FULL DESCRIPTION OF MOUNT ISA CONTAMINANT RESEARCH
Title of work toward better environment outcomes:

Human and environmental health risks associated with metal mining in and around Mount Isa, north-west Queensland, Australia

Brief summary of the research:

Our research represents the only comprehensive peer-reviewed environmental investigation of sources, risks and implications of metal contaminants to human and ecosystem health in and around Mount Isa. It details the historic and ongoing impact of catchment land uses, primarily Xstrata’s Mount Isa Mines operations, on the natural and urban environment. Environmental lead is a particular focus because of the recognized negative intellectual and socio-behavioural impacts on children. Our findings have been published in national and international journals and media and have been instrumental in highlighting the environmental contaminant problem at Mount Isa to the public and industry and government stakeholders. Our research has taken a holistic approach. We have applied a ‘source-to-sink’ method, to examine the impact of Xstrata’s Mount Isa Mines’ operations (XMIM), Australia’s leading lead-zinc-silver and copper producer, on the adjoining natural and urban environment.

We have examined metal and microbial contaminants in river sediments and waters, the potable water treatment system, aquatic biota, urban soils, household dusts and aerosols in order to understand the sources, pathways and relative environmental and human health risks associated with catchment land uses. We have complemented our studies by examining the: i) local geology to elucidate the relationship between natural mineralization and environmental contamination; ii) blood lead data of Mount Isa children to understand the real health impact of environmental contaminant exposure; and iii) efficacy of the advice and treatments being used to limit exposure to lead in the Mount Isa community. While other unpublished studies have been undertaken, they have either not focused on the urban environment and the risks posed to its residents, or have been severely limited in their spatial assessment. Therefore, our work represents the first independent, comprehensive, system-wide published human and environmental assessment of the impacts arising from metal and smelting mining on Mount Isa’s natural and urban environment since ore extraction and processing began in 1931.

Research aims and objectives

The principal aim of our program of study was to evaluate qualitatively and quantitatively the “human and environmental health risks associated with metal mining in and around Mount Isa”. In doing so, we aimed to understand for the first time the actual environmental and human health impacts associated with metal contaminants in a range of media including air, biota, dust, sediment, soil, and water. These findings were developed environmental and human health risk
assessment frameworks, in order to fully understand the relationship between environmental contaminants, primarily lead, and the impacts on the local community and surrounding ecosystems. Overall, we aimed to generate sound scientific data to help the Mount Isa community and government and industry stakeholders make informed, evidence-based decisions with respect to public and environmental health. Although the focus of this research is based in and around Mount Isa, the methods, results and implications are of direct and significant relevance to other national mining and smelting towns.

The specific objectives of our program of study were to:

1. Quantify the extent and impact of mining-related activities at Mount Isa on the surrounding human (urban) and natural environments;

2. Examine the degree to which the community and ecosystems that surround mining-related activities are being exposed to environmental metals via a range of pathways, including soil, sediment, water and air;

3. Evaluate the seasonal variation and relationship of proximity to the contamination source as factors influencing exposure;

4. Determine the potential risk of harm of metals associated with different environmental media by reference to relevant international and Australian guidelines for the assessment of human and ecological health. This evaluation also included the estimation of the uptake of digested metals (bioaccessibility) by using simulated human gastro-intestinal tract acid extractions;

5. Recommend possible management schemes based on research outcomes to reduce the negative impacts of metal contaminants in the community and the environment;

6. Provide baseline data to enable natural resource, industry and health authorities to make more informed decisions regarding metal contaminant management in the upper Leichhardt River catchment and Mount Isa urban area.

Background – Environmental lead contamination in Australian mining and smelting towns

Mining is a major industry in Australia and contributes approximately 8% to the annual gross domestic product. However, contamination of urban, riverine and agricultural ecosystems with fine-grained toxic metal mining waste is commonly associated with these activities. Several environmental and geochemical studies have highlighted metal contamination issues at Australian mining, smelting and port towns, including Broken Hill, Port Pirie, Lake Macquarie, Wollongong, Rosebery and Esperance. In towns such as Broken Hill, Port Pirie and Mount Isa, these problems may be exacerbated by the prevailing semi-arid climate, where sporadic, high-intensity rains are followed by extended dry periods. Consequently, metals are exposed to highly variable physicochemical conditions, which may influence significantly the chemical and physical distribution patterns,
remobilization routes and exposure pathways. For example, semi-arid environments are characterised by low rainfall, sparse vegetation and localized winds that can generate considerable dust (grainsize < 250 µm). Dusts are readily entrained, often harbour toxic metals, in particular lead, which are easily inhaled and/or ingested.

The deleterious consequences of environmental lead exposure are well understood by the scientific and medical communities. The neurotoxic effect of lead on children is a particular concern, especially if they are exposed at a young age. In addition, with other biologic and socio-demographic factors, exposure to lead has been linked with decreased IQ and academic achievement, as well as to a range of socio-behavioural problems such as attention deficit hyperactivity disorder (ADHD), learning difficulties, oppositional/conduct disorders, and delinquency. These are disabling mental health issues that often persist into adolescence or adulthood. To date, the majority of research on the neurocognitive and behavioural effects of lead exposure across development has been conducted in the US, and there are very few studies that have examined impacts and long-term outcomes in Australian populations.

The Mount Isa contaminant problem

A handful of studies in the upper Leichhardt River catchment and Mount Isa urban area had previously identified the presence of elevated aqueous and sediment- and soil-associated concentrations of potentially toxic metals and synergistic elements (e.g. silver, aluminium, arsenic, cadmium, copper, lead, sulphur, selenium and zinc), with some concentrations exceeding Queensland Environmental Protection Agency investigation thresholds for contaminated land. However, the source of contamination, including the extent and impact of mining-related activities at Mount Isa on the adjacent community, and surrounding urban and natural systems, was unquantified. The lack of research on the environmental and human health impacts in the region was surprising, given that mining and ore processing had been conducted in Mount Isa for over 80 years, and that research in other areas had shown clear links between large-scale mining, environmental pollution and human health problems. Where previous research had been conducted in Mount Isa, findings were generally recorded in grey literature, government reports, or had only recently become accessible in the public domain. For example, the Parry (2000) report on metals in the soils and surface waters that surround the mining and smelting operations at Mount Isa was released in 2008, following complaints from the contributing scientist that the research was not available to the public.

There were three major factors to be considered in our studies of Mount Isa and the environmental contaminant problems. Firstly, Mount Isa is located in the semi-arid zone of Australia and experiences climatic extremes throughout the year. This has significant implications for the storage, transportation, physicochemical alteration and exposure pathways of metal contaminants
in both the riverine and urban settings. Secondly, the Mount Isa community relies on wet season stormwater runoff from the upper Leichhardt River catchment to resupply their principal potable water reservoir. Such runoff has historically been contaminated with a range of potentially harmful contaminants and little was known about the hazards and risks to water quality throughout the water supply network. Finally, many of the local Mount Isa residents and indigenous Kalkadoon people, including young children, utilise floodwaters, dry season waterholes and dusty environments for recreation and other purposes. It is therefore highly likely that some members of the community are being exposed directly to a range of metals in a variety of environmental media. Preliminary studies have indicated that environmental contaminants may be present in and around Mount Isa. However, systematic sampling had not been completed to evaluate the specific level of human or environmental risk in Mount Isa's residential areas. In summary, given the potential risks particularly to children, there was a pressing need to examine empirically the threat that environmental metal contamination poses to the health of the Mount Isa community and the surrounding environments. Therefore, it was timely that an independent body conducted a systematic evaluation, with no conflict of interest, of the human and environmental health risks associated with metal mining in and around Mount Isa.

Research outcomes

Our program of study has produced numerous outputs that reflect the research objectives. These are described below (Study 1 through to Study 12) and are separated into three broad themes:

(i) aqueous contaminants in river environments;
(ii) non-aqueous metals in the urban environment; and
(iii) public health risks and impacts of environmental contamination.

These themes relate to the systematic, integrated and multi-disciplinary approach we have used to elucidate the impact of catchment land use activities on natural and human systems in and around Mount Isa.

(i) AQUEOUS CONTAMINANTS IN RIVER ENVIRONMENTS

Study 1


In the first instance, we sought to characterise the impact of mining activities on sediments in the upper Leichhardt River, which runs adjacent to XMIM and Mount Isa city (Study 1). Study 1 revealed that sediment-metals were significantly elevated adjacent to the footprint of XMIM and that the tributaries draining the mining lease were clearly contributing sediment-associated copper, cadmium, lead and zinc to the main channel of the Leichhardt River. This research provided an
important baseline for the subsequent studies, which were designed to understand more clearly the spatial and temporal release, transfer and storage of metals, and other contaminants, in the upper Leichhardt River system.

**Study 2**


Upon identifying that sediment-metals, at environmentally undesirable levels, were present in the channel system, we set out to understand the broad-scale risks that these contaminants may pose to water quality in the upper Leichhardt River-Lake Moondarra catchment. In order to characterise these risks, we undertook a source-to-sink assessment of the water quality arising from land use activities in the catchment. This research (Study 2) details how we identified sources of metal and microbial contamination in water and sediment, as well as quantifying the extent of pollution using Australian regulatory risk assessment frameworks. We also collected and analysed fish and crayfish tissue to determine if the metals were being absorbed by aquatic species – a measure of bioavailability. The results showed that water quality in the river channels was seriously impaired and were unsafe for human activity both from a metal and microbial contamination perspective. The study also revealed that the river borne metals were particulate bound and are not bio/accumulating in fish species in Lake Moondarra. In addition, because the metals were primarily particulate bound the potable treatment system (Clear Water Lagoon), which relies largely on sedimentation and filtration by aquatic vegetation, was able to produce potable water within Australian drinking water guidelines.

**Study 3**


In order to complete our catchment water cycle assessment, we obtained environmental data from the natural reed-bed potable water processing facility (Clear Water Lagoon), which is used to treat runoff from the upper Leichhardt River-Lake Moondarra catchment for drinking water supplies (Study 3). The research details the design and utility of sedimentation pond and aquatic macrophytes that are fundamental in the output of potable water to the Mount Isa community and associated industries. Overall, this study demonstrates the efficacy of the Clear Water Lagoon system for the treatment of drinking water supplies.
**Study 4**


Our water quality assessment of the Clear Water Lagoon system (Study 3 and also included in T. Kuypers, unpublished MPhil. thesis, 2009) was not limited to a bio-physical and chemical assessment. We paralleled this study with an economic evaluation (Study 4), where we compared the cost of replacing the natural reed-bed clarification system with the more commonly used slow sand filtration system. Our study showed that not only was the system effective at removing metal and microbial contaminants, but it is ~ 35 % cheaper to run (estimated $12.6 million) over a 100 year life cycle.

**Study 5**


Having established the broad-scale knowledge that metals contaminants are present in the upper Leichhardt River, we sought to better understand the effect of seasonality on the transfer of contaminants throughout the system. The wet season flows were typically flashy, violent and turbid and potentially dangerous to measure and observe. In response, we developed a field-based siphon sampling method for use in semi-arid environments (Study 5). This sampling method allowed us to capture rising stage flood waters and any associated metal contaminants.

**Study 6**


The method described in Study 5 was used to capture catchment runoff and river flows associated with major storm events in 2007 (Study 6). The results showed that during wet season flow metals exhibited a high affinity to the total suspended sediment load (i.e. particulate bound fraction) and are transferred in flush pulses. These data confirmed that metals are being derived from the mining lease and that during the early stages of river flow, collected water samples exceeded Australian environmental guidelines values by several hundred times. These findings are significant because they reveal that targeted remediation needs to occur in the upper Leichhardt River adjacent to XMIM and in the associated tributaries. In addition, our findings showed that to reduce exposure to environmental lead and other metals that it would be prudent for management to fence off the river channel close to the mine and that appropriate signage needs be placed in this area to indicate the health risks associated with swimming and recreating in contaminated river water.
**Study 7**


To complete the assessment associated with aqueous metal environments, we sought to ascertain the capacity of geomorphological units, such as pools, to physically and chemically store and alter metal contaminants (Study 7). This is an important element of our assessment because although the river only flows during or shortly after rainfall events, the channel retains water in these pools throughout the dry season. These pools provide essential drinking water resources for domestic livestock and are utilised by local people for bathing and swimming. Through investigating the geochemical properties of river sediment, this study further confirms that metal contaminants are sourced from the mining and smelting activities at Mount Isa. However, this study showed that the pools were not a major repository of sediment metals and did not pose the same environmental health risk as floodwater or dry channel bed sediments, indentified in the earlier studies. Although the risk is much reduced, we have advocated as a precautionary measure, restricting access to the pools to limit or completely mitigate exposure to these environments for humans.

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**(ii) NON-AQUEOUS METALS IN THE URBAN ENVIRONMENT**

**Study 8**


To parallel the studies undertaken in the aqueous environments, we further sought to understand and characterise the metals in the terrestrial setting, primarily in Mount Isa urban area. Study 8 is the first of two studies that investigated the spatial relationships between likely sources and causes of elevated dust- and soil-metal concentrations (cadmium, copper, lead and zinc) across the urban area of Mount Isa. During this study, we employed a broad-scale sampling technique to better understand the spatial distribution of metals in soil and dusts throughout the Mount Isa urban area. We used multiple lines of evidence in this study to support our conclusions that surface urban soils were contaminated by mining and smelting emissions. In addition to 60 soil samples, we collected a further 49 samples from shallow pits, analysed geological data, undertook geographic information systems spatial modelling of soils and carried out atmospheric AUSPLUME modelling of airborne lead. Our results were also interrogated using statistical analyses to show that the soil surface spatial metal patterns and inter-metal relationships could not be caused localised weathering of the mineralised sub-surface ore bodes. Akin to the studies of aqueous metals, this research also provides unequivocal evidence that both historic and ongoing emissions from mining activities are contaminating the urban environment.
**Study 9**


Following from the findings in Study 8, and the public revealing of lead poisoning issues in Mount Isa children (Queensland Health, 2008), Study 9 was undertaken to examine and identify potential sites, pathways and bioaccessibility of urban metal sources in Mount Isa, with a particular emphasis on their potential impact on childhood health. This study utilised lead isotopic geochemical fingerprinting techniques and simulating human physiology (to measure metal bioaccessibility) to characterise and quantify the sources and risks of metals throughout residential homes in Mount Isa. This study provides further evidence that both historic and ongoing emissions from mining activities are contaminating the urban environment and having an adverse effect on human and environmental health. Most significantly, this study shows that on average 70 % of metals in a digested soil or dust samples is bioaccessible, i.e. freely available for the body to take into the blood stream. Given the ongoing contamination originating from mining and smelting activities, this study emphasises that remediation and reductions in mine emissions are required and more stringent regulatory actions are warranted.

**(iii) PUBLIC HEALTH RISKS AND IMPACTS OF ENVIRONMENTAL CONTAMINATION**

**Study 10**


Having identified the spatial and temporal impact of emissions from the mining and smelting operations at Mount Isa, we began to evaluate the response to the emerging public health problem by the Queensland Government and Xstrata Mount Isa Mines Pty Ltd. In both cases we identified systematic policy, media statements and advertising that minimized the well-understood risk and effects of childhood exposure to environmental lead (Study 10). These included statements such as that by the Queensland Health Director who noted that he “was not able to say what concerns someone with a blood lead level of more than 30 µg/dL should have.” We were prompted to write our article, supported by local media coverage, because we knew from the research literature that such statements are both misleading and ill informed. Indeed, we were particularly concerned that such comments came from the Director of Queensland Government’s medical authority, which played down the risk of lead exposure, contrary to the international medical and scientific literature. Further, Xstrata Mount Isa Mines Pty Ltd have also maintained that the environmental lead in the urban area is elevated due to natural causes (from in situ weathered mineralized bedrock) and
therefore they cannot be held responsible for blood lead problem (Appendix A)

**Study 11**


Study 10 exposed the underlying challenges for advocates dealing with policy and political challenges in addressing major public health problems. This prompted a detailed analysis of the environmental lead problem, which included collaborating with Professor Bruce Lanphear, the world’s foremost expert in childhood environmental lead poisoning (Study 11).

In Study 11 we examined and reviewed the literature in relation to the irreversibility of low level exposure to lead effects, the intervention strategies that have been applied in ‘leaded towns’ and the efficacy of environmental and human health treatments. We used Mount Isa as a case study and benchmarked the environmental and human responses here to those used at other lead mining and smelting locations across Australia (e.g. Port Pirie, Lake Macquarie, Broken Hill) as well as internationally. The data shows that 11.3 % of children aged between 1-4 years in Mount Isa (n = 400) have blood lead levels greater than 10 µg/dL. The outcomes of this study revealed clearly that not only are the policy approaches inadequate in Mount Isa [because they deal with secondary rather than primary prevention], but that the emerging evidence shows that current national policy guidelines for acceptable maximum levels of lead exposure (10 µg/dL) are too high by 5-8 µg/dL. This latter point is significant because ~40 % of Mount Isa’s children under 5 years of age blood lead levels > 6 µg/dL. Such levels have been shown to result in significant and measurable impacts on socio-behavioral patterns including attention deficit hyperactivity disorders, learning difficulties, oppositional/conduct disorders and delinquency.

**Study 12**


In our latest study (Study 12), an editorial article in the Australian Medical Journal, we showed that Mount Isa’s environmental lead problem was not natural, as has been consistently argued by industry and government stakeholders and that blood lead levels were significantly elevated relative to national and international standards. The magnitude of the problem is demonstrated in our study where we showed that a child every nine days is lead poisoned, which is a situation that is entirely preventable with the correct remediation program. The value of this study is that the journal is read by medical practitioners across Australia and will highlight the need to take real action regarding metal contamination and associated human health impacts, in and around Mount Isa.
This research would not have been possible without the interdisciplinary skills of my students and colleagues. Although I am the lead researcher, they have all made significant contributions to the findings on Mount Isa and the contaminant problems. Their details along with other acknowledgements are provided below.

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