



# *Lead Pathways Study – Air* Executive Summary

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*Health Risk Assessment of Contaminants to Mount Isa City by:*

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# UNIVERSITY OF QUEENSLAND'S CENTRE FOR MINED LAND REHABILITATION (CMLR)

Formally established in 1993, the Centre for Mined Land Rehabilitation (CMLR) at The University of Queensland (UQ) consists of a collaborative and multi-disciplinary grouping of research, teaching and support staff and postgraduate students dedicated to delivering excellence in environmental research and education to the Queensland, national and international minerals industry and associated government sectors.

The Centre is widely recognised as the source of quality research and postgraduate students at the cutting edge of issues in mining environmental management and sustainability. It has built a reputation for the provision of the scientific research that is necessary to support and underpin the decisions that need to be made to minimise the environmental risks by the mining and processing of the full spectrum of commodities including coal, gold, bauxite, alumina, base metals, heavy mineral sands and oil, both in Australia and overseas.

The Centre is one of six UQ research centres that make up the Sustainable Minerals Institute (SMI – [www.smi.uq.edu.au](http://www.smi.uq.edu.au)). The SMI was established in 2001 as a joint initiative of the Queensland Government, UQ and the minerals industry, to provide an overarching framework for progressing minerals industry research and education, with the purpose of providing 'knowledge-based solutions' to meet the sustainability challenges in the global mining industry'.

## EXPERIENCE OF CONSULTANTS



### Associate Professor Barry Noller

Associate Professor Noller has a PhD (1978) in Environmental Chemistry from the University of Tasmania. He worked as a Research Fellow at the Australian National University (1978-1980), Senior Research Scientist at the Alligator Rivers Region Research Institute, Jabiru, Northern

Territory (1980-1990) and then as Principal Environmental Chemist for the Department of Mines and Energy, Darwin Northern Territory (1990-1998). During this period Professor Noller was involved with the environmental management and regulation of all mines in the Northern Territory and was technical manager of the Northern Territory study on Bird Usage Patterns on Mining Tailings and their Management to Reduce Mortalities completed in 1998. He was also a co-author and reviewer of the Best Practice Environmental Management in Mining Handbook on Cyanide Management. From 1998-2006 Professor Noller was Deputy Director of the National Research Centre for Environmental Toxicology (EnTox) – The University of Queensland, Coopers Plains, Qld. EnTox has a strong involvement with the utilisation of the risk assessment process to deal with toxicological hazards, including in environmental systems. Since November 2006, Professor Noller has been appointed as Honorary Research Consultant and Principal Research Fellow at the Centre of Mined Land Rehabilitation (CMLR) a centre at The University of Queensland's St Lucia campus and a part of the Sustainable Minerals Institute.

Associate Professor Noller has been working and publishing in the field of environmental chemistry and industrial toxicology for the past 40 years and has presented > 400 conference papers and published > 200 papers. His professional activities undertaken

at four different centres have covered processes and fates of trace substances in the environment, particularly in tropical environmental systems with special reference to risk management associated with their application and studies of the bioavailability of toxic elements in mine wastes, including waters. He has undertaken several consulting activities in Queensland, Tasmania, New South Wales and the Northern Territory and was appointed in 2007 as Lead Author of the Australian Government Leading Practice Sustainable Development Program for the Mining Industry Handbook on Cyanide Management. He has been project leader of the Lead Pathways Study conducted for Mount Isa Mines since 2007. The Land Report was released in 2009 and the Water Report in September 2012.



### Dr Jiajia Zheng

Dr Jiajia Zheng was a Research Officer at CMLR, the University of Queensland. Dr Zheng completed her PhD at CMLR in June 2013 and looked at the lead from mining and mineral processing activities to the community via the air-dust pathway. Dr Zheng has a Masters

degree in Environmental Geochemistry from the School of Earth Science, the University of Queensland. Her Masters research project was on Peat Deposits of Moreton Bay: Natural Archives of Environmental Pollution. Prior to her study in Australia, Dr Zheng was studying at the China University of Geosciences (Wuhan), majoring in Economic Geology.

Dr Zheng's research interests are principally in environmental risk assessment and management in mining and mineral industry by combining chemical and physical properties of hazardous materials using various approaches such as X-ray absorption spectroscopy and radiogenic isotope measurements as forensic tools. Dr Zheng is also interested in the fate and the interaction of heavy metals and metalloids in the air-soil-dust materials and their potential toxicological responses to human and ecology system.



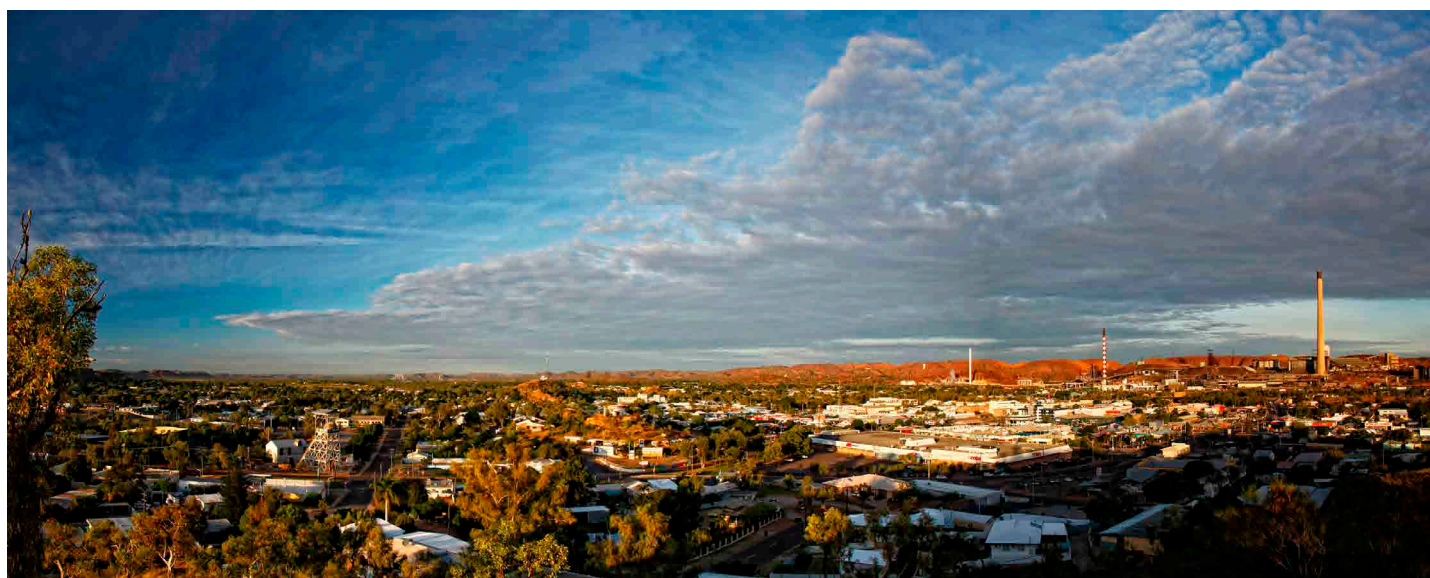
### Dr Trang Huynh

Dr Trang Huynh has a PhD degree in Environmental Science from the University of Melbourne (2008). Her PhD research project was on bioavailability of heavy metals in soil and biosolids during phytoextraction. She completed her Master of Science Degree majoring in

Soil Science at The University of Sydney (2001) with a thesis on crystallographic and chemical properties of copper and cadmium substituted goethites using the X-ray Synchrotron technique. She worked as a researcher and lecturer on soil and environmental chemistry in Vietnam for seven years. During this period, she was involved in several international funded projects in Vietnam as a project coordinator, researcher and project evaluator. Dr Trang Huynh is currently a Postdoctoral Research Fellow with the CMLR at The University of Queensland.

Dr Trang Huynh research interests are principally in biogeochemistry, environmental and water/soil chemistry, plant-soil interaction and the behaviour of heavy metals and metalloids in the environment. She is also interested in understanding and applying advanced techniques such as Diffusion Gradient in Thin-film (DGT) and Synchrotron Technique to measure heavy metal/loid speciation in the environment especially at mining sites. One of her current research focus is on the impacts of contaminants from mining activities to human and ecological health.

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## PREAMBLE

The *Lead Pathways Study – Air Report* is one of several reports derived from a series of studies at Mount Isa City. The project team was tasked to carry out hazard assessment, exposure assessment and health risk assessment of lead (Pb) by utilising the enHealth risk assessment framework.

Within the National Environmental Protection Measures (NEPM) for soil contamination, there is allowance for higher tier and more refined risk assessment beyond the initial total concentration screening and tier-two steps. This provides a more refined site specific and evidence-based risk assessment that this research-based study aimed to deliver. The study included an extensive survey of various dust/soils samples of mining/smeltering origins and residential area including a statistically based house-hold dust campaign. Several techniques were employed to provide physical and chemical characteristics of these samples. The rationale for choosing a particular technique or a set of related techniques is explained in relevant chapters of the report. Bioavailability/bioaccessibility measurement was performed for a more refined exposure assessment instead of using the default of 100% bioavailability assumption.

Amongst the chosen techniques, Synchrotron-based X-ray absorption spectroscopy method is an important one that affords Pb speciation/composition data and is the best cutting edge method to help with the interpretation of bioavailability/bioaccessibility data. The Pb isotope study is employed to understand the complexity of a particular sample matrix. It has demonstrated that soil contamination could have come from multiple sources including past and present, natural and anthropogenic inputs.

Bioaccessibility (BAC) data were obtained as a surrogate estimate for the absolute bioavailability (ABA). A correction factor between BAC and ABA was derived based on ABA data obtained from 12 selected, representative but diverse set of samples. It may be prudent to point out that while the correlation between BAC and ABA is not ideal the most conservative conversion factor is used for the calculation of estimated ABA values. This study also found that the

mean of BAC obtained from four pH values over the whole gastrointestinal tract rather than a single acid pH for the stomach phase is the best predictor of blood lead in children. The predicted risk in terms of blood lead in children agrees with the ultimate 'gold standard' of human blood survey conducted by Queensland Health. This study also indirectly confirms that relative bioavailability (RBA) and BAC (gastric phase) could over estimate potential risk as already suggested in published studies. An important detail to recognise is that gastric-only bioaccessibility measurement will over-predict bioavailability of lead; this can be demonstrated by using the USEPA IEUBK model to predict blood lead increase from ingestion of only soil by children. Food in the stomach and intestine is a very important factor in lead absorption. Following solubilisation in the stomach lead is transferred with nutrients from food to the intestine whether absorption of lead occurs. Lead absorption occurs via the intestinal phase and not from the gastric/stomach phase where solubilisation occurs. An average pH representing the fast, semi-fed and full-fed states of the stomach and the near neutral pH of the intestine is selected to provide an intermediate pH for testing in the PBET and represents a nutritional status intermediate between fasting and fed states. This also represents a more realistic exposure scenario of a daily life rather than the most conservative assumption that exposure only occurs during the fast-state (hunger).

### Lead Pathways Study

Land Report	✓	Released July 2009
Water Report	✓	Released September 2012
Air Report	✓	Released February 2017



## EXECUTIVE SUMMARY\*

### CONTEXT

Glencore, through its subsidiary Mount Isa Mines Limited ('MIM'), conducts copper and lead–zinc–silver mining and processing operations adjacent to the City of Mount Isa. These operations generate dust and metallurgical fumes that can contain heavy metals such as copper, lead, zinc and cadmium, as well as 'metalloids'<sup>1</sup> such as arsenic and silicon (NPI, 2012).

In addition, while the mining operations are conducted on and under the Mount Isa Mines lease, there are also areas of natural mineralisation within the boundaries of the City of Mount Isa that have elevated levels of these metals and metalloids. Indeed, parts of the city are built on land that is encompassed by the MIM mining lease (ML 8058).

MIM has for over 40 years operated an air-quality control ('AQC') system to limit the exposure of the population of Mount Isa to these airborne dusts and fumes. (Wrigley, 1992). The AQC system controllers shut down the smelters and curtail certain dusty operations, when necessary, to maintain the air quality in Mount Isa. This is normally done based on weather forecasting and measurements of atmospheric conditions. In addition, there is a system of 10 continuous real-time sulfur dioxide ('SO<sub>2</sub>') monitors that warns the controllers if unexpected weather events are leading to an increase in the concentration of SO<sub>2</sub> in the community (MIM, 2012a). The system also includes 5 passive monitoring stations, 9 high-volume samplers and 10 dust depositional gauges for monitoring dust in the Mount Isa city air (MIM, 2012a). The data from these samplers show that the air quality in Mount Isa has met MIM's operating licence conditions (DEHP, 2013, MIM, 2012c). The control of fumes is only ancillary to SO<sub>2</sub> control (MIM, 2012a).

Of the metals and metalloids measured in these monitoring devices, lead has had the greatest focus due to its potential

health effects. It is known to be toxic to humans and animals at sufficiently high doses (Donovan, 1996). In recent decades, the focus on lead toxicity has shifted from high-dose effects in people showing symptoms of lead poisoning to the effects of exposure to lower doses that cause no acute symptoms, particularly in the case of children and fetuses (Needleman, 2004).

As a result of studies that indicated that blood lead levels greater than 10–15 micrograms per decilitre<sup>2</sup> of blood ('µg/dL') can affect intellectual development, there has been a drive to lower blood lead levels in the population, and particularly in children (Donovan, 1996). This has led to a lowering of the threshold level at which steps should be taken to reduce exposure to lead from  $\geq 25$  µg/dL<sup>3</sup> for a member of the general population (OECD, 1993) to a level of  $\geq 10$  µg/dL for children (U.S. CDC, 2013). The Australian National Health and Medical Research Council ('NHMRC') in 1993 emphasised its concern over exposure to lead, especially in young children, and recommended that a blood lead level of less than 10 µg/dL, the level currently recommended<sup>4</sup> (NHMRC, 2009), should be achieved for all Australians and set the following targets for reductions in blood lead levels by the end of 1998:

- 15 µg/dL for all Australians who are not occupationally exposed
- 90 per cent of all children aged from 1–4 years having blood lead levels below 10 µg/dL (Donovan, 1996).

\* Download the full report, including references and appendices at [www.mountisamines.com.au](http://www.mountisamines.com.au)

1 Elements that have properties intermediate between metals and non-metals.

2 1 decilitre is equal to 100 millilitres.

3 '≥' means 'greater than or equal to'.

4 The NHMRC blood lead level for investigation is currently 5 µg/dL NHMRC (2016) 'Managing individual exposure to lead in Australia – a guide for health practitioners'. National Health and Medical Research Council, Commonwealth of Australia. Canberra. April 2016.



This recommended lead level, however, should be considered as the level at which sources of exposure should be investigated, rather than a simple interpretation of a 'safe' level or a 'level of concern'.

As a result of these concerns and other trends, lead exposures of the general populations in developed countries have been reduced by the elimination of lead from such things as fruit pesticides, lead water pipes, paint, petrol and solder in food and drink cans (OECD, 1993). There has been a corresponding reduction in the blood lead levels in these populations. For example, the second national health and nutrition examination survey ('NHANES II' 1976–1980) conducted in the United States found that average blood lead levels in children aged 6 months to 2 years was 16.3 µg/dL (Goyer, 1991). For children aged 1–5 years, 88.2 per cent had blood lead levels  $\geq 10$  µg/dL, 53 per cent had blood lead levels  $\geq 15$  µg/dL and 9.3 per cent had blood lead levels  $\geq 25$  µg/dL (U.S. CDC, 1994). By the time of the first phase (1988–1991) of the third US national health and nutrition examination survey ('NHANES III' 1988–1994), there had been a 78 per cent decline in the estimated geometric mean blood lead level for the US population as a whole, and only 8.9 per cent of children aged 1–5 years had blood lead levels  $\geq 10$  µg/dL (U.S. CDC, 1994). By the 2007–2010 NHANES cycle, only 2.6 per cent of 1–5 year olds had blood lead levels  $\geq 5$  µg/dL and the geometric mean was 1.3 µg/dL (U.S. CDC, 2013).

There has also been a decline in the blood lead levels in children in Mount Isa. In 2007, Queensland Health, a Queensland government department, surveyed 400 children aged 1–4 years

who were volunteered by parents or guardians and found that their geometric mean blood lead level was 4.97 µg/dL, and that 11.3 per cent had blood lead levels  $\geq 10$  µg/dL, with two (0.5 per cent) having blood lead levels exceeding 20 µg/dL (Queensland Health, 2011). A follow-up survey of 167 children aged 1–4 years and based on a whole of community response, conducted in 2010, found that their geometric mean blood lead level was 4.27 µg/dL, with 4.8 per cent  $\geq 10$  µg/dL, and one child at 22.4 µg/dL (Queensland Health, 2011). The decline in both the geometric mean and the number of children  $\geq 10$  µg/dL for the 2010 survey compared with 2007 was statistically significant<sup>5</sup>.

For comparison, the last national blood lead survey of children's blood lead level, conducted in 1995, found that the geometric mean for 1,575 Australian children aged 1–4 years was 5.05 µg/dL and that 7.3 per cent of them had blood lead levels  $\geq 10$  µg/dL (Donovan, 1996). Four of the children (0.25 per cent) had blood lead levels  $\geq 25$  µg/dL (Donovan, 1996). This study did not include children from Mount Isa and would still have included exposure from lead in petrol.

In late 2006, Mount Isa Mines commissioned a *Lead Pathways Study* to investigate the natural and industrial pathways of lead and other heavy metals into the Mount Isa community, and assessing the potential human and ecological health risk<sup>6</sup>. The evaluation addressed all exposure pathways that could be affected by air dispersion (i.e., ingestion, inhalation and dermal exposures from airborne materials). This study is headed by The University of Queensland's Centre for Mined Land Rehabilitation, in collaboration with the National Research Centre for Environmental Toxicology.

## PURPOSE

This report is the third of the three reports that comprise the *Lead Pathways Study*. The other two reports were the *Lead Pathways Study – Land* (published in July 2009) and the *Lead Pathways Study – Water* (published in September 2012).

The risk assessment process used in the study followed the recognised Australian Government risk assessment framework as laid out by enHealth, a part of the Australian Government's Department of Health and Ageing.

The purpose of these reports is to provide Mount Isa Mines, members of the Mount Isa community and other stakeholders (such as the Queensland Government) with a better understanding of sources of lead and other metals and metalloids, and the exposure of members of the public to them, so that the risks are understood and action can be taken if necessary to maintain public health.

The specific purpose of this report, the *Lead Pathways Study – Air* is to provide the findings of investigations designed to:

1. determine contributions of lead-containing particles and fumes from sources in the mining and processing operations to blood lead levels in the community, particularly of children less than five years old<sup>7</sup>
2. estimate air particulates as a potentially significant lead exposure source for inhalation and ingestion by members of the community and, particularly, children
3. determine appropriate actions and follow up works to manage the risks.

5 The Queensland Health report used the definition of statistical significance that is commonly used in science, i.e. that there is less than a one-in-twenty probability that the observed decline was due to random variation rather than being a real result.

6 The *Lead Pathways Study – Air* report dates from December 2012 and refers to guidelines that may have changed. These are identified where appropriate.

7 The Queensland Health blood lead surveys at Mount Isa surveyed children 1–4 years of age. The USEPA (2010) Integrated Exposure Uptake Biokinetic (IEUBK) model for blood lead prediction uses an age range of 0.5–7 years as default.

## FOCUSSING QUESTIONS

The focussing questions for this study were:

1. What are the potential pathways of lead and other heavy metals and metalloids from mining and mineral processing activities, and natural mineralisation?
2. How does the form of lead in the environment affect its ability to affect human health?
3. What is the risk to the health of the Mount Isa population, particularly to young children, from exposure to heavy metals and metalloids in air and dust found in the City's environment?
4. What procedure was used to determine the risk to the health of the Mount Isa population?
5. What measures can be taken to reduce the risk?
6. What would benefit from further examination?



## CONCLUSIONS

### Potential Pathways

The potential exposure pathways of lead into the human body are:

- ingestion through the mouth and, subsequently, the digestive system
- inhalation through the mouth and nose into the lungs
- absorption through the skin.

Of these three pathways, the two major routes of lead absorption by the human body are through ingestion and inhalation pathways, whereas absorption through the skin is considered to be insignificant (IPCS, 1995).

Ingestion through the mouth into the digestive system can be through food and drink, or through non-nutritive substances such as dirt and paint. Babies and small children often put their thumbs or fingers in their mouths, which can result in transferring lead-contaminated dust into their mouths.

Particles less than 250 µm in size are the most likely to enter through the ingestion route because coarser particles are less likely to adhere to hands and be transferred to the mouth.

Food in the stomach and intestine is an important factor in lead absorption. Previous studies evaluated lead isotope absorption by volunteers who were fed lead with meals or specific foods, or while fasting. For the volunteers who were fasting, as much as 71 per cent of soluble lead was absorbed (Heard et al., 1983). However, when the lead was ingested with a meal, absorption fell to a range of 3–7 per cent of the dose (Heard et al., 1983, James et al., 1985, Maddaloni et al., 1998).

Age is a significant variable for lead absorption and metabolism. The portion of ingested lead taken up by the body is typically less than 5 per cent for adults, but as high as 50 per cent for children (Zeigler et al., 1978). Infants and

### The potential pathways of lead into the human body are:



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Inhalation through the mouth and nose into the lungs



Absorption through the skin (absorption through the skin is considered to be insignificant)

toddlers are at greater risk due to increased exposure (through hand-to-mouth behaviour), increased ability to absorb lead, the susceptibility of their rapidly developing central nervous systems, and their less-developed gastrointestinal tract (Maynard et al., 2005).

The inhalation pathway consists of breathing in solid particles or liquid droplets found in air. Particles and droplets that are less than 10 micrometres (‘µm’) in diameter (known as ‘PM<sub>10</sub>’

particles) and those less than 2.5 µm ('PM<sub>2.5</sub>' particles) pose the greatest problems for human health, because they can penetrate deep into the lungs and get into the bloodstream (IPCS, 1995). Particles larger than about 7 µm tend to deposit on the walls of the airways (the thoracic region) and become part of the mucus that is moved up to the mouth and then swallowed (IPCS, 1995). PM<sub>2.5</sub> gives an approximation for fine mode particles, and therefore alveolar deposition, while PM<sub>10</sub> indicates the thoracic aerosol component (Raunemaa, 2002).

Lead absorbed through ingestion or inhalation moves into the body's circulatory system and from there can move into various organs or the bones. Lead is gradually excreted from the body. Two important routes of lead excretion from the body are urine and faeces (IPCS, 1995).

A lead uptake study indicated that 20 per cent of dosed lead was bound to the skeleton after three weeks (Heard and Chamberlain, 1984). The half-life of lead in the human body is approximately 30 days in blood stream and 10–30 years in bone (JECFA, 2011).

## Measuring the effect of Form of Lead in the Environment on Human Health

Simply analysing the concentration of lead or other contaminants in soils, dusts or other materials is usually not an accurate measure of the potential health effect of the contamination (Ng et al., 2010). The health effects depend, in part, on the body's ability to absorb the contaminating substance.

The ability of the human body to absorb lead depends on the form of the lead. Lead can exist as metal or as a chemical compound. Minerals are naturally-occurring chemical compounds.

The solubility of lead minerals and other compounds relate to their uptake or absorption in the human body via ingestion exposure and is described as bioaccessibility. The bioaccessibility of lead as a free ionic species such as lead acetate is higher than less soluble mineral forms (Ruby et al., 1999). Lead sulfate (PbSO<sub>4</sub>, known as 'anglesite' in its mineral form) is less soluble than lead acetate but more soluble than highly insoluble lead sulfide, and lead carbonate (PbCO<sub>3</sub> – 'cerussite' in its mineral form) is 1.3 times more soluble (IPCS, 1995). Cerussite, however, is soluble in hydrochloric acid (Read, 1970) (a component of stomach digestive juices (Burtis et al., 1988)). It is much more easily absorbed into the circulatory system via ingestion exposure than galena or anglesite (U.S. EPA, 2007b, Dieter et al., 1993, Ruby et al., 1999).

Lead mineral type, and the matrix in which it resides, affect its *bioavailability*. The bioavailability of lead is the fraction of the lead ingested and/or inhaled that reaches the circulatory system in the body and can thus be measured in the blood.

Bioavailability is the fraction of dose that reaches the systemic circulation of a receptor (e.g. humans) and is determined using living organisms. Because of the ethical issues associated with using people, most of the tests to determine bioavailability of samples of lead-containing materials (such as dirt and dusts) are carried out using animal test subjects, usually rats or mice,

but also pigs (U.S. EPA, 2007b) rabbits (Freeman et al., 1993) and monkeys (Freeman et al., 1995).

Recent studies using animals have demonstrated that the bioavailability of lead from some soils and mine waste materials may be considerably lower than some have previously assumed (Bruce et al., 2007, Diacomanolis et al., 2007), due to the type of minerals present.

Bioavailability is considered the 'gold standard' for measuring uptake of lead by the body, but the cost of the tests and the ethical issues associated with animal testing mean that it often cannot be applied.

A report by the United States' Environmental Protection Agency ('US EPA') (2007b) showed bioavailability by mineral type, as general guide, with galena having a relatively low value compared to lead oxide and with cerussite having the highest bioavailability.

The concept of *bioaccessibility* was developed as a proxy for bioavailability to reduce the need to use living animals in the assays. Bioaccessibility is the soluble fraction under laboratory-simulated conditions, i.e. an indicator of bioavailability to the receptor (e.g. humans). The bioaccessibility of ingested lead is determined using a simulated digestive system, mimicking the chemical environment in the stomach and intestines. Such tests include the one used in this report that is known as the 'physiologically-based extraction test' ('PBET'). Bioaccessibility tests also include those that use simulations of the fluids found in lungs to mimic absorption of contaminants through the lungs.

Bioaccessibility gives a prediction of bioavailability. Results from these bioaccessibility tests tend to be higher for lead than from bioavailability tests (Bruce et al., 2007, Diacomanolis et al., 2007).

Bioavailability tests, using Sprague Dawley® rats, were conducted for this study at the Queensland Health and Forensic Scientific Services Biological Research Facility, Coopers Plains (Animal Ethics approval number 07P05) on ten representative samples obtained from the mine site and the residential areas of Mount Isa.

These samples were:

- a composite sample of community soils
- a composite sample of roof gutter dusts
- a composite sample of carpet dusts
- dust collected from the lead smelter
- dust collected from the surface of the Number 5 tailings dam
- sediment from the Leichhardt River
- material collected from a naturally mineralised outcrop of the Urquhart Shale (on the Barkley Highway, adjacent to the RSL Club's main gate)
- a sample of lead concentrate
- dust collected from the copper smelter
- a slurry prepared from particulates dislodged from 50 high-volume air samples, the number necessary to generate sufficient sample for the tests.

The samples were analysed at Entox, a centre of The University of Queensland within the Queensland Health facility. The bioavailabilities were determined from measurements of the lead content of the rats' blood and urine after they were dosed orally with the lead-bearing samples. All the composite samples had bioavailability results less than 10 per cent, with the highest being 6.2 per cent determined from lead measured in blood samples from rats dosed orally with the slurry of composite air particulates collected by the high-volume samplers from 50 air-PM<sub>10</sub> filters collected at Mount Isa city from 2008 to 2010 (HVA slurry; see Table 115, page 249).

Bioaccessibility tests were conducted on the same samples to allow a relationship between bioavailability and bioaccessibility to be determined. This meant that the bioavailability of samples could be calculated from bioaccessibility tests and no further tests using live animals were necessary.

The results of work conducted for this study indicated that bioavailability can be calculated from the bioaccessibility of a representative data set using the equation, which was derived from Table 117 (page 253) and based on the upper 95 per cent confidence interval level for slope (0.17) of the line fitted through zero:

$$\%ABA = \%BAC \times 0.17$$

This equation shows that the bioavailability of a sample is less than 20 per cent of its bioaccessibility when calculated from an individual measurement of bioaccessibility.

It is thus important to identify the various forms of lead from different sources and to assess the quantities potentially available for ingestion and/or inhalation exposure by the Mount Isa community.

## Health Risks from Airborne Lead

Based on the results of this study, the risk to young children from inhalation of airborne lead in Mount Isa is very low. The contribution of airborne sources of lead via the inhalation pathway to blood lead levels ranges from 0.2 to 2.1 per cent of the total blood lead. On the other hand, the contribution from dust and soil via the ingestion route ranges from 37 to 93 per cent (with a median value of 74 per cent). Dietary intake of lead makes up most of the balance of lead intake via the digestion route (Walker and Griffin, 1998). Thus, inhalation is shown to be less than 5 per cent of the total exposure for people living in Mount Isa, while total ingestion is greater than 95 per cent.

Only a few studies of urban environments have previously reported the contribution of inhalation of lead to be less than 6 per cent of the contribution to blood lead level (Davies et al., 1990, Dong and Hu, 2012). The relatively low contribution of exposure to lead via inhalation arises because the maximum weight of air particulate matter which can be inhaled by a child or adult is quite small. This current study confirms that inhalation exposure is less significant compared to ingestion.

High-volume samplers capturing total particulates suspended in the air at five different locations in Mount Isa show that the air

concentrations at these sites are lower than the maximum level of < 0.5 µg/m<sup>3</sup> (measured as air-PM<sub>10</sub>, averaged over a year) set in the Australian government's *National Environmental Protection Measure for Air* and the *Queensland Environmental Protection Policy (Air)*. The latter is collected as total suspended particulates (TSP) with a size cut-off of 50 µm which includes air-PM<sub>10</sub> as a subset. None of the monitoring sites has had an annual average exceeding the NEPM for air since 2009. Although a size difference exists between TSP and air-PM<sub>10</sub>, there is unlikely to be any variation in exposure of lead between TSP and air-PM<sub>10</sub> to the population as the bioaccessibility of lead for the HVA slurry (20.5%; Table 118) prepared from air-PM<sub>10</sub> filters collected at Mount Isa city was almost the same as the median for soil <250 µm fraction (22%) (Table 103). The HVA slurry has lead composition and %BAC that shows it to be soil-derived material (Section 3.10).

The mean bioaccessibility (BAC) of lead in natural mineralisation in Mount Isa city was 2% compared with 24% in garden soil samples tested in this study and about an order of magnitude lower than the often-adopted default value of 100%. The actual individual % BAC value obtained from each house specific dust sampling program was used in the IEUBK modelling of blood lead level.

The results of tests to determine the bioavailability and bioaccessibility of lead in air and dusts in the Mount Isa city environment were inputted to the Integrated Exposure Uptake Biokinetic ('IEUBK') model developed by the US EPA. This model is used to predict blood lead levels in children from a child's exposure to lead and the bioavailability of the lead to which it



< 5%

### INHALATION VIA AIR

Breathing in airborne dust (PM<sub>10</sub>) contributed less than 5% to total lead exposure for people living in Mount Isa.



37–93%

### INGESTION VIA DUST OR SOIL

Swallowing lead in soil or surface dust (PM<sub>250</sub>) made up between 37% and 93% (median 74%) of total lead exposure contributions.



< 24%

### INGESTION VIA FOOD

Ingestion via dietary intake of lead made up most of the remaining contribution to total lead exposure contributions, based on national data (Food Safety Authority of Australia and New Zealand).



has been exposed (U.S. EPA, 2010). The IEUBK model has been in use for about 20 years and has been widely used by regulators for children's health risk assessments to guide decision making (Díaz-Barriga et al., 1997, Dong and Hu, 2012).

The actual individual BAC value and predicted ABA obtained from each house specific dust and soil sample set was used in the IEUBK modelling of blood lead level. Since local house specific dietary lead intake was not determined, the national average dietary lead intake was assumed for the Mount Isa children and used for the IEUBK modelling together with other default values such as maternal blood lead, soil ingestion rate etc. Despite these limitations, the IEUBK model affords a means for identifying potential lead exposure risk of children who might be living in a specific house. The discrepancy between blood survey and predicted blood lead level by the model may be due to several factors including sampling/survey period, different population (residency of children), and default input parameters for the model not being representative of Mount Isa children.

## Method Used to Determine the Health Risk in Mount Isa

These conclusions about the health risk to children in Mount Isa are based on an investigation that followed the Australian human health risk assessment procedure from enHealth.

EnHealth has developed a method for assessing the health risks of contaminants and potentially toxic substances on the population. The LPS-Air study followed enHealth's method to try to understand the possible exposure of the Mount Isa community to lead and other associated metals and metalloids. The research followed the enHealth risk assessment approach of:

- issue identification
- hazard assessment
- exposure assessment
- risk characterisation.

The project assessed the concentrations of heavy metals and metalloids in source materials, air particulates, garden soil and dust accumulation around Mount Isa City, and in areas of the mine leases and background sites. As far as possible, all potential sources of lead that could contribute to dispersion and exposure pathways of heavy metals and metalloids were identified. The study thus included historical mining sediments and natural mineralisation as potential sources, and assessed if the effects were of significance to the air–dust pathway in Mount Isa.

## Issue identification

Potential sources of the lead to which the community could be exposed via the air–particulate pathway were identified. The origin of lead to this pathway is primarily the Urquhart Shale, which is the geological formation that contains the lead and copper minerals that are mined in Mount Isa. The Urquhart Shale includes natural outcrops of mineralised material, some of which occur in the residential areas that are close to the mining operations.

The mobilisation of deposited airborne particulates from mine-related sources and/or from local surface soils derived from lead-enriched bedrock creates the direct source to community, if these particulates are present in and around the residences of Mount Isa.

To assess the concentrations of lead (and other heavy metals and the metalloid, arsenic) in material at and related to these sources, samples were collected from areas of:



1. natural outcrops of the Urquhart Shale containing the lead mineralisation and several other geological formations (mainly shale and referred to as 'background rock' or 'BGR'), without lead mineralisation, occurring adjacent to the Urquhart Shale and up to approximately 30 km from the city centre.



2. the Mount Isa mine site including:
  - i. waste rock dumps
  - ii. run-of-mine ('ROM') ore stockpiles
  - iii. lead smelter
  - iv. lead slag piles
  - v. copper crusher
  - vi. copper smelter
  - vii. copper slag piles
  - viii. tailings storage facility
  - ix. historical tailings removed from the Leichhardt River in 2008
  - x. fallout on the mine site
  - xi. dust from the haul roads associated with the Black Star open cut mine.



3. the Mount Isa residential area at locations inside and outside of houses, including:
  - i. garden soil
  - ii. the fraction of soil particles less than 10 µm in size (the 'PM<sub>10</sub> fraction'), which relate to soil particles dispersed by wind
  - iii. fallout dust in gardens
  - iv. dust on verandas
  - v. dust on roofs
  - vi. dust from roof gutters
  - vii. outdoor air particulates
  - viii. dust from carpets
  - ix. dust from other floor surfaces (such as timber floors or tiles)
  - x. dust from interior window sills
  - xi. dust from window troughs
  - xii. indoor air particulates.

Sixty-seven houses were used to examine the spatial distribution of lead and other heavy metal and the metalloid concentrations across the city. This was a statistically-representative number for Mount Isa city that was calculated using a sample size equation (Equation 4) from the geometric standard deviation (1.8 µg/dL) of the Mount Isa blood lead survey (Queensland Health, 2008) with a minimum analytical difference of 1.2 µg/dL and corrected for confounding factors (Kupper and Hafner, 1989).

Total concentration data of metals and the metalloid were examined by Q-Q plots and the Shapiro-Wilk Test to determine whether the data were normally distributed (i.e. whether they fall on a bell-shaped curve). These results indicated that the data for most elements in the samples were not normally distributed, and thus statistical tests used for normal distributions could not be used to determine the associations between various data sets. Instead, non-parametric tests were used for the statistical analyses (see Section 2.6 page 142 and Section 3.1.1 page 145). Most environmental data sets are not normal with random outliers.

Median values and geometric means were used because arithmetic means cannot be used for data that are not normally distributed.

The samples were analysed using the following analytical techniques:

- analytical chemistry techniques to determine the total concentrations of metals and the metalloid in the samples, primarily through NATA-registered analytical laboratories, but samples of air particulates, fallout dust and background rock were analysed by the Earth Science Geochemistry and Centre for Mined Land Rehabilitation ('CMLR') laboratories at the University of Queensland
- lead isotope concentration measurements, undertaken in the Radiogenic Isotope Facility ('RIF') at the University of Queensland, using high-resolution, multi-collector inductively-charged plasma mass spectroscopy ('MC-ICP-MS'). These had a higher level of accuracy, by a factor of 100 times, than all previous measurements of lead isotopes in Mount Isa
- lead  $L_{III}$  edge x-ray absorption near-edge spectroscopy ('XANES'), undertaken at the Australian National Beamline Facility, which was located at the Photon Factory in Tsukuba, Japan, with the resulting spectra being analysed using a series of steps, as part of a well-defined statistical procedure, to determine the composition of the lead minerals present, including principal component analysis ('PCA') followed by target transformation to select the set of model compounds for linear combination fitting (Section 2.4.3.1.1)
- x-ray diffraction, undertaken at the Centre for Microscopy and Microanalysis ('CMM') at the University of Queensland, to identify the mineral forms of lead present in samples, as a complement to the XANES analysis
- particle size analysis using a Malvern Mastersizer 2000 located in the School of Chemical Engineering at the University of Queensland
- scanning electron microscopy ('SEM'), undertaken at the CMM to understand the physical characteristics (such as

shape and surface roughness) of the particles present in the samples

- bioavailability testing on 10 samples of different types of lead-bearing Mount Isa material, using Sprague Dawley® rats at the Queensland Health and Forensic Scientific Services Biological Research Facility, Coopers Plains (as described above)
- bioaccessibility using the PBET (see Measuring the effect of Form of Lead in the Environment on Human Health, page 7, for more detail) to simulate the human digestive tract (see Section 2.4.5.2, page 136).

The XANES results were independently reviewed by Dr Jade Aitken, of the University of Sydney, to confirm and validate the findings.

## Hazard assessment

The framework of hazard assessment for the Lead Pathways model is given in Figure 11 Lead pathways model (blue arrows indicate potentially significant lead pathways in Mount Isa) (page 108).

The two critical factors determining the likelihood of lead getting into the blood via the air–dust pathway, and from there into other organs of the body, are the size of the lead particles in the environment and the chemical form of the lead.

The critical particles are those that are less than about 250 µm in size, which can enter the body via the ingestion pathway, and those less than about 10 µm in size, which can enter via the inhalation pathway. The study found lead particles in these size ranges present in dirt, dust and air samples in Mount Isa. However, as already mentioned, lead in air in PM<sub>10</sub> particles is below the annual average of 0.5 µg/m<sup>3</sup> specified by the *National Environmental Protection Measure for Air*, so inhalation is unlikely to be a significant source of lead.

The bioavailability tests showed that the highest bioavailability of the samples tested was 6.2 per cent (for the high-volume PM<sub>10</sub> particulate slurry) and that the bioavailabilities for the other samples were almost all less than 3 per cent (Section 3.5 and Table 117).

The same 10 samples were subjected to the PBET to determine bioaccessibility. The raw results indicated that the bioaccessibility results were about nine times higher than the bioavailability results, corresponding to a mean slope of 0.11 (Table 117). The poor relation between ABA and BAc, demonstrated by  $r^2=0.0096$ , arises from the limited data set for representative samples having very low measured ABA.

This study used a more conservative conversion of bioaccessibility to bioavailability for the measured set of representative samples (Table 117) by calculating the 95 per cent confidence interval. The slope of the upper level of the 95 per cent confidence interval (0.17) was selected as being most conservative, which resulted in the use of the conversion equation on page 9 to convert from bioaccessibility to bioavailability. In statistics, the 95 per cent confidence interval is normally used. In this case, the 95 per cent confidence interval has a lower bound slope



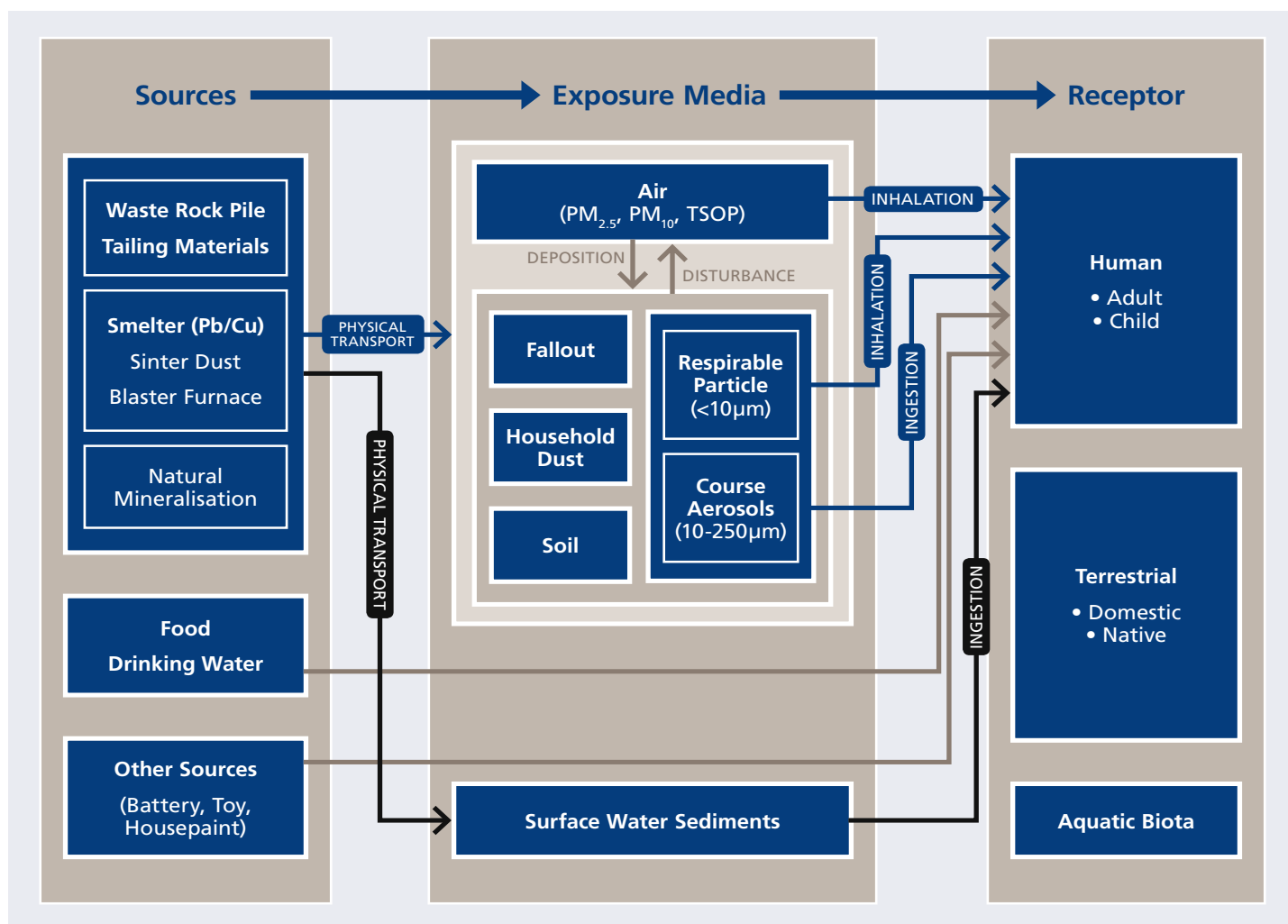


Figure 11 Lead pathways model (blue arrows indicate potentially significant lead pathways in Mount Isa)

of 0.05 and an upper bound slope of 0.17. The basis of using a conservative approach is demonstrated in Australia by the NEPC (2013) using upper bound values, such as BMDL<sub>05</sub> for arsenic, following withdrawal of the PTWLs for arsenic and lead in 2010 (JECFA, 2010). As a result of using the conservative approach, the bioaccessibility was assumed to overestimate the bioavailability of the samples by a factor of 5.88 times rather than 9 times, meaning that the calculated bioavailabilities used in this study were higher than indicated by the raw results, which have a slope of 0.11. That is, the conversion factor used, which lies within the 95 per cent confidence interval, results in the conservative assumption of more lead being absorbed by the body than the actual bioavailability tests indicate.

The median bioaccessibility of sub-set of ten representative and/or composite samples for bioavailability measurement was 14.9% (cf. mean 14.8% Table 117) which was lower than all samples obtained from the mine site (%BAC = 29; Table 101) and the city samples (%BAC = 21; Table 114).

## Exposure assessment

The US EPA's IEUBK model has default values for the various sources of lead to which a child might be exposed. These default values include, but are not limited to: lead in food,

maternal blood lead level, the bioavailabilities of lead in dusts that might be ingested or inhaled, and lead in water. The accuracy of the predictions produced by the model will depend on correction of these default values for site-specific values. These site-specific values included measured levels of lead in dust, soil and high-volume PM<sub>10</sub> air sampling in a sample set of 67 houses in Mount Isa.

## Risk characterisation

Risk characterisation brings together the previous three steps of the risk assessment and enables the risk to be assessed, in this case the potential effects of lead on the population of Mount Isa, and provides a way to consider what decision or management processes may be needed to deal with identified risks.

If the dust and soil input parameters in the IEUBK model were adjusted using the absolute bioavailability data, there was no predicted exceedance ( $\geq 10 \mu\text{g/dL}$ ) of the NHMRC blood lead investigation level that would result from living in the houses sampled. The model predicted that the soil contributed 19 per cent (median value) of the blood lead and the various sources of dust, 51 per cent. Given the dominant role of ingestion as the transfer pathway of lead to children, it is likely that hand-



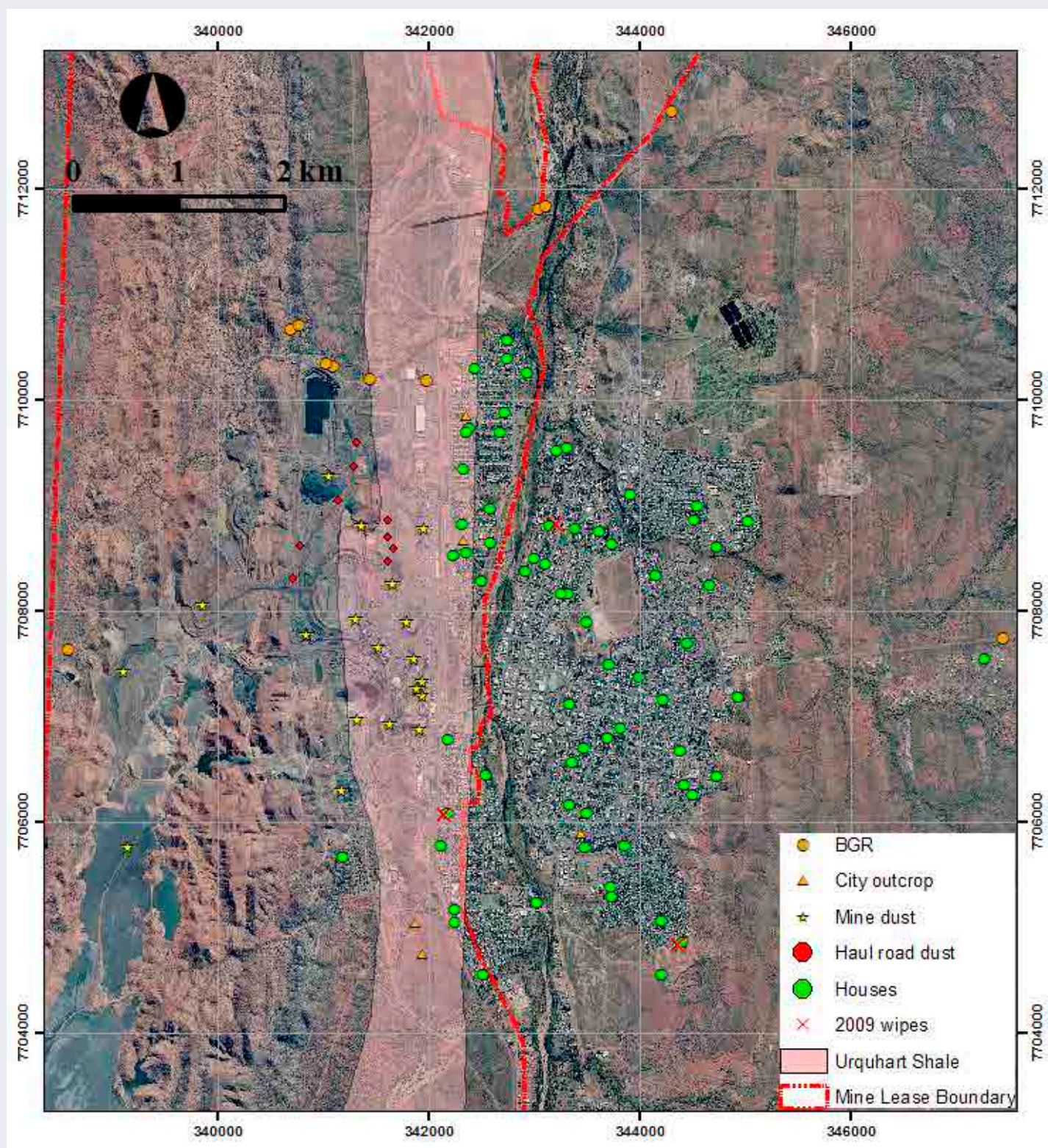


Figure 13 Locations of sampled residential houses, the mine site, and geological sequence outcrops\*

\* BGR are background rocks comprising bulk bedrock samples from different geological units not associated with Urquhart Shale lead mineralisation in and beyond Mount Isa City residential area.



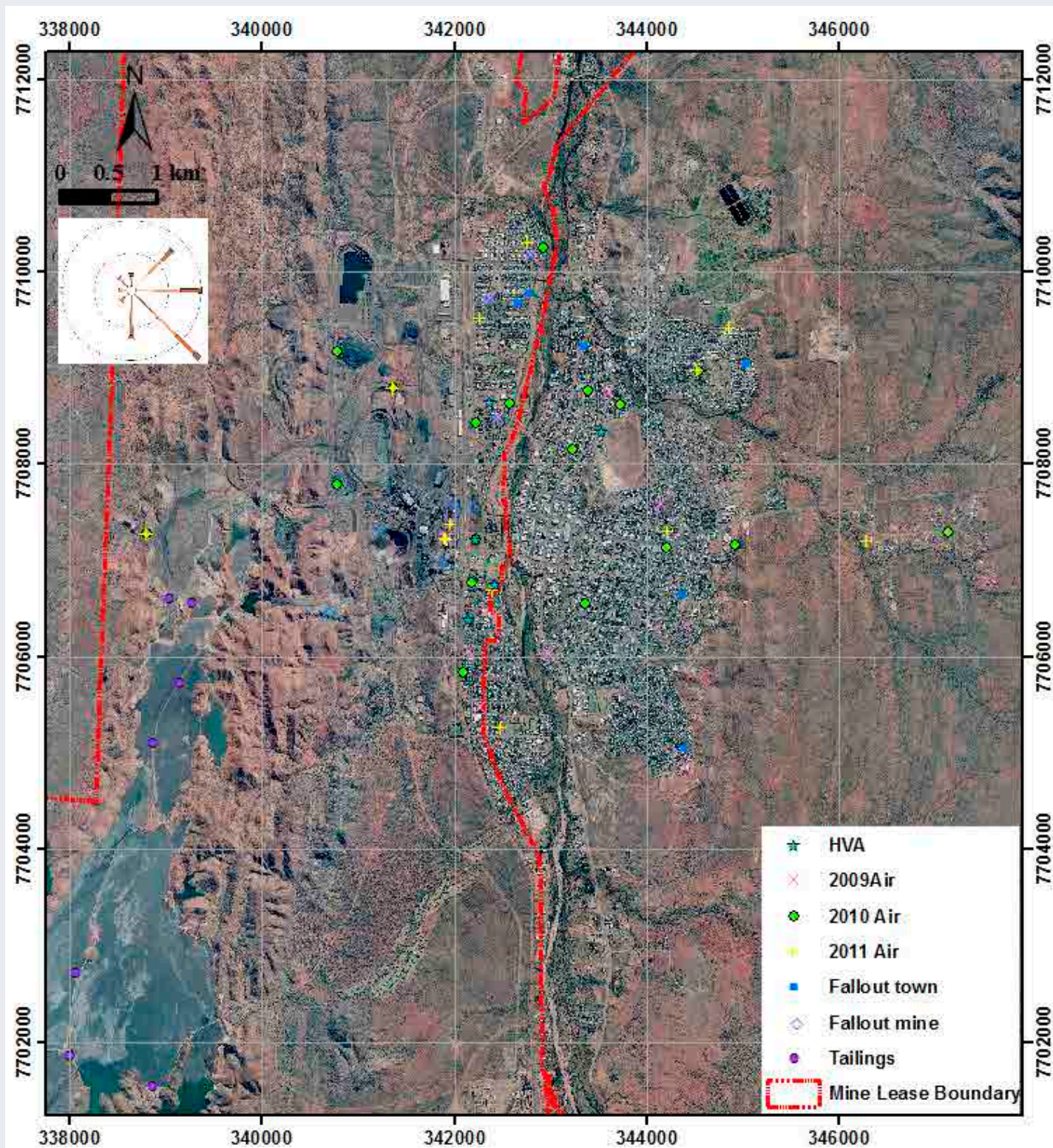


Figure 14 Locations for sampled air particulates and fallout from residential houses and the mine site



## IEUBK MODEL

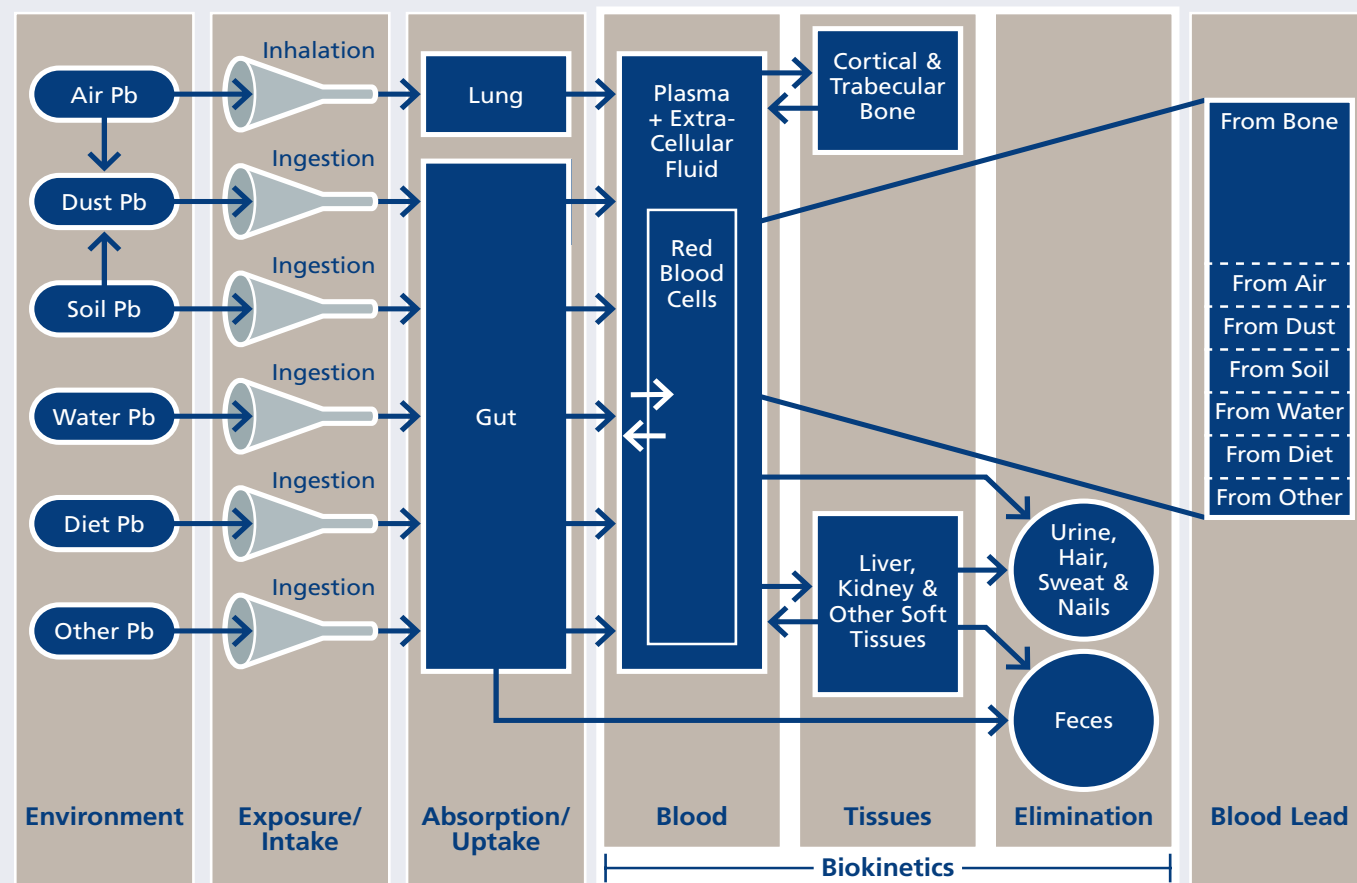


Figure 8 Lead pathway via environmental exposure sources, absorption compartments, critical body tissue compartments, and elimination

to-mouth behaviour by young children in an environment where lead in soil and dust is present is a significant contributing influence on blood lead concentrations.

The predicted blood lead results produced by the IEUBK model are in the form of probability distributions rather than a single value for each house. The model predicts different values for children grouped according to age within the range of either 0.5–7 or 1–4 years. Thus, the output results are summarised in terms of geometric means for each house and the associated probability of exceedance of the recommended level.

When the more conservative bioaccessibility numbers were used for the dust and soil samples, the IEUBK model predicted a mean value of the geometric means of the blood lead level for children living in each of the 67 houses of 3.8 µg/dL, and a median of 3.4 µg/dL, with 1 per cent of the children exceeding the recommended level of 10 µg/dL or a median of 3.8 µg/dL, with 1 per cent of the children exceeding the recommended level of 5 µg/dL (see Table 128, page 286). The highest predicted levels were associated with houses with the highest levels of lead in the dust and garden soils and these were located in areas underlain by the Urquhart Shale.

The blood lead concentrations predicted by the IEUBK model were compared with blood lead screening programs undertaken

by Queensland Health in Mount Isa in 2006–2007 and 2010 for children aged 1–4 years (only this age group was tested) (see the data from Table 140 'Comparison of blood lead concentrations between the IEUBK model's prediction and blood lead testing programs for children in Mount Isa' following this text).

The geometric mean of blood lead concentrations of the children tested by Queensland Health was 4.97 µg/dL in 2006–2007 and 4.27 µg/dL in 2010. Note also that the use of 'average' bioaccessibility data produced a closer match to the Queensland Health measurements of children's blood lead levels in Mount Isa.

There are several possible explanations for the difference between the measured blood lead levels and the IEUBK model predictions using the preferred bioavailability of lead, including:

- the houses sampled for this study might not have been the same as those in which the children sampled in the Queensland Health study were living, and it is thus possible that there exist houses where children have higher exposures to lead than in those sampled in this study
- children with higher blood lead levels in the Queensland Health study might have been ingesting more dust or soil than the default amount of 100 mg/day set by the model (e.g. through eating dirt)

8 5 µg/dL is the current NHMRC (2016) blood lead level for investigation.



Location Data source	Mount Isa Queensland Health (2011)	Mount Isa Queensland Health (2011)	Mount Isa IEUBK model prediction (BAc approach) in this study	Mount Isa IEUBK model prediction (ABA approach) in this study
Test time	2006–2007	2010	2008 and 2010	2008 and 2010
Age group	1–4 years	1–4 years	1–4 years	1–4 years
Test number (n)	400	167	67	67
Maximum (µg/dL)	31.5	22.4	11.2	3.19
Minimum (µg/dL)	1.3	1.9	1.6	1.18
Number over 10 µg/dL	45	8	1	0
Percentage over 10 µg/dL	11.3%	4.8%	1.5%	0
Geometric mean (µg/dL)	4.97	4.27	3.8	1.63
95% confidence interval	(4.69, 5.24)	(3.96, 4.61)	(3.35, 4.25)	(1.53, 1.72)
Number over 5 µg/dL	203	73	17	0
Percentage over 5 µg/dL	50.8	43.7	25.37%	0

Table 140: Comparison of blood lead concentrations between the IEUBK model's prediction and blood lead testing programs for children in Mount Isa.

- the dietary intake of lead by children in Mount Isa might be higher than the assumed Food Safety Authority of Australian and New Zealand ('FSANZ') national diet data<sup>9</sup>, which were used as input data for the model
- the children might have been exposed to additional sources of lead from lead-based paint, leaded petrol residues, and lead acid batteries that were not included in the IEUBK model input assumptions.

## Sources of the Lead in the Mount Isa Environment

The results in this study indicate that the PM<sub>10</sub> air particulates exiting from the Mount Isa smelter stacks were not the major sources of lead exposure via inhalation in the Mount Isa city area at the times the samples were taken. The major source of lead exposure is via ingestion in the community and is from air particulates (< 250 µm diameter) that are on the ground from deposition as fallout.

This conclusion is based on measurements of lead isotope ratios that show a clear fingerprint of lead originating from the Urquhart Shale on the mine site and in Urquhart Shale outcrops in the city area. The copper smelter stack samples, on the other hand, have their own distinct fingerprint, and this was not visible in the samples obtained from the city during this study.

The XANES analysis of PM<sub>10</sub> air particulates exiting from the Mount Isa lead smelter stack contained negligible lead sulfide, whereas near surface samples of dust and fallout from the lead smelter/sinter plant area collected at the surface or at 2–3 metres above ground usually contained lead sulfide. Roof gutter dust did not contain lead sulfide.

In addition, PM<sub>10</sub> samples obtained during a period in 2010 when the lead smelter was shut down for maintenance showed no apparent difference in lead concentrations from those taken

in 2009 and 2011. This implies a minimal contribution from the lead smelter operations to these samples to the 2009 and 2011 samples, when the smelter was operating together with re-entrainment of deposited smelter dust.

Lead isotope ratios can show origin of lead regardless of chemical or mineral form while XANES analysis gives the chemical form. XANES analysis may show differences even when lead isotope ratios are shown to be the same.

Further, PM<sub>10</sub> particles obtained in the lead smelter and from the lead slag stockpile showed smoother features than those from the city samples or the mining samples. This again indicates that the lead blast furnace and its slag product are not major contributors to the PM<sub>10</sub> samples collected in the city.

This finding contrasts with that reported for Port Pirie, where the source of lead in the community has been attributed to both the lead smelter there and re-entrainment of dusts. A sub-set of seven behavioural factors was most predictive of an elevated blood lead level for the 1982 Port Pirie blood lead survey (Wilson et al., 1986) and were incorporated in the program to reduce the risk of elevated blood lead levels in Port Pirie children. These were:

- household members who worked with lead in their occupations
- living in a house with flaking paint on the outside walls
- biting finger nails
- eating lunch at home on school days
- when at school, appearing to have relatively dirty clothing
- when at school, appearing to have relatively dirty hands
- living on a household block with a large area of exposed dirt.

<sup>9</sup> A national average based on foods regularly consumed by the Australian population such as from supermarkets that might be underestimate the dietary intake of a population who live in a mineral rich or smelting area and consume locally grown food items

Some of these factors may also play a role in Mount Isa, particularly in cases where children are found to have higher blood lead levels. A key difference between locations is that Mount Isa has both mining and smelting of lead whereas Port Pirie has smelting, only.

The lead isotope ratio work indicated the existence of a second source of lead in the Mount Isa environment, tentatively identified as the Cromwell sequence located to the east and upstream of the Mount Isa city area. Lead from this source was found to have mixed, probably over geological time, with lead from the Urquhart Shale. This mixing was most apparent in garden soils, nature strip soils (referred to as 'footpath' samples), the soil PM<sub>10</sub> fraction, PM<sub>10</sub> in outdoor air, carpet dust and, to a lesser extent, window trough dust.

It was not possible from the lead isotope work to distinguish between lead originating from the Urquhart Shale in the residential area and that being mined on the mine site.

XANES analysis of samples showed that samples from Black Star open cut and the processing areas contained significant lead sulfide (PbS), but it was absent from the haul road, tailings dam surface material and the surface outcrops of the Urquhart Shale. In the latter three materials, the lead was predominantly present as lead-goethite.

The presence of lead sulfide in fallout, PM<sub>10</sub>, carpet dust samples in the city indicates that some of the material collected originated from mining and/or processing activities. However, the presence of large proportions of lead-goethite in these samples makes it impossible to rule out dusts from other sources, such as garden soils and other exposures of bare earth in the city, haul roads and tailings dams.

## Risk Reduction Measures

Use of the IEUBK model indicated that the key contributions to blood lead levels in Mount Isa children were from lead in soil, surface dust and food. The contributions from airborne dust and water were insignificant in comparison. The houses with the highest concentrations of lead in dust and soil were those with the highest predicted blood lead levels in children.

Queensland Health has found associations in Mount Isa between children's blood lead and factors, such as owning pets, chewing non-food items, and bare soil in the backyard (Queensland Health, 2008, Queensland Health, 2011).

Lead in carpet dust makes a significant contribution to blood lead levels as confirmed by the high correlation ( $r^2 = 0.79$ ) between the IEUBK model's predicted blood lead concentrations for young children (1–4 years) and the bioaccessibility-adjusted data for lead in carpet dust. The IEUBK model also predicted that blood lead concentrations for young children are significantly correlated with bioavailability-adjusted lead in carpet dust ( $r^2 = 0.79$ ); in comparison, the

correlation with garden soil was somewhat lower ( $r^2 = 0.35$ ). This finding confirms the significant contribution to blood lead level risk from lead in carpet dust as a health risk as well as a source of lead, and indeed a greater risk than that from garden soil.

The following measures could be taken to further reduce the exposure of Mount Isa children to lead and their consequent risk of having an elevated blood lead level:



- **Industry operations:** Continue to focus on effective measures to reduce mine dust transfers from key lead sources at the mine site operations, such as haul road dust, mining activities, surface tailings, crushed ore transfer, concentrate handling and the surface dust lying in the lead smelter area (as distinct from stack emissions which are deposited far beyond the Mount Isa city area). Ensure that clean-in, clean-out policies continue to be enforced in all lead work areas.



- **Maintaining the home environment:** Bare patches in gardens should be covered with grasses. Carpets should be replaced with timber or other hard floor coverings, and cleaned with phosphate-based cleaning agents. Phosphate is known to immobilise lead and reduce its bioavailability upon ingestion. Houses should be cleaned frequently, by vacuuming and wiping away any accumulated dust (preferably with a damp cloth). Pet ownership should be reviewed in areas with elevated lead concentrations in the soils.



- **Personal hygiene:** Ensure children clean their hands frequently, particularly before meals. Try to reduce children's habits such as sucking non-food items. Keep children away from all potential sources of lead from both geogenic and anthropogenic origins.



- **Attention to diet:** Wash home grown fruit and vegetables thoroughly before eating/cooking; peeling root crops will also reduce lead exposure. Better still: avoid eating home grown vegetables and fruits whose skin cannot be peeled before consuming. Good nutritional food contains certain food components that can also reduce lead adsorption resulting in lower blood lead.





## RECOMMENDATIONS

1. Ensure that all Mount Isa residents, in particular young children, have their blood lead levels monitored. This is to ensure that health management actions are taken, any circumstances leading to elevated blood lead levels in children are identified early, and exposures to lead are minimised.
2. Maintain the existing mechanisms in place to minimise transfer of lead to the residential areas, such as the vehicle washing, clean-in, clean-out clothes policies, the AQC system, road sweeping and watering.
3. Continue to look for ways to minimise the transfer of dusts, particularly those containing lead and other heavy metals and the metalloid, from the active mining and processing areas to the city.
4. Emphasise the importance of a clean home environment in Mount Isa.
5. Consider replacing carpets with timber or other hard floor coverings, and cleaning these floor coverings with phosphate-based cleaning agents.
6. Promote personal hygiene, such as cleaning children's hands frequently and before meals and minimising specific habits of very young children such as sucking non-food items and keep away from uses of lead including historical paint and petrol residues.
7. Wash all home grown fruit and vegetables thoroughly before eating/cooking; peeling root crops will also reduce lead exposure.
8. Highlight the improvement in children's blood lead levels that has occurred in Mount Isa as a result of actions taken by MIM and members of the Mount Isa community. These results show that measures being taken are helping to minimise children's blood lead levels and demonstrate that a diligent approach to reducing lead exposures does work.





## Areas that would benefit from further work

Areas that would benefit from further work include:

1. A closer examination of the reasons for the differences between the blood lead levels predicted by the IEUBK model and those measured in the Queensland Health survey. As mentioned on page 16, these might include differences in the populations sampled in the two studies or additional sources of lead exposure that were not accounted for in the IEUBK modelling (such as a higher dietary intake than in the national food basket, higher than normal ingestion of such lead-containing materials as dirt, or exposure to a lead source not considered in the model).
2. More work to pinpoint the sources of lead at the mine site to enable further reductions in transfers from the mining and processing activities to the residential areas. Testing soils for houses overlying the Urquhart Shale area should be undertaken to determine whether they are an issue.
3. Investigation of homes of children with elevated blood lead levels to determine whether there are other sources of lead, such as lead paint on toys or lead incorporated into plastic toys, lead solder used in making stained glass, lead in batteries being recycled at residences, and lead in ceramic dishware or leaded crystal beverage containers.
4. More work to increase the number of measurements of bioavailability to improve the statistical relationship between bioaccessibility and bioavailability.
5. Consider the issues raised that would benefit from further work and determine whether this work is necessary.





## Professor Jack Ng

Professor Jack Ng has a PhD in Environmental Toxicology and Chemistry from The University of Queensland. He is a certified toxicologist (Diplomate of the American Board of Toxicology). Jack is currently the Theme Leader of Environmental Health Risk

Assessment at the Queensland Alliance for Environmental Health Sciences (QAEHS, incorporating the former National Research Centre for Environmental Toxicology (Entox)), Faculty of Health and Behavioural Sciences of The University of Queensland. He is also the Program Leader for Minimising Uncertainty in Risk Assessment Program in the CRC-CARE (Contamination Assessment and Remediation of the Environment). He has extensive research experience in the fields of Environmental Toxicology and Chemistry, heavy metals and natural toxins. He focuses on the relevance of speciation and bioavailability as key parameters for risk assessment. Much of his research aims to generate data to fill gaps that are necessary for a risk-based approach under the risk assessment framework. Jack has a list of over 400 publications of which about 200 are peer reviewed articles, monographs, technical reports and book chapters. He has completed numerous technical reports related to risk assessment of contaminated sites for the industrial as well as government agencies.

At an international level, Jack's expertise in his field of environmental toxicology research and risk assessment has been recognised by the World Health Organisation (WHO), International Agency for Research on Cancer (IARC), and WHO/FAO Joint Expert Committee on Food Additives (JECFA) as demonstrated by his contribution to a number of monographs and technical reports produced by these agencies. Jack is a Coordinating Editor of the Environmental Geochemistry and Health Journal, editorial board member of Journal of Toxicology, and reviewer of numerous international scientific journals, national and international granting agencies.

At a national level, Jack served as a member of the National Health and Medical Research Council Health Investigation Levels (HIL) Working Committee who oversaw the setting of the current National Environmental Protection Measures (NEPM) HILs. He was also a member of the CRC CARE Project Advisory Group for the setting of Health Screening Levels (HSL) for petroleum hydrocarbons which have been adopted nationally by various jurisdictions and stakeholders. Jack is the lead author of the Bioavailability/Bioaccessibility Technical and Guidance documents, and the latter has been adopted into the current NEPM by the National Environmental Protection Council (NEPC) in 2013. Jack is an assessor for Registrants and Fellows of Toxicologist and/or Risk Assessor of the Australasian College of Toxicology and Risk Assessment. Jack provides toxicology expert support to a number of environmental auditors in Australia.



## Dr Violet Diacomanolis

Dr Violet Diacomanolis has completed her PhD in June 2013 with the National Research Centre for Environmental Toxicology, the University of Queensland, and undertaking the rat bioavailability study for the Lead Pathway Project at Mount Isa.

Dr Diacomanolis has a Masters degree in Toxicology from the University of Tehran.



## Dr Raijeli Taga

Dr Raijeli Taga has completed her PhD in 2016 with the CMLR, the University of Queensland, and undertook a variety of the studies for the Lead Pathway Project at Mount Isa. Dr Taga also has undertaken a Masters degree in Environmental Toxicology

at the University of Queensland.



## Professor Hugh Harris

Professor Hugh Harris is an Australian Research Council Queen Elizabeth II Fellow in the School of Chemistry and Physics at the University of Adelaide. He has a PhD in Chemistry from the University of New South Wales (2000), and has worked as a

postdoctoral fellow at Stanford University and the University of Sydney. His main research focus is on utilising synchrotron-based techniques, such as x-ray absorption spectroscopy and x-ray fluorescence imaging, to understand the roles that metals play in biological systems. This spans work on fundamental biochemical and structural studies of metalloproteins, deciphering modes of action of metal-based pharmaceuticals, and the relationship between intake of essential or toxic heavy elements and the development and progression of a range of diseases. He has demonstrated the advantages of x-ray techniques in the area by determining the chemical form of mercury in fish bound for human consumption, showing that mercury from dental amalgams can migrate through teeth to the bloodstream and by mapping intracellular targets for elements such as selenium and arsenic.

He is the author of nearly fifty journal publications, including papers in highly regarded journals such as *Science*, *Environmental Science and Technology* and *Chemical Research in Toxicology*. He has served on a number of committees for the Australian Synchrotron including as chair of the X-ray Fluorescence Microscopy Proposal Advisory Committee, the User Advisory Committee and the National Science Consultative Group.

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