

The identification and assessment of water quality hazards in the Leichhardt River, Mount Isa, Queensland

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Abstract

This article discusses the location, type and sources of water contamination within the upper reaches of the ephemeral Leichhardt River, NW Queensland. The study specifically examines water quality in a series of the disconnected dry season remnant pools, which occur 19 km upstream of Lake Moondarra, Mount Isa's potable water reservoir. These pools are significant because they provide a vital drinking water source for native and domestic fauna, but more importantly, are often used for recreational swimming and as an important aboriginal meeting place. The city's sewerage infrastructure, associated wastewater reuse scheme and Cu and Pb-Zn-Ag mining and smelting activities have been identified as contributors to impaired water quality within the catchment. Five of the fourteen sites tested were found to be unfit for primary human contact as a result of faecal contamination. All sites exceeded the aquatic guidelines for healthy ecosystems (ANZECC, 2000) for TP and TN. Water soluble Cd, Cu, Pb and Zn concentrations exceeded the ANZECC (2000) lower limit for ecosystem survival in five of the nine pools examined. In addition, eight pools exceeded the upper ANZECC guideline (2000) values for soluble Cu.

Keywords

Mount Isa, water quality, heavy metals, pathogens, nutrients, risk identification

Introduction

Ephemeral rivers and streams cover most of Australia's interior and possess hydrological characteristics that reflect the continent's highly variable rainfall and runoff regime. Despite the perceived remoteness of the interior, agricultural activities, mining and inland communities are having an increasing impact on water quality and quantity. Many studies have investigated the dynamics of contaminant sources and mobility within temperate-perennial systems (Miller, 1997; Hudson-Edwards *et al.*, 2005), while ephemeral rivers have received relatively little attention. The variable hydrologic regimes that characterise Australia's ephemeral rivers present a considerable challenge to the management of water quality hazards, a task that is particularly important in potable water supply catchments.

Water quality risk assessment

Upstream prevention of contamination provides greater surety of water quality than removal of contaminants by downstream treatment. Thus, the most effective barrier is to protect the source waters. Analysis based risk assessment is the first step to identifying the activities posing the greatest threat to water quality. Risk assessment provides a basis upon which to organise and analyse data, assumptions and uncertainties to evaluate any deleterious effects from landuse or industrial activities that might affect human health and/or environmental integrity. Thus, it is not surprising that the Australian water industry is gradually adopting a risk management approach to ensure that water quality is maintained throughout the supply chain (Nadebaum *et al.*, 2001). Once potential water quality hazards have been identified, management strategies and preventative measures can then be implemented to mitigate or control the hazard, thereby minimising risk. The level of preventative action implemented to control an environmental hazard should be proportional to the associated risk (Nadebaum *et al.*, 2001). This ensures that restoration efforts are directed effectively and all decisions are based upon scientific (quantitative) water quality analyses rather than judgemental (qualitative) decisions.

The Leichhardt River is an ephemeral system in NW Queensland where several landuse activities in the catchment contribute to poor water quality. The river drains into Lake Moondarra, where water is drawn for filtration by an engineered reed bed system, Clear Water Lagoon (Figure 1), which is the primary process in

the treatment of Mount Isa's potable water supply. Although Mount Isa Water Board undertakes regular water quality analyses at the Clear Water Lagoon-Lake Moondarra reservoir system, the hazards and risks to water quality along the Leichhardt River have never been independently assessed. This study reports the results of the first stage of a research program that aims to identify the major risks to water quality in the Leichhardt River-Lake Moondarra water supply catchment.

Study area

The Leichhardt River drains the semi-arid tropical zone of NW Queensland (Figure 1), which is characterised by a warm-dry season between April and September and a hot-wet season from October to March. Annual rainfall is highly sporadic and localised, ranging from 480 mm to 1,250 mm (Taylor & Hudson-Edwards, 2005), with large inter-annual variations resulting from fluctuations in monsoonal intensity. Consequently, the Leichhardt River is an ephemeral system, flowing only during and shortly after rainfall. For the remainder of the year the riverbed remains dry with the exception of a series of disconnected permanent and temporary pools.

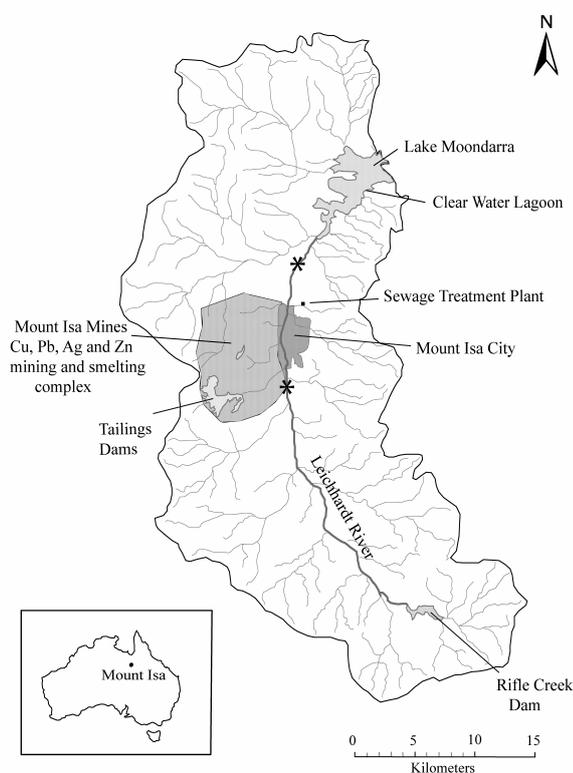


Figure 1. The drainage network of the upper Leichhardt River catchment (Mount Isa, NW Queensland). The general study sampling area is between the asterisks (*) with detail provided in Figure 2.

In the late 1950s the upper Leichhardt River was dammed to create Lake Moondarra (20° 34' S, 139° 35' E) to capture runoff from the Selwyn Ranges to provide water to Mount Isa City and Xstrata Mount Isa Mines (XMIM). Nineteen kilometers upstream of the Lake is the urban area of Mount Isa (population 20, 695: ABS census 2004, 2006), the City's sewage treatment plant and XMIM (Figure 1). The catchment area above the dam is c.1113 km² (Taylor & Hudson-Edwards, 2005) and is characterised by thin sandy soils, sparse vegetation and localised areas of highly mineralized bedrock.

An overview of the potential risks to catchment water quality and their associated hazards identified the Mount Isa sewage system and XMIM mining and smelting as being two significant activities that could affect water quality. In addition, cattle grazing adjacent to the Leichhardt River, Lake Moondarra recreational activities (e.g. boating, fishing and water skiing) and the urban centre of Mount Isa were also recognised as being potentially significant sources of pathogen contamination.

Potential hazards to water quality

Mount Isa Waste Water Treatment Plant (MIWWTP) is designed to treat the City's effluent for reuse as irrigation water for sports fields, the cemetery and horse paddocks (Figure 2). The effluent reuse scheme is designed to prevent the discharge of treated effluent into the waterways throughout the urban centre, which remain dry for the majority of the year. The inflow (~ 4900 kl/ day) is treated by clarifiers, biological trickling filters and a secondary sedimentation tank, with the processed effluent discharged into retention ponds. The effluent then passes through a series of lagoons before being used for irrigation. Despite the MIWWTP's 100% re-use design, the system is sometimes unable to adequately treat and distribute the effluent water via the irrigation scheme. This often occurs during wet season rains, which have been known to result in direct releases into adjacent urban waterways (Figure 2). Underground blasting by XMIM is suspected to have damaged sewerage lines so that they may now be inadvertently contributing to the natural water system, resulting in deleterious effects. Finlayson (1980) investigated nutrient delivery to Lake Moondarra and reported high levels of nitrogen and phosphorus (up to 10 mg/L) at the MIWWTP outlet during the dry season. Despite recent upgrades to the MIWWTP, Breakaway and Depot Creeks (Figure 2) still receive runoff from the effluent reuse scheme via irrigated horse paddocks, as well as the occasional direct inputs from the MIWWTP detention ponds.

Mount Isa has a number of open cut and underground mines exploiting the large stratiform Cu and Pb-Zn-Ag-bearing ore deposits. The ores were discovered in 1923 with large-scale mining beginning in the 1930s and continues to the present. Despite the large-scale nature and long history of mining activity within the Mount Isa region, there is a paucity of publicly available information regarding water and sediment associated heavy metal contamination within the Leichhardt River. It has only been since the late 1980s that strict environmental regulations have been enforced within the Mount Isa region (EPA, 2001). However the National Pollution Inventory (2005) reported that between 1998-2005 mining and smelting operations contributed the largest input of heavy metal contaminants to soil and water systems. Remediation attempts of the river bed were undertaken by XMIM in the 1990s. The channel zone of the Leichhardt River running through the township was dredged of contaminated materials (XMIM, personal communication). Notwithstanding the naturally occurring mineralised bedrock outcrops within the vicinity of the XMIM mining lease (Mathias & Clark, 1975), recent studies have revealed extensive heavy metal contamination remains stored in the river bed and along associated tributaries such as Death Adder Creek and Star and King Gullies (Taylor & Hudson-Edwards, 2005; Taylor & Hudson-Edwards, In review).

The level of risk arising from these potential hazards is determined by the nature of exposure. During the dry season a large population of aboriginal people reside in the river bed and come into primary contact with the temporary and permanent pools. A possible risk to Mount Isa's potable drinking water supply also exists, with Lake Moondarra just 19 km downstream of MIWWTP and XMIM.

Methods

Nutrient and pathogen analyses

The water sampling campaign was conducted during the dry season of September 2006. Fourteen samples were collected from permanent pools within the Mount Isa urban catchment for nutrient and bacteriological analyses. The sampled pools were selected on the basis of proximity to MIWWTP. Four samples were also collected from upstream Leichhardt River pools and four from Breakaway Creek to characterise the remainder of the urban catchment. Nutrient samples were collected in HDPE bottles and were rinsed 3 times with the sample water before final collection. Brown glass detergent washed sample bottles were used for the collection of bacterial water quality indicators with a small air space left at the top of the bottle to ensure the survival of anaerobic bacteria. Sample bottles were connected to an extendable sampler and were submerged to a depth of 30 cm in the centre of the pool. Samples were stored immediately on ice in insulated containers (1-4°C), prior to transportation to Simmonds and Bristow Pty Ltd, Brisbane, a NATA accredited laboratory for the analysis of total phosphorus (TP), total nitrogen (TN), enterococcus, *E. coli* and faecal coliforms.

Heavy metal analyses

Surface water samples were collected for heavy metal analyses from nine remnant pools within reaches of the Leichhardt River adjacent to, and downstream of Mount Isa city (Figure 2). These samples were filtered in the field to 0.45 µm, acidified with nitric acid to pH < 2 and stored in HDPE bottles at 4 °C until delivery to the National Measurement Institute (NMI), Pymble, NSW. Major cations and total heavy metal

concentrations were analysed by ICP-MS and ICP-AES. Ion chromatography and acid base titration was used to determine Cl, SO₄ and HCO₃, respectively. To ascertain the physico-chemical properties of the water, in-field sampling of pH, conductivity, dissolved oxygen, and water depth was also recorded at each site using a handheld YSI- meter. Blanks, replicates and certified reference materials (25 % of the sample batch) were included for quality control purposes. Analytical accuracy was determined using certified reference material (CRM) provided by NMI.

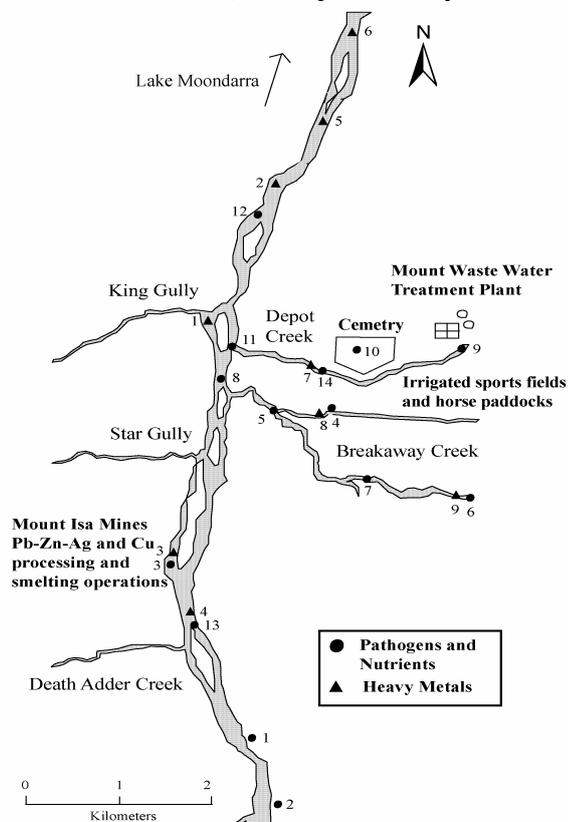


Figure 2. Sample site location map at Mount Isa. The location of sample sites within the upper Leichhardt River are shown in Figure 1.

Results were compared to ANZECC Water Quality Guidelines (2000) as per recommendations contained within the Queensland Water Quality Guidelines (EPA, 2006). While it would be ideal to compare results with locally derived reference values, little or no local water quality data exists. Further, there are no specific guidelines for the evaluation of water quality in Queensland’s ephemeral rivers (EPA, 2006). In the absence of environment-specific guidelines, we have compared our data to the ANZECC (2000) fresh water quality guidelines. However, for heavy metals it is appropriate to apply normal guideline values, as the effects on the biota under stagnant conditions will be similar to those during flowing conditions. Thus, it is considered acceptable to apply the ANZECC Guidelines (2000) in the absence of anything more suitable (EPA, 2006).

Results

Although some of the water bodies appeared to be natural in origin, the permanency of many of the water bodies within the catchment appears to be attributable to various artificial point-source inputs. These include: intermittent releases from MIWWTP storage tank, runoff from the irrigated horse paddocks, inputs from the industrial estates, urban yards and leaking pipes. In addition, at the time of sampling, Breakaway and Depot Creeks (Figure 2) were flowing slowly and appeared to be receiving runoff primarily from the paddocks irrigated by the effluent reuse scheme.

Table 1. Analytical results for nutrient and bacteriological analyses.

Analytes	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	Site 14	Water Quality Guidelines*
Total Phosphorus (mg/L)	0.29	0.20	0.17	2.90	0.26	3.00	0.32	1.60	0.38	0.18	2.00	0.25	0.24	0.54	0.03 (QLD rivers)
Total Nitrogen (mg/L)	6.50	0.49	0.55	6.20	1.10	9.90	0.70	1.50	0.04	1.50	1.50	1.10	0.78	0.60	0.25
Faecal Coliforms (CFU /100 mL)	220.00	< 2	7.00	220.00	80.00	2.00	72.00	10.00	8.00	< 1	>120	< 1	> 110	> 120	150.00
Enterococcus (orgs /100 mL)	900.00	23.00	2.00	17.00	11.00	8.00	4.00	4.00	17.00	< 2	70.00	280.00	8.00	50.00	35.00

*Faecal Coliforms and Enterococcus ANZECC (2000) Guidelines for Recreational Water Quality, Primary Contact.

Summary nutrient and bacteriological results are presented in Table 1. All sites exceed the aquatic guidelines for healthy ecosystems (ANZECC, 2000) for TP and TN. Site 6 grossly exceeded guidelines (TP 3 mg/L, TN 9.9 mg/L) by 100 times and 40 times respectively. As a result of nutrient enrichment, all of the smaller water bodies were characterised by extensive algal growth. Many were bordered by typha reeds, indicating permanency of flow or pooled water. Site 1 (Figure 2), fed by a broken pipe, recorded the highest values for Faecal Coliform (220 CFU/100mL) and Enterococcus (900 orgs/100mL). In addition, Sites 11 (70 orgs/100mL), 12 (280 orgs/100mL) and 14 (50 orgs/100mL) exceeded Enterococcus guidelines values of 35 orgs/100 mL (ANZECC, 2000).

Table 2. Water geochemistry of nine remnant pools, Mount Isa, September 2006.

Sample	pH	Temp (°C)	Conductivity (mS/cm)	Dissolved Oxygen (mg/L)	Ca (mg/L)	Na (mg/L)	K (mg/L)	Cd (ug/L)	Cu (ug/L)	Fe (ug/L)	Pb (ug/L)	Mn (mg/L)	Zn (ug/L)	Cl (mg/L)	HCO ₃ (mg/L)	S (mg/L)
Pool 1	8.95	23.38	5358	16.22	59	1240	15.0	0.34	11.00	13	1.1	130	8.4	1500	320	950
Pool 2	8.52	26.88	3761	13.16	69	780	13.0	0.33	4.40	39	BD	89	9.3	1100	180	680
Pool 3	8.28	28.27	2029	7.40	66	320	9.3	0.44	7.40	27	1.6	55	8.9	520	270	370
Pool 4	8.39	26.45	2936	9.66	58	600	8.5	0.54	3.70	23	BD	69	140.0	690	440	600
Pool 5	8.60	32.26	3933	15.25	55	810	13.0	0.60	12.00	110	9.6	83	17.0	1000	200	680
Pool 6	9.17	30.36	5014	14.91	74	1130	16.0	1.20	7.30	70	1.1	120	3.6	1100	120	870
Pool 7	8.51	24.96	2360	16.80	46	430	5.4	0.00	1.70	61	12.0	47	4.8	540	670	230
Pool 8	8.52	25.52	4200	19.21	45	470	8.1	0.00	2.70	79	BD	56	4.0	750	790	730
Pool 9	7.70	27.60	1929	14.02	54	740	3.9	0.00	2.70	17	BD	100	4.7	380	1300	52
ANZECC Guidelines (2000)*	6-7.5	NA	NA	NA	NA	NA	NA	0.06-0.8	1-2.5	NA	1-9.4	NA	2.4-31	NA	NA	NA

*Trigger Values for ecosystem survival- 99% protection (lower) level and 80% protection (upper) level of species (ANZECC, 2000).

The water chemistry data for the nine remnant pools is presented in Table 2. The pools were shallow (no more than 1 m deep), irregularly shaped and contained warm alkaline NaCl rich waters, with high concentrations of dissolved oxygen and notable soluble heavy metal concentrations. Pool 5 was the most contaminated with soluble heavy metals (Cd 0.6 µg/L, Cu 12 µg/L, Pb 9.6 µg/L and Zn 17 µg/L). Maximum concentrations of Zn (140 µg/L), Pb (12 µg/L) and Cd (1.2 µg/L) were recorded in Pools 4, 7 and 6, respectively (Figure 2). Pool 8 had the lowest concentrations of soluble heavy metals. More than half of the pools exceeded the acceptable guidelines for lower limit ecosystem survival (ANZECC, 2000) for all soluble Cd, Cu, Pb, and Zn concentrations. Of the nine samples 89% exceeded the upper guideline (ANZECC, 2000) for Cu and more than 20% of the other samples exceeded this guideline for Cd, Pb and Zn.

Discussion

Five of the fourteen pools tested were found to be unfit for primary contact as a result of faecal contamination. Pollution of these water resources with pathogenic organisms is of concern with respect to human health, and while in such condition primary contact should be avoided. No distinct point-source was identified to be the cause. Broken pipes, runoff from the effluent reuse scheme and direct releases from the MIWWTP are all contributors. The elevated nutrient concentrations throughout the upper catchment are likely to have impacted ecosystem functioning as well as diminishing their inherent value and utility as a water resource. Scheduled wet season sampling of the flow through town and into Lake Moondarra will provide a better understanding of the risks posed to the town's water supply by broken pipes, MIWWTP and runoff from the effluent reuse scheme.

The remnant pools located directly below the township and closest to Lake Moondarra contain the highest concentrations of soluble heavy metals. The reasons for these elevated concentrations may be related to industrial or mining discharges; natural inputs of metals from local geological formations (Mathias & Clark, 1975) or changing chemical stages of metal speciation due to evaporation and precipitation cycles (Hudson-Edwards *et al.*, 2005). Irrespective of the source of contamination, the environmental and health risks posed by the pools represent a localised hazard and are of concern due to their proximity to the principal drinking water supply. Indigenous community groups, livestock and native fauna that use these pools for recreation and drinking water. Exposure risk is increased through direct ingestion of water, which appears to be of greatest risk in pool 5, the most frequently used swimming hole. Ongoing research to ascertain the bioaccessibility of these heavy metals as well as variations in their concentrations throughout the seasonal climatic cycle is being undertaken by the authors.

Conclusion

This assessment of the water quality hazards and risks within the Leichhardt River catchment represents the first step in implementing a catchment management approach to water quality improvement. This dry season sampling program has need to pursue water analyses throughout the wet season in order to quantify thoroughly the risk that pathogens, nutrients and heavy metals pose to the quality of the potable water supply. This preliminary study reveals that contaminants within the Leichhardt River catchment are not uniformly distributed but have a spatial relationship to known point sources of pollution, specifically MIWWTP and XMIM.

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