening, children playing)
* Dust – inhalation outdoors and indoors
* Water – ingestion via drinking tank water or bottled water
* Water – dermal contact and ingestion whilst showering or bathing in tank water
* Water – dermal contact and ingestion whilst swimming in local dams or swimming pools
* Locally grown foods – ingestion of locally grown produce

The above exposure pathways are all complete linkages and relevant to the study area.

All of the above exposure pathways with the exception of swimming in local dams or swimming pools have been modelled in the HRA. The exposure risks due to dermal contact and ingestion of water whilst swimming in local dams or swimming pools has not been included in the modelling as there is insufficient information regarding the concentrations of COPC in dams or swimming pools to support the calculation of an estimated daily intake (EDI) from this pathway.

The objective of the overall program was to develop a HRA for the metals of interest to:

* Provide an understanding of the potential level of risk to human health in the area
* Establish how much of the risk to human health is contributed to mine activities.

# What are chemicals of interest?

A chemical of interest (CoI) is defined in this report as a chemical that is related to:

* Geology of Costerfield. The Costerfield township is located within the Costerfield Dome (a geological term) which is at or close to the surface approximately 1 km west of the Costerfield Township. This dome includes zones of mineral enrichment (enriched with metals including gold, antimony and arsenic) that are relatively unique in Australia.
* Historical mining in Costerfield. Historic mining occurred by both open cut and underground mining and was most productive during two periods, 1860 to 1883 and 1904 to 1925, with only intermittent small scale production during 1934 to 1950. During 1995, a processing plant was constructed for the re-treatment of tailings and the oxide portion of the mine wastes at the Brunswick open pit mine (Mandalay Resources, 2012). These activities redistributed mineral content within the Dome and also introduced additional processing chemicals.
* Current mining in Costerfield. The Brunswick Processing Plant comprises a two-stage crushing process, two milling stages in series, with closed circuit classification and gravity concentration. The flotation circuit produces antimony-gold flotation concentrate (SKR Consulting, 2013). The flotation tailings are sent to an onsite tailings storage facility. Flotation processes typically use chemical conditioning agents and intense agitation and/or sparging of the crushed ore slurry to produce mineral rich foam concentrate.
* A component of construction materials that are commonly used in construction of water tanks and/or house roofs.

Golder (2015) undertook a Desktop Review of the history of the Costerfield township (Appendix A). This review considered the geological setting of the area and the current/ historical mine activities which have occurred, or are occurring, in the Costerfield area. It concluded that antimony and to a lesser extent arsenic are the two metals present in the environment that are related to the geology, historical and current mining operations.

One of the objectives of the Desktop Review was to produce a target list of chemicals to inform the analytical schedule for the environmental sampling. To generate the target list a number of data sets were evaluated and assessed. These included:

* Desktop review of mining processes.
* Department of Primary Industries (DPI) dataset of geochemical results across central Victoria,containing 73,812 samples that were tested for the following metals: gold (Au), silver (Ag), arsenic (As), antimony (Sb), mercury (Hg), tungsten (W), aluminium (Al), calcium (Ca), iron (Fe), manganese (Mn) and lead (Pb).
* Mandalay ore data from August 2014, containing 20 samples (10 ore samples and 10 low grade samples) analysed for the following metals gold (Au), silver (Ag), aluminium (Al), arsenic (As), boron (B), barium (Ba), beryllium (Be), bismuth (Bi), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), potassium (K), magnesium (Mg), manganese (Mn), molybdenum (Mo), sodium (Na), nickel (Ni), phosphorus (P), lead (Pb), sulfur (S), antimony (Sb), selenium (Se), tin (Sn), strontium (Sr), titanium (Ti).

This information was used together with initial field sample results to consider which chemicals should be included in the field program.

The process of selecting CoI considered a number of factors including:

* Is the chemical a natural constituent of the body, in its mineral form, is it a hazardous chemical?
* Are the levels of the chemical above levels normally found in soil or water?
* Are the levels of minerals in the ore below health screening values?

Using a prioritistation screening process (reported in Appendix A) the list of CoI was determined. In all, more than 18 chemicals were assessed for whether they met the criteria as CoI. Chemicals were “screened in” if they were:

* Present in the ore above normal soil concentrations; and/or
* Found in tank water and/or roof construction materials; and/or
* Related to historical mining processes; and/or
* A marker of soil quality (geochemistry).

This process of screening chemicals in and out of a risk assessment is a standard process defined within international and national HRA methodology.

The reason for screening chemicals out is that these are unlikely to contribute to health risk (individually) and are unlikely to contribute or interact with other chemicals.

The COI informed the analytical schedule for the environmental data collected during the data collection phase of the project (June 2014 to September 2015).

Table 2 provides a summary of the COI, the reason for selection and the analytical schedule. Analysis undertaken during the environmental monitoring program in 2014-2015 assessed these COI.

Table 2: COI Identified for Next Phase of Works

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Chemical of Interest | | Reason for selection | Recommended Analytical Schedule | | | | | |
| Soil | Water | Sediment | Air | Eggs | Lamb |
| 1 | Antimony | Present in ore above normal soil levels |  |  |  |  |  |  |
| 2 | Arsenic | Present in ore above normal soil levels |  |  |  |  |  |  |
| 4 | Copper | Found in tank and roof construction materials |  |  |  |  |  |  |
| 5 | Cyanide1 | Historical mining process chemical |  |  |  |  |  |  |
| 6 | Iron | Soil quality (geochemistry) marker |  |  |  |  |  |  |
| 7 | Lead | Found in tank and roof construction materials |  |  |  |  |  |  |
| 8 | Manganese | Soil quality (geochemistry) marker |  |  |  |  |  |  |
| 9 | Mercury | Historical mining processes |  |  |  |  |  |  |
| 10 | Zinc | Found in tank and roof construction materials |  |  |  |  |  |  |
| 11 | Cadmium | Found in tank and roof construction materials |  |  |  |  |  |  |
| 12 | Nickel | Found in tank and roof construction materials |  |  |  |  |  |  |

✓- recommended for analysis 🗶 - not recommended for analysis

1 Cyanide is recommended for analysis in soils only as it is considered unlikely to be present in other matrices based on historical use and low potential for bioaccumulation.

# chemicals of potential concern (COPC)

## Selection of COPC and their toxicity values

The 12 COI (plus an additional 6 for some samples) were reported within the environmental data collected from June 2014 to September 2015. Three COPC were subsequently selected for consideration in the HRA.

The process of selecting COPC begins with the review of the environmental data set collected during the 18 month field program, including soil, tank water, and outdoor air dust data. This was followed by a screening process that considered the individual contaminant toxicity, the prevalence of a chemical within and across media (soil, water, air), and the likelihood that a detected chemical was related to the identified issues at Costerfield. The goal of the process was to identify those chemicals that people could be exposed to at levels of health concern.

Chemical concentrations in each of the environmental media identified in the CSM are discussed in the following appendices:

* D1 – Soil
* D2 – Water
* D3 – Air
* D4 – Food
* D5 – Surface Dust.

The process for selecting COPC is described in Appendix D. Antimony, arsenic and lead were selected as COPC based on review of all results for metals in soil, tank water, metals in PM10 (dust in air), eggs, sheep and other information evaluated. Appendix I provides additional information about the sources of these COPCs.

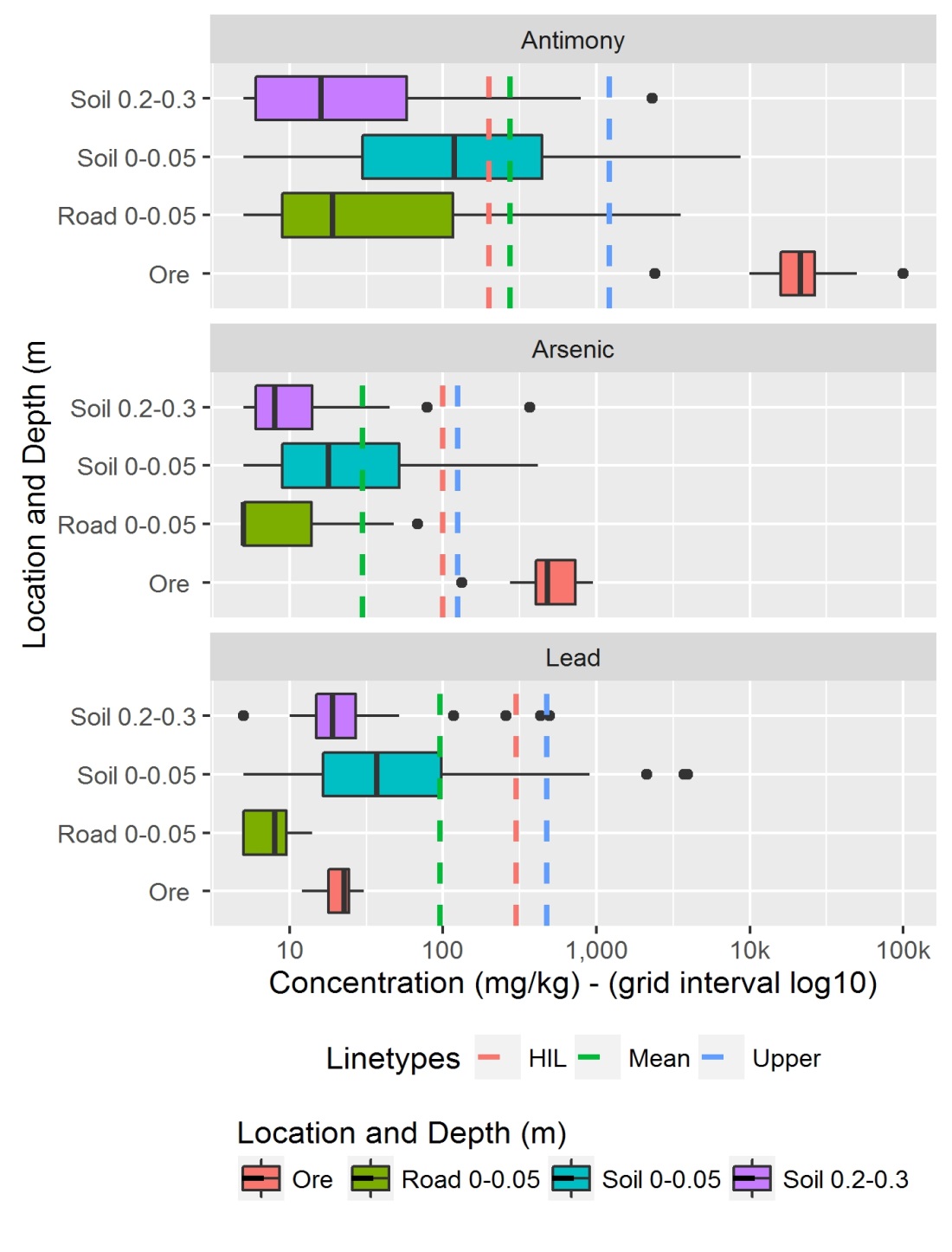
The following COPC (chemicals that people are most likely exposed to at levels of health concern) were identified:

* Antimony. Antimony was found to exceed the health based criterion for soil of 200 mg/kg in 63 of 248 soil sample results. In tank water it exceeds the drinking water guideline in almost all samples within the Costerfield.  
    
  The World Health Organisation in 2003 (WHO 2003) reviewed the toxicology of antimony and its compounds. The WHO determined that the level where no adverse effects was observed was 6,000 micrograms per kilogram body-weight per day. At higher doses (45,000 micrograms per kilogram body-weight) marked, but reversible, loss of body-weight gain occurred, together with slight changes to liver and spleen, probably related and in conjunction with distinctly reduced food and water intake at this dose. The WHO applied a safety factor of 1000 fold to derive a tolerable daily intake (TDI[[8]](#footnote-8)) of 6 micrograms per kilogram body-weight per day. The use of the TDI in assessing health risk is discussed in Section 7.0 and Appendix G.
* Arsenic. Arsenic was found to exceed the health based screening criterion for soil of 100 mg/kg in only a small proportion (20 of 248) soil sample results. In all tank water samples tested, arsenic was below the Australian Drinking Water Guideline (both total and filtered).  
    
  The Australian Pesticides and Veterinary Medicines Authority (APVMA, 2005) conducted a toxicity review of arsenic and concluded that arsenic appears to behave like a carcinogen which exhibits a threshold effect. Based on the assessment that a threshold dose-response approach for the assessment of carcinogen effects associated with arsenic exposure is considered appropriate, the National Environment Protection Council (NEPC 2013) adopted a TDI of 2 µg/kg/day. The TDI is a lifetime average daily dose that is protective of both non cancer and cancer effects due to arsenic exposure.
* Lead. Only 8% of lead soil sample results contained lead at concentrations above the health based screening criterion of 300 mg/kg. Only 5% of tank water samples were above the Australian Drinking Water Guideline. Appendix I provides a detailed analysis of whether these occasional exceedances are related to the geology or mining legacy of Costerfield. It was concluded that the elevated lead concentrations in soil and water are likely due to a mixture of sources, with the highest concentrations due to anthropogenic (man made) sources of lead contamination some of which are common to all urban areas (lead in fuel, paint and other industrial products). This conclusion was based on very specific testing called isotope analysis (reported in Appendix D6) and a comparison of soil and tank water results from other parts of Victoria and Australia (Appendix I). It is not possible to distinguish between the man made sources of lead based upon the available data.  
    
  In May 2015 the National Health and Medical Research Council (NHMRC 2015) produced a statement titled *Evidence on the Effects of Lead on Human Health[[9]](#footnote-9)* The Statement concludes that the “*health effects of lead found an association between blood lead levels less than 10 micrograms per decilitre and health effects, including reduced Intelligence Quotient and academic achievement in children, behavioural problems in children, increased blood pressure in adults and a delay in sexual maturation in adolescent boys and girls”*. It recommends that *“if a person has a blood lead level greater than 5 micrograms per decilitre, the source of exposure should be investigated and reduced*.”   
    
  The toxicity benchmark for lead (equivalent to a TDI) used in this HRA has been derived by the World Health Organization as a level that will not result in any detectable level of adverse health effects in children (0.6 µg/kg body weight/day) or in adults (1.3 µg/kg body weight/day). Exposure at or around this toxicity value would result in blood lead levels of less than 3 micrograms per decilitre and it is therefore consistent with the NHMRC statement. The use of this approach is highly conservative and is based on the latest research on the health effects of lead. Additional technical details are provided in Appendix F.

Figure 3 provides a consolidated summary of the soil data for the COPC. The boxes in the figures show the most frequent soil concentrations for each COPC. The figure is a statistical description of the soil data. The technical detail of this figure is provided in Appendix I. The figure shows:

* The concentrations of lead, antimony and arsenic selected to represent an average exposure in Costerfield are higher than most of the soil results in Costerfield for all three metals. This is particularly true for lead. The average value used in the HRA calculations is higher than 80% of the soil values in Costerfield.
* The concentrations selected to represent the upper exposure of lead, antimony and arsenic in Costerfield is one of the highest results in the entire dataset. This demonstrates that the “upper estimate” is an appropriate value to describe a reasonable maximum exposure scenario (refer to Section 6 and Appendix E).
* Antimony and arsenic levels in the Mandalay Ore are much higher than those in Costerfield soil. However the lead concentrations in ore are less than most values in soil. An examination of why this is so is provided in Appendix I, indicates that the occassional high lead values in soil are not unique to Costerfield and most likely represent common environmental sources of lead contamination.

The HRA assumes that a person (1 year old, 2 year old, 10 year old, adult) plays/works outdoors at a location where the soil concentration for each of the COPC is present for two hours per day each day of the year. As can be seen from the Figure this is unlikely at any individual properties in Costerfield.



Soil Value used in the “Upper Estimate” of exposure is the third highest value found in Costerfield HRA

Soil value used in the ‘average’ estimate of exposure is greater than 80% of the soil values for antimony

Soil lead is higher than ore lead. High results in soil are occasional.

Figure 3: Statistical Summary of Soil COPC Values.

Description of soil values used in the HRA (green and blue dotted lines). Comparison between surface soil values (light blue and purple boxes) and ore concentration (red boxes) for each COPC. The black dots are outliers (i.e. the highest concentrations in soil for each metal).

## Sources of COCP in Costerfield

To assist in understanding the potential exposure of residents in Costerfield to the COCP, a review of the environmental data, available historical information (Appendix A) and published data on these chemicals in the Australian environment (where available has been considered.

### Antimony and Arsenic

Review for the environmental data for soil and water in Costerfield indicate that the concentrations are different in Costerfield compared to other parts of Victoria because of the geological and mining legacy in the area. The results (refer Appendix I) suggest that the elevated levels of antimony and arsenic are positively correlated as these metals are found co-located naturally in the Costerfield geology. Antimony and arsenic are known components of the local geology; specifically the mineralised zones of sulphide minerals such as stibnite and adjacent altered host rocks of the Costerfield Formation. The extensive distribution of mine wastes (particularly tailings) within Costerfield is likely to be a significant source of antimony and associated arsenic in the environment. This is supported by the soil data which indicates that the antimony and arsenic concentrations are closely correlated in the Dome, and their presence is consistent with the geology of the area.

In summary, the analysis of the data in Appendix I found that the soil concentrations of antimony and arsenic are naturally occurring in the geology of the Costerfield Dome, with an increase in the soil concentration of up to 15% due to current mining related dust contributions.

Farming and residential development within the Costerfield area is unlikely to have significantly contributed to the antimony load within the local environment.

### Lead

Throughout the HRA report and its appendices there is information on lead. This section consolidates the information on lead to assist the reader to contextualise the conclusions around lead in Costerfield.

Occasionally in Costerfield, as is in many other parts of Victoria, high levels of lead in tank water and soil are encountered. It is most likely that these high levels are due to widespread historical anthropogenic (man made) uses of lead rather than the geological features that make Costerfield different to other regions.

The reason for this conclusions are based on multiple lines of evidence. These include:

1. **Lead in Costerfield tank water is typical of lead in other parts of Australia (Appendix D2)**

* Lead is a common metal found in in tank water due to roofing, guttering and pipework materials (CSIRO 2008; enHealth 2010; Andra et al. 2014).
* Five percent of tank water samples from Costerfield were above the Australian Drinking Water Guideline (ADWG). This is within what is expected based on Australian surveys of lead in rainwater tanks.
* The lead in Costerfield tank water was mostly identified in the unfiltered samples. Most but not all filtered samples did not exceed the ADWG. This indicates that the lead is mainly insoluble and particulate bound. This is a consistent pattern with literature in other parts of Australia.
* Chapman et al (2006) conducted a national survey of rainwater tank water quality. This included 38 tanks from Adelaide, Brisbane, Canberra, Broken Hill, Melbourne, Sydney and Wolllongong. The survey concluded that the main health concern with use of tank water as a potable water supply is lead. Lead was detected in 79% of tanks, with 9% of tanks having levels equal to or exceeding the ADWG. The high lead values originated from a variety of tanks in practically all the towns/cities tested indicating that the contamination is common and widespread.
* Magyar et al (2008) conducted a survey of 55 rain water tanks and concluded that lead concentrations were elevated in approximately 33% of the tank water at up to 35 times the ADWG.

1. **Lead present in Costerfield Dust in Air (Ambient lead in PM10 Appendix D3) is within levels measured in urban areas.**

* The annual average lead concentrations in Costerfield are 350 times less than the national annual standard of 0.5 micrograms per cubic metre of air (µg/m3).   
    
  Appendix D3 Table 8 and Table 10 provide the lead in PM10 results for the two monitoring locations in Costerfield. The lead concentrations in air range between less than detection (< 0.0004) to 0.011 µg/m3. The annual average lead in air concentration was 0.0011 µg/m3 and 0.0014 µg/m3 at residence 1 and 2 respectively.
* The maximum concentration in Costerfield (0.011 µg/m3) is less than levels measured in metropolitan Melbourne (0.02 µg/m3)[[10]](#footnote-10) and within levels measured in urban (cities and towns) areas of NSW (0.002 – 0.099 µg/m3) [[11]](#footnote-11)

1. **A statistical analysis of lead in soil found that the distribution of high lead concentrations is not correlated to the geology of Costerfield suggesting an alternative source of lead in these elevated results.**

* Appendix I Figure 3 provides a detailed analysis of whether the elevated concentrations of lead are related to the geology of Costerfield. Where there are high concentrations of lead, the corresponding antimony concentrations are not significantly higher than other samples. This suggests that at the lower concentrations, the presence of the two metals is correlated, as would be expected within Costerfield, as lead is present in the ore, however at higher concentrations there may be an alternative source of lead in the environment.
* The concentrations of lead within Costerfield appear to follow a similar distribution to the other data gathered in Victoria. Olszowy et al (1995) for a Victorian old suburb with low traffic volume. This suggests that the lead in the Costerfield environment is similar to that of an established urban environment with low impact from vehicle traffic.

1. **Lead Isotope analysis found that the soil samples tested are unlikely to be of the same geological origin as the Costerfield ore. This suggestion alternative sources of lead in these samples.**

* Appendix D6 Section 4 details lead isotope testing conducted by the University of Melbourne School of Earth Sciences. The isotope testing was conducted on four Costerfield soil samples. The soil samples were selected based on total lead results (all four contain elevated lead concentrations).   
    
  The results suggest that the lead in soil is most likely a mixture of anthropogenic sources and unlikely to be solely from the Costerfield ore. The isotope analysis does not allow additional characterisation of the anthropogenic source (i.e. it is not possible to distinguish between common sources of lead and lead nitrate used in mining).

### Mining in Costerfield and Lead

Appendix I Section provides a summary of lead use in both historical and current mining operations.

The lifecycle of lead in current operations can be described as:

* **The ore** mined is mostly made up of stibnite Sb2S3 but also contains some bournonite, a lead antimony sulphide PbCuSbS3 and other lead sulphides which make up the lead content. The concentrations of lead in the ore (12 to 31 mg/kg) are presented in Appendix I Table 1.
* Lead nitrate (a soluble man made compound of lead) is used in current **mining processing** as an activator for stibnite (Sb2S3) in antimony ores. In the current process lead nitrate is added during the flotation process to produce the mineral concentrate. It is added within a managed aqueous system. As such it is not expected to enter the environment as dust or be emitted to the environment with waste rock (note this expectation is consistent with the results of tank water testing and ambient air monitoring).   
    
  With respect to lead, current reagent consumption rates for lead nitrate is 400 g per one dry metric tonne of processed ore (Mandalay 26/02/16). Lead nitrate (Pb(NO3)2)is added in liquid solution into the slurry (ore rock mixed with water) during the processing of ore to aid recovery of metals. The process occurs in a liquefied form and no dust is generated. This is equivalent to a concentration of 400 mg/kg, which remains mainly in the flotation circuit although some could be expected to be in the processed ore (concentrate) and tailings.
* A limited environmental assessment of Mandalay’s processes (undertaken by Snowden, 2012) reported that potential contaminants to the environment associated with the Costerfield mines may include antimony (from stibnite), arsenic from (arsenopyrite), cyanide (from historical processing) as well as lead (lead nitrate), caustic soda, acids and other flotation reagents used in the gold extraction process (Snowden, 2012).
* Data on the composition of the concentrate and tailings is limited. Mandalay Resources proved two sets of data, one is as referred to in Appendix D5 (Mandalay 07/07/15 email re:‘Concentrate’ Place:Frangos) and more recent information provided in February 2016 (Mandalay 26/02/16 email re:‘Concentrate data - lead analysis’ Brauns:Foot).
* In **the Concentrate**, Mandalay (26/02/16) report that the lead concentration ranges from 1100 mg/kg to 2000 mg/kg (results taken from 6 of the last 8 shipments to China), due to the concentration of antimony minerals including bournonite which contains naturally occurring lead. The concentrate is thickened and pressed into polypropylene concentrate bags and sealed in sea containers for shipping to China. Mandalay advise that the concentrate has an average moisture content of 14% (2015 average moisture content) and no dust is generated during packing and shipment.
* **In the tailings**, Mandalay report that the lead concentration is 224 mg/kg due to the addition of the lead nitrate in processing. Mandalay advise that the liquid tailings are pumped by closed pipeline to the Brunswick tailings storage facility where solids settle out and sink below the water level (Mandalay 26/02/16).
* It was also suspected in 2014 before the field works began that **historical waste materials** may have been used to pave roads in Costerfield. Road samples were taken during the field investigations. The surface road sample lead concentrations were found to be within soil background levels (i.e. approximately 1-30 mg/kg).   
    
  Air emission sources were examined during the development of a dust deposition model (Appendix D3). The main source of dust generation in current mining operations is truck movement. The road lead results are consistent with ambient air monitoring indicating low lead in airborne dust.

Appendix A and Appendix I Section 2.1 provides a summary of the **historical mining activities**.

* Historic mining occurred by both open cut and underground mining and was most productive during two periods, 1860 to 1883 and 1904 to 1925, with only intermittent small scale production during 1934 to 1950.
* It was not possible to document the extent of lead nitrate use historically.
* Appendix A notes that there is a potential for lead to be present in historic mining waste areas however targeted sampling of the waste areas has not be conducted.

It is most likely that these occasional high levels of lead in soil and tank water are due to widespread historical anthropogenic (man made) uses of lead rather than the geological features that make Costerfield different to other regions.

Based on the above lines of evidence it can be concluded that the elevated lead concentrations are unlikely to be related to the Costerfield ore. It is likely that there are a mixture of anthropogenic (man made) sources that contribute to the elevated lead in soil.

# How Do WE estimate the exposure of People to chemicals in the environment?

Humans come into contact with COPC in the environment in many ways. For example, we may inhale dust as we breathe, eat food that carry chemical residues, drink water, touch soils, or absorb chemicals through our skin. In each case, the HRA needs to estimate exposure and intake using several variables.

**Exposure** is defined as contact between a COPC and the exterior of an exposed person's body (skin and openings into the body such as mouth, nostrils, and cuts or breaks in the skin).

**Intake** is defined as the processes through which COPC cross the boundary from outside to inside the body. Intake refers to processes like ingestion and inhalation that physically move the COPC through an opening in the outer body, such as the mouth, nose, or a skin puncture. Intake includes the fraction of the COPC that enters the body through the gut or skin. ·In this HRA “intake” is referred to as “Estimated Daily Intake” or “EDI”.



Figure 4: Conceptual Exposure Model

Note: The Exposure model includes contributions from current mining activity. The air monitoring, soil and tank water results measured in Costerfield include any potential contribution of mine related dust within Costerfield. The possible contributions of the current mining activities to these pathways is discussed in Appendix I.

Figure 4 is a generalised version of how people may be exposed to the COPC. The exposure assessment needs to inform stakeholders not only about health risk but under what conditions these health risks are manifested.

Exposure assessments describe how frequently contact occurs, how long it lasts, its intensity (i.e. the concentration of the chemical), and the route by which COPC enter the body.

Exposure assessment is a multi-step process that requires a lot of concentration data combined with a lot of estimates of exposure. The exposure assessment requires information on the physical and chemical properties of each COPC, the medium by which each COPC comes into contact with humans, and how concentrated each COPC is within that medium. The exposure assessment also needs data on the demographics of the exposed population, major routes of exposure for that group, and relevant behaviour and lifestyle issues, such as how much water is consumed and how frequently people are outdoors or at their properties.

The exposure model describing the possible mechanisms of exposure is presented in Figure 4. This model is referred to in this HRA as a “Conceptual Exposure Model” or “CSM”.

Appendix E provides the detailed technical exposure assessment. It contains a summary of all equations and accompanying input parameters and assumptions. The calculated EDI are also provided.

Exposure assessment requires consideration of the:

* Variations in concentrations used for different exposure estimates (e.g. soil and water concentrations for each COPC)
* Uncertainty in the intake values (different rates of consumption of soil or water)
* Different behaviours (e.g., permanent residents or part time residents)
* Different body types of older and younger people (i.e., body weight and skin surface area calculations for different age groupings)
* Contribution of different sources of COPC (e.g. natural versus current mining operations)

Because the EDI combines the estimates of the concentrations of the metals in the environment with human activities that might result in exposure to the metals, it is necessary to consider a range of environmental concentrations and a range of human activities and behaviours to make the EDI representative and relevant to different people and different circumstances. This requires statistical descriptions of each factor that contribute to the EDI.

The EDI estimates also need to inform stakeholders on the findings of the HRA. In this HRA two questions are posed and the EDI are calculated to support the answers to these questions.

The first question (Is it safe to live in Costerfield?) is addressed using a range of exposure estimates that is most applicable to the current residents of Costerfield. Two EDI estimates are provided:

* Average Estimate of EDI. Combining the averages in soil, water and air with average circumstances of exposure results in an EDI that is relevant to most people in Costerfield.
* Upper Estimate of EDI. Combining a range of statistical estimates for many inputs such as the soil concentration and the amount of soil ingested each day by a person results in what is known as a reasonable worst case. This estimate is intended to exceed the EDI for most people in Costerfield. It is intended as a plausible yet unlikely estimate of exposure.

Both estimates are important as it is important to describe a range of different circumstances and also to account for uncertainties in the information available on which to make estimates.

The second question (What can be done to manage exposure within Costerfield?) requires a more detailed evaluation of the Upper Estimate. The upper estimates are not likely estimates of exposure but are plausible. For instance this estimate assumes that a person spends 2 hours a day each day of the year in the same spot and the worst case result (anywhere in Costerfield) and that one of the highest soil concentrations anywhere in Costerfield for all three metals co-occurs at this spot. The person ingests two litres of tank water containing one of the highest tank water results anywhere in Costerfield for each metal every day of the year. This would be an unusual occurrence however it is included in the HRA to understand the uncertainties in the EDI.

## Exposure Assessment Results

Table 4 describes the circumstances and scenarios used to calculate EDI. The calculated EDI are provided in Appendix E.

Table 3: Exposure Assessment: Age Groupings, Pathways, Scenarios and Key Assumptions

| Type of Resident | Resident Age Groups | Exposed Each Day Via | Use of Tank Water |
| --- | --- | --- | --- |
| **Permanent Residents**  Stays in Costerfield  365 days per year. | * Infant (1 year old) * Young child  (2 year old) * Older Child  (10 year old) * Adult | * Soil ingestion * Home-grown food (egg meat), * Breathing in dust in air * Bathing using tank water | * Use tank water as their primary drinking water source. |
| * Do not use tank water for drinking purposes (but do bathe in tank water) |
| **Weekend Residents**  Stays in Costerfield  104 days per year  (2 days per week). | * Infant  (1 year old) * Young child  (2 year old) * Older Child  (10 year old) * Adult | * Soil ingestion * Home-grown food (egg meat), * Breathing in dust in air * Bathing using tank water | * Use tank water as their primary drinking water source. |
| * Do not use tank water for drinking purposes (but do bathe in tank water) |

## Contribution of Different Exposure Pathways to the EDI

Appendix E includes tables of each EDI and graphs showing the contribution of each exposure pathway to the total EDI. The following general conclusions are drawn from this analysis:

* When EDI are calculated assuming tank water is the primary source of drinking water for residents in Costerfield, the results indicate that, in most cases, the majority of the EDI is due to tank water ingestion.
  + For the Upper Estimate of exposure, tank water and soil ingestion are both important contributors to the EDI of antimony.
  + For the Average Estimate of exposure, soil ingestion contributes a greater proportion to the overall EDI of lead than tank water.
* When the EDIs are calculated excluding tank water, the main contributor to the EDI is ingestion of soil.
* Bathing (showering and baths) is not a significant contributor to the overall EDI.
* Eating locally grown lamb or eggs is not a significant contributor to the overall EDI.
* Breathing in the dust in the air (indoors or outdoors) is not a significant contributor to the overall EDI.

# findings of the health risk assessment

Appendix G presents the findings of the HRA. The technical approach to making findings is to calculate what is known as a hazard quotient (HQ) and a hazard index (HI).

* The hazard quotient (HQ). Each estimated EDI (refer section 6.0) for each metal is compared to a health benchmark called a tolerable daily intake (TDI), which is specific for each metal. The TDI is a safe intake expressed as an average daily intake that should not cause adverse health effects to a person over a lifetime. Because the TDI is a lifetime average daily intake, the estimated lifetime EDI is calculated and used for assessing health risk for a community. The hazard quotient is calculated by dividing the EDI by the TDI. The ratio of the EDI to the TDI (the margin) is then used to make decisions about the risk of adverse health effects.
* The hazard index (HI). To consider health risks due to the combined exposure of each metal, each of the HQs is added up to derive the hazard index. That is, the hazard index equals the sum of the hazard quotients. This is a conservative assumption that in reality is likely to overestimate the health risk. However it is done to err on the side of caution.

Given the multiple levels of conservatism built into a HRA, there is generally a high level of confidence that risks are not under-estimated. On this basis the following Figure 5is used to interpret the HI.

Figure 5: Interpreting Findings (hazard quotient HQ and hazard index HI).

Appendix G provides additional information on how findings of the HRA can be interpreted. It provides the HQ and HI for each of the 16 exposure estimates made in the HRA.

## Is it safe to live in Costerfield?

The question is technically expressed as:”*Do the environmental levels of antimony and other metals present a health risk to people living in Costerfield ?*”

Given that the purpose of the HRA is to identify potential risks associated with the Costerfield Dome and the mining activities within it, the risk characterisation results (HQ and HI) are presented for antimony and arsenic.

### Conclusions Specific to Living with the Mining Legacy within the Costerfield Dome

Antimony and arsenic soil levels in Costerfield are different to other parts of Victoria because of the geological and mining legacy in Costerfield. The results of the risk assessment for permanent residents in Costerfield (Upper and Average exposure estimates) are summarised in Table 4 using the key described in Figure 5.

Table 4: Conclusion for health risk to Costerfield Permanent Residents (Antimony and Arsenic)

| Estimate Type | **Key Assumption** | **Conclusion** |
| --- | --- | --- |
| Upper Estimate  Permanent Residents | **Use tank water** as their primary drinking water source. | Minimal Concern for adverse health effects |
| **Do not use tank water** for drinking purposes (but do bathe in tank water) | Negligible Concern for adverse health effects |
| **Average Estimate**  Permanent Residents | **Use tank water** as their primary drinking water source. | Negligible Concern for adverse health effects |
| **Do not use tank water** for drinking purposes (but do bathe in tank water) | Negligible Concern for adverse health effects |

Table 4 concludes that the environmental levels of antimony and arsenic in Costerfield do not present a health risk.

Table 5 presents the results for **weekend residents** either including or excluding tank water use show a **negligible concern for adverse health effects.**

Table 5: Conclusion for health risk to Costerfield Weekend Residents (Antimony and Arsenic)

| Estimate Type | **Key Assumption** | **Conclusion** |
| --- | --- | --- |
| Upper Estimate  Permanent Residents | **Use tank water** as their primary drinking water source. | Negligible Concern for adverse health effects |
| **Do not use tank water** for drinking purposes (but do bathe in tank water) | Negligible Concern for adverse health effects |
| **Average Estimate**  Permanent Residents | **Use tank water** as their primary drinking water source. | Negligible Concern for adverse health effects |
| **Do not use tank water** for drinking purposes (but do bathe in tank water) | Negligible Concern for adverse health effects |

A full set of results for each age group is provided in Appendix G.

It is safe to live in Costerfield. Although the antimony and associated metals (arsenic) in Costerfield are generally higher than other parts of Victoria, these present minimal to negligible concern for adverse health risks.

### Conclusions Including Lead Contamination

On some occasions in Costerfield, as is in many other parts of Victoria, high levels of lead in tank water and soil are encountered. It is most likely that these high levels are due to widespread historical use of anthropogenic (man made) lead. Table 6 summarises the results using the key described in Figure 5.

Table 6: Conclusion for health risk to Costerfield Permanent Residents (Antimony, Arsenic and Lead)

| Estimate Type | **Key Assumption** | **Conclusion** |
| --- | --- | --- |
| Upper Estimate  Permanent Residents | **Use tank water** as their primary drinking water source. | Some Concern for adverse health effects |
| **Do not use tank water** for drinking purposes (but do bathe in tank water) | Minimal Concern for adverse health effects |
| **Average Estimate**  Permanent Residents | **Use tank water** as their primary drinking water source. | Negligible Concern for adverse health effects |
| **Do not use tank water** for drinking purposes (but do bathe in tank water) | Negligible Concern for adverse health effects |

The conclusions in Table 6 are based on high lead concentrations in soil and tank water. These do not co-occur at the same property, thus these results are considered unlikely to be representative of Costerfield residents.

However lead exposure from soil and tank water is plausible and the results in Table 6 emphasise the need for careful management of exposure.

Table 7 provides the results for **weekend residents** and, either including or excluding tank water use show a **negligible concern for adverse health effects.**

Table 7: Conclusion for health risk to Costerfield Weekend Residents (Antimony, Arsenic and Lead)

| Estimate Type | **Key Assumption** | **Conclusion** |
| --- | --- | --- |
| Upper Estimate  Weekend Residents | **Use tank water** as their primary drinking water source. | Minimal Concern for adverse health effects |
| **Do not use tank water** for drinking purposes (but do bathe in tank water) | Negligible Concern for adverse health effects |
| Average Estimate  Weekend Residents | **Use tank water** as their primary drinking water source. | Negligible Concern for adverse health effects |
| **Do not use tank water** for drinking purposes (but do bathe in tank water) | Negligible Concern for adverse health effects |

## Is the dust harmful to health?

Appendix D3 presents a summary of the air quality monitoring program conducted by Golder in the vicinity of Mandalay Resources gold-antimony operation at Costerfield.

Dust monitoring was undertaken at two community locations referred to as Residence 1 and Residence 2.

* Residence 1 is approximately 1.3 km north of the Brunswick Plant.
* Residence 2 is approximately 1 km south east of the Brunswick Plant.

The locations were chosen to investigate the current mining operations dust levels over an extended period of time (12 months). At each location, air quality monitors were used to measure:

* PM10 Particulate matter with an equivalent aerodynamic diameter (EAD) less than 10 microns.
* PM2.5 Particulate matter with an EAD less than 2.5 microns (PM2.5).
* Particulate metal, measured in the PM10 fraction. The metals measured were mercury, arsenic, cadmium, copper, manganese, nickel, lead, antimony, zinc and iron.
* Indicative PM10 , which was estimatedusing a continuous laser light scattering instrument, co-located with the PM10 monitors. The indicative results provide a measure of PM10 trends and variation.
* Respiratory Crystalline Silica (residence 1 only).

In addition to the air quality monitoring program, dust deposition gauge results were provided by Mandalay Resources for review and a dust deposition model was generated by Golder (refer Appendix D3).

The results on air quality assessment show that:

* All measures of air quality were within Victorian Government compliance requirements.
* The dust in air (PM10 and PM2.5) was below national standards.
* The metals in the dust were not at harmful levels. This e antimony, arsenic and lead levels were always below health based air guideline values.
* Dust from the direction of current mining activities was found to contribute to dust and antimony levels in air on approximately a third of the days in the monitoring period (Appendix D3).

Residence 2

Residence 1

The dust levels and concentrations of antimony in PM10 (respirable dust in air) at Residence 1 and 2 measured in Costerfield are not at levels harmful to health.

## Is tank water safe to drink?

Tank cleaning at select properties was undertaken from 10 July until 22 August 2014. To assess the success of tank cleaning, post cleaning water monitoring was undertaken from October 2014 until May 2015. At eight properties, approximately monthly water sampling was undertaken during this period.

The total antimony concentrations reported for this tank water monitoring are described in Appendix D2. A decrease in antimony concentrations was observed following tank cleaning. However, in most cases the reduced concentration of antimony still exceeded the Australian Drinking Water Guideline (ADWG) for antimony. In addition, the antimony concentrations were observed to trend upwards during the monitoring period, following the initial decrease.

Antimony concentrations in tank water regularly exceeded the ADWG both before and following tank cleaning. For this reason, residents should not continue to drink tank water.

The tank cleaning and subsequent monitoring did not support tank cleaning as a suitable measure to mitigate exceedences to the ADWG.

## Is it safe to shower / bath in tank water?

The exposure pathways included in the HRA included ingestion and dermal contact while bathing / showering with tank water.

For permanent residents, the HRA assumed that a resident showers/baths for 20 minutes every day of the year. The amount of tank water ingested during bathing was conservatively considered to be the same as that ingested during swimming (i.e. this swimming water ingestion is a standard risk assessment parameter). The rate of dermal penetration of the metals through the skin (dermal permeability coefficient of compound in water) was estimated using US EPA default values for metals. It is noted that these defaults are uncertain and chosen by the US EPA to be conservative estimates of dermal permeability.

The HRA found that the contribution of bathing water ingestion to the EDI of antimony, arsenic and lead is negligible.

At the concentrations of arsenic, antimony and lead present in tank water (low microgram per litre levels) evidence for allergic reactions was not identified in the scientific literature.

The estimates for dermal permeability and thus the contribution to daily exposure (EDI) would increase if large areas of skin were damaged, such as when there is a pre-existing skin conditions. However given the relatively short exposure time it is unlikely that the contribution of bathing to the EDI would increase significantly even under these circumstances.

Tank water can continue to be used for showering and bathing.

## Is it safe to consume home-grown eggs and lamb?

As part of the ongoing works to assess antimony levels within the environs of Costerfield, egg and sheep samples were collected and submitted for laboratory analysis in October 2014.

Sheep sampling was coordinated and undertaken by the Department of Environment and Primary Industries (DEPI), and analysis of the samples of meat was completed by the National Measurement Institute (NMI). Egg samples were collected by Golder and analysis of egg samples was also completed by NMI.

For permanent residents it was assumed that a resident consumes home grown eggs or lamb every day of the year. The consumption rates are based on average and upper estimates of consumption based on Australian Bureau of Statistics surveys of Australian food consumption rates. The consumption rates vary based on age and are documented in Appendix E.

The contribution of home grown produce (egg and lamb) to the EDI of arsenic, antimony and lead is very low.

The analytical results for the eggs and lamb meat did not exceed Australian food standards for contaminant levels (where available).

Home grown eggs and lamb in Costerfield are not harmful to health.

## Is it safe to play in the yard and work in the garden?

Direct ingestion of soil is not normally a significant source of chemical exposure for adults, although there can be some hand-to-mouth transfer from household dusts during food preparation.

Direct ingestion of soil and dusts by hand-to-mouth transfer can be a more significant exposure source in children (enHealth 2012 a, b).The reason for this is that children (particularly young children aged 1-7 years of age) can have intimate contact with soil during play.

Using average estimates of exposure, where a child plays outdoors on every day of the year, the HRA found that it is safe to play in the yard and work in the garden.

Using upper estimates of exposure (i.e. reasonable worst case exposure estimates) there is minimal to some concern for adverse health effects. Assuming tank water is not consumed, the contribution of lead in soil to the overall HI is approximately 90%.

In most cases it is safe to play in the yard and work in the garden. However in some unlikely exposure circumstances (children play or adults work at the point in the yard where the highest lead concentrations are present everyday) it is not safe to play in the yard and work in the garden. Mitigation measures are discussed in Section 9.0.

## Is it safe to swim in a swimming pool?

Monitoring of swimming pool water located within the study area was undertaken approximately monthly from October 2014 until May 2015 (excluding November). The results of this are discussed in Appendix D3. The results suggest that there are potential risks to health if the pool is left uncovered, which allows dust deposition over a period of time. This risk can be managed though regular cleaning or covering the pool whilst not in use. If the pool is covered or cleaned regularly, risks of swimming are considered to be acceptable.

Swimming pools can be used safely, however they require regular cleaning and cover to avoid dust deposition and subsequent accumulation of antimony concentrations.

# Variability In HRA

The risk assessment process involves a number of steps (e.g. exposure assessment, toxicity assessment and risk characterisation), each of which incorporates the use of assumptions and simplifications to manage uncertainty or lack of knowledge about the correct value. Without such assumptions and simplifications it would not be possible to quantitatively evaluate the potential for health effects.

Although uncertainties in the risk assessment may influence its accuracy, the assumptions are used to manage uncertainties and err on the side of safety. Therefore there is a bias in the evaluation to over -estimate health risks.

In any risk assessment, the conservatism surrounding one parameter (such as metal concentrations in soil, or the amount of soil ingested) at least adds to the level of risk, and most times multiplies it. Conservatisms in other parameters leads to a cumulative or compound conservatism for the overall assessment which can be very large. This is especially so when gross, unrealistic default parameters are used in lieu of measured data.

The above issues are why in this HRA, a range of risk estimates are produced. These are intended to describe a range of assumptions in order to consider uncertainties.

To the extent possible, uncertainties and assumptions are described within the HRA. However Appendix H provides a more detailed look at some of the most important assumptions.

There are some uncertainties in individual parameters used to estimate exposure. In particular soil concentrations and human behaviour assumptions related to soil contact are variable. The HRA has been designed to take a conservative approach to these issues. As a consequence there is a high degree of confidence that risks have not been under-estimated in this HRA.

# What are the next steps?

Risk Management

The HRA provides considerable detail about the context of exposure to metals in Costerfield and the magnitude of potential risks. The results are intended to be reviewed by all stakeholders in the context of how exposure can be reduced. The process for considering measures to minimise exposure is called risk management.

The main elements of risk management, as outlined in AS/NZS 4360:2009, are:

* Communicate and consult, this is an ongoing process and is not a single event or outcome.
* Establish the context
* Identify risks
* Analyse risks
* Evaluate risks
* Treat risks
* Monitor and review

## Risk Communication

The risk management process can be used to address some of the current issues at Costerfield. Many of these are identified within the RM Consulting Group (RMCG 2015) report. In particular issues around communication and establishing the context have been improved since May 2014.

In addition to the communication strategies and protocols that have been implemented since May 2014, the Victorian Government should produce and communicate advice to residents about ways of reducing exposure to metals in the environment. Many of these messages have been published in previous newsletters and factual communications. However these should be revisited in light of the detailed analysis presented in the HRA. The emphasis in such communications should be on ways to reduce exposure. Some of the messages/recommendations to consider include:

* Cleaning indoor areas regularly to reduce the collection of dust by mopping frequently with a damp cloth.
* Using gloves when gardening and wash hands thoroughly before eating.
* Washing locally grown vegetables clean of soil with water that meets Australian Drinking Water Guidelines before eating.
* Keeping toys clean of any soil or dust.
* Ensuring children clean their hands thoroughly after playing outside.
* Considering covering bare soil in play areas and garden beds with a layer of fresh soil or mulch where preschool-aged children may be present.

## Dust management

Mining and processing project risks are generally identified and managed at all stages of an operation’s life cycle. Significant risks that are defined, communicated, understood and satisfactorily addressed early in the mine life cycle are more likely to be accepted as well managed by stakeholders who have an interest in the mining project. Materials stewardship provides a central framework for an integrated risk approach to responsible management of materials used in mining and mineral processing, particularly wastes, hazardous substances and products. The project risks should be reviewed on a regular basis.

In terms of air quality, elevated PM10 and PM10 antimony concentrations were reported on days when winds were blowing both from the direction of current mining activities, and not from the direction of the current mining activities suggesting that the source of PM10 and PM10 antimony in Costerfield are diverse. The levels of PM10 and antimony are within national standards and health based air guideline values respectively. Dust from current mining activities was found to contribute to dust and antimony levels in air on approximately a third of the days in the monitoring period.

The dust deposition model presented in Appendix D3 investigated each activity within the current mining operation that could contribute to dust emissions. It was found that truck movement was the largest factor for dust emissions.

Lead nitrate is currently used in mining operations and lead waste (at levels (approximately 200 mg/kg) less than health screening levels (300 mg/kg)) are stored in tailings dam.

Although a reactive dust management strategy is in place and improvements to dust management have been made, a continuous improvement culture should be encouraged to review dust and waste management practices on a regular basis with the aim of achieving dust and waste levels as low as reasonably practicable.

Dust management practices at the current mining operations and other activities (e.g. road grading, land disturbance activities in the area) should be reviewed and aim to achieve dust levels as low as reasonably practicable.

## Use of Tank Water

Rainwater tanks attached to house roofs when used as the primary source of drinking water were found to be a significant contributor to exposure to antimony and also lead. Many tank water results were higher than the Australian Drinking Water Guidelines for antimony. A few results were higher than the Australian Drinking Water Guidelines for lead.

A program of cleaning the tanks and refilling these with drinking water from a reticulated water supply did reduce levels of antimony. However within 6 months the antimony levels were above the guideline levels.

As discussed in Appendix I even a small amount of dust, within compliance levels for dust deposition, is likely to contribute to antimony levels in rain water tanks attached to roofs. As a consequence:

* At present tank water should not be used as a source of drinking water in Costerfield. This includes use in preparing food for infants.
* A cost benefit analysis should be conducted to consider a range of alternative supply options as well as technologies that can be applied to tanks or taps to remove metals from the water.

## Maintenance of Swimming Pools

The pool results for antimony reported concentrations less than the adopted primary contact recreation (swimming) guideline, with the exception of the initial round of sampling undertaken in October 2014. The pool was emptied, cleaned and refilled with potable water following the first round of sampling, resulting in the decreased antimony concentration in subsequent sampling. However, it is noted that the reported antimony concentrations appeared to be increasing each month from December to May.

As a consequence:

* Swimming pools should be cleaned on a regular basis
* Measures to avoid dust deposition should be considered (see Section 9.2).

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# important information

Your attention is drawn to the document titled - “Important Information Relating to this Report”, which is included in Appendix J of this report. The statements presented in that document are intended to inform a reader of the report about its proper use. There are important limitations as to who can use the report and how it can be used. It is important that a reader of the report understands and has realistic expectations about those matters. The Important Information document does not alter the obligations Golder Associates has under the contract between it and its client.

Signature Page

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Desk Top Review - Antimony in the Costerfield Area



HRA - Introduction and Methodology



Problem Formulation



Environmental Data Review  
(Soil, Water, Air, Food, Surface Dust, Bioaccessibility in soil, Soil Isotope Analysis)



Exposure Assessment



Toxicity Profiles



Risk Characterisation   
(HRA Results)



Variability, Sensitivity and Uncertainty Analysis



Sources of Metals in the Environment



Important Information Relating to this Report

|  |
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|  |
| --- |
| GA Logo Small_RGB from Phil |

1. The key has been adapted from the United States National Toxicology Program ‘Level of Concern’ Categories NTP (2005). [↑](#footnote-ref-1)
2. Now Victorian Department of Economic Development, Jobs, Transport and Resources (DEDJTR) [↑](#footnote-ref-2)
3. This is lower than the human health risk screening level derived by Golder (refer Appendix F) of 1 µg/m3. [↑](#footnote-ref-3)
4. <https://www.google.com.au/url?sa=t&rct=j&q=&esrc=s&source=web&cd=7&ved=0ahUKEwiWp5rQwIzLAhVB_GMKHQH2CW4QFgg_MAY&url=https%3A%2F%2Fwww2.health.vic.gov.au%2FApi%2Fdownloadmedia%2F%257B05D0678F-56B9-4402-87F9-AF3FB798E54A%257D&usg=AFQjCNF5a6Ur4hKNrcSM4nZQDUz07H2lJA&bvm=bv.114733917,d.cGc> [↑](#footnote-ref-4)
5. Personal communications during June-August 2014 with residents. [↑](#footnote-ref-5)
6. <http://www.energyandresources.vic.gov.au/__data/assets/pdf_file/0003/1145487/Antimony-in-the-Costerfield-Area.pdf> [↑](#footnote-ref-6)
7. <http://www.energyandresources.vic.gov.au/__data/assets/word_doc/0020/1198100/Independent_Engagement_Costerfield_Report.docx> [↑](#footnote-ref-7)
8. The tolerable daily intake (TDI) is defined as the amount of daily intake of a substance that can occur over a lifetime without appreciable lifetime health risk. It is typically expressed in units of micrograms per kilogram body-weight per day (WHO 1994). [↑](#footnote-ref-8)
9. https://www.nhmrc.gov.au/guidelines-publications/eh58 [↑](#footnote-ref-9)
10. EPA Victoria (2012) Table 93: Annual average lead (Collingwood 1995–2004) [↑](#footnote-ref-10)
11. NSW (2002) [↑](#footnote-ref-11)