Impact of a coal mine waste discharge on water quality and aquatic ecosystems in the Blue Mountains World Heritage area.

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Key Points

- Water quality of a high conservation-value freshwater river (Wollangambe River, NSW) is polluted by wastewater discharge from a coal mine.
- The wastewater increases salinity, metals, pH and water temperature.
- Downstream of the contamination point, the ecosystem of the river, as reflected by aquatic macroinvertebrates, was adversely affected.
- The NSW EPA is failing to regulate the mine discharge through an *Environmental Protection Licence*.
- Despite continuing contamination, both the NSW and Commonwealth Governments continue to provide approvals to expand and modify the mine's operations.

Abstract

Disposal of coal mine wastewater to the headwaters of a high conservation value waterway caused water pollution and ecological degradation of a World Heritage listed upland river. Below the mine, macroinvertebrate family richness decreased by 65% and abundance by 90%. Upstream of the waste discharge had very low electrical conductivity (EC) of 30.0µS/cm and pH was acidic (5.6) in contrast to that below the mine which showed EC 11 times higher (342 µS/cm) and a shift in pH to 7.2. The concentration of zinc below the mine was 101.5 µg/L and while below the permitted discharge level of 2500 µg/L as set in the environmental protection license (EPL), was 10 times greater than the recommended ANZECC guidelines for the protection of ecosystems. Nickel is not regulated under the mines EPL yet a concentration of more than double the recommended guideline was reported. Mine discharge also increased water temperature in the Wollangambe River by more than 2.5° C. The data clearly points to a need to review both the operation of the mine and the enabling regulatory system that currently allows pollution of zinc 200 times greater than recommended by the ANZECC guideline and generally does not adequately consider the impacts of the mine on the downstream National Park and World Heritage listed waterways.

Keywords

Water chemistry, coal mine wastewater, zinc, salt, thermal pollution, contamination, pollution licensing, Blue Mountains National Park, Wollangambe River

Introduction

Underground and open-cut coal mining generates large volumes of waste water which is often contaminated by underground and surface processes associated with mining activity (Johnson, 2003). Coal is a valuable resource to the NSW economy and in 2009/10 accounted for $13.2 billion in income, employed more than 19,000 people and returned $1.2 billion in royalties to the State Government (NSW Trade and Investment 2013).

Water pollution from the disposal of wastewater is one of several problematic environmental issues associated with coal mining (Tiwary, 2000). In the Sydney Basin the common practice for coal mines is to dispose of wastewater to nearby streams and rivers (e.g. Wright, 2011). In NSW mine wastewater pollution is regulated by the Environmental Protection Agency (EPA) through 'Environmental Protection Licenses' (EPLs).

These licenses specify waste water discharge conditions including concentration limits that are intended to control adverse impacts to the receiving waterways (Graham & Wright, 2012). As part of the development approval and pollution licensing process for a new or expanded mine, an environmental impact statement for the proposed activity is required. The statement must consider the predicted impacts of any activity on water, including the physical and chemical properties and their risk to the environment and human health, as defined by the Australian and New Zealand guidelines for fresh and marine water quality (ANZECC 2000) (NSW Department or Environment and Climate Change 2009).

There are few investigations of the magnitude and impact of coal mine wastewater discharges to otherwise clean and largely unmodified catchments (e.g. Wright & Burgin, 2009). Such situations are ideal for testing the response of macroinvertebrate community structure to altered water quality conditions due to a single point source of pollution. In this study we measured water quality and macroinvertebrates in order to detect and measure the presence of any adverse ecological or water quality effects from a single coal mine discharge on a small and otherwise clean upland stream.

Method

Study Area

Field sample collection was carried out on four upland streams (Table 1) in the upper Wollangambe River catchment (11,138 ha) in the Greater Blue Mountains area (33°28’S, 150°17’E) of NSW (Figure 1). Most of the study area is naturally vegetated and is protected as part of Blue Mountains National Park estate, although small sections are privately owned (such as the land subject to underground coal mining and sand mining operations) or as part of government corporations (such as the forestry operations) (Figure 1). Approximately 800 ha or 7% of the study catchment has been cleared, the remaining containing remnant natural vegetation. The majority of the Wollangambe catchment below the mine discharge point is within the Greater Blue Mountains World Heritage Area (NPWS, 2001).

The Clarence Colliery (Figure 1) discharges waste water to the upper Wollangambe River. Wastewater is generated through underground coal mining operations, coal washing and stockpiling at the mine surface (Cohen, 2002). The discharge of waste water from the mine to the Wollangambe River is regulated by the NSW EPA under the Protection of the Environment Operations (1997) Act (POEO Act). The volume of wastewater and discharge limits on selected attributes is regulated under ‘Environment Protection Licence’ (EPL) number 726 (EPL 726).

Four sampling sites were selected for this study (Table 1; Figure 1). Site W1 was located on the Wollangambe River and provided a reference site upstream of the mine discharge point. Three sites were located in longitudinal succession along the Wollangambe River below the mine discharge point. Two sites (W2 and W3) were located approximately 0.1 km and 1.0 km below the mine with addition impacted sampling site W4 located approximately 16 km downstream of the mine discharge point. The considerable distance between site W3 and W4 was due to rugged terrain and inaccessibility to this section of the Wollangambe River.

Macroinvertebrates

Macroinvertebrates were collected from all four sites in May 2013. Five replicate quantitative benthic macroinvertebrate samples were collected from cobble riffle zones (Resh & Jackson, 1993) randomly selected within a 15 m stream reach. A ‘kick’ net with a frame of 30 x 30 cm and 250 μm mesh was used (Wright & Burgin 2009) to collect invertebrates and sampling was achieved by disturbing stream detritus and benthic materials for a period of 30 seconds over a 900 cm^2 area, immediately upstream of the net. Net contents were immediately placed into a sealed and labeled storage container and preserved in 70% ethanol.

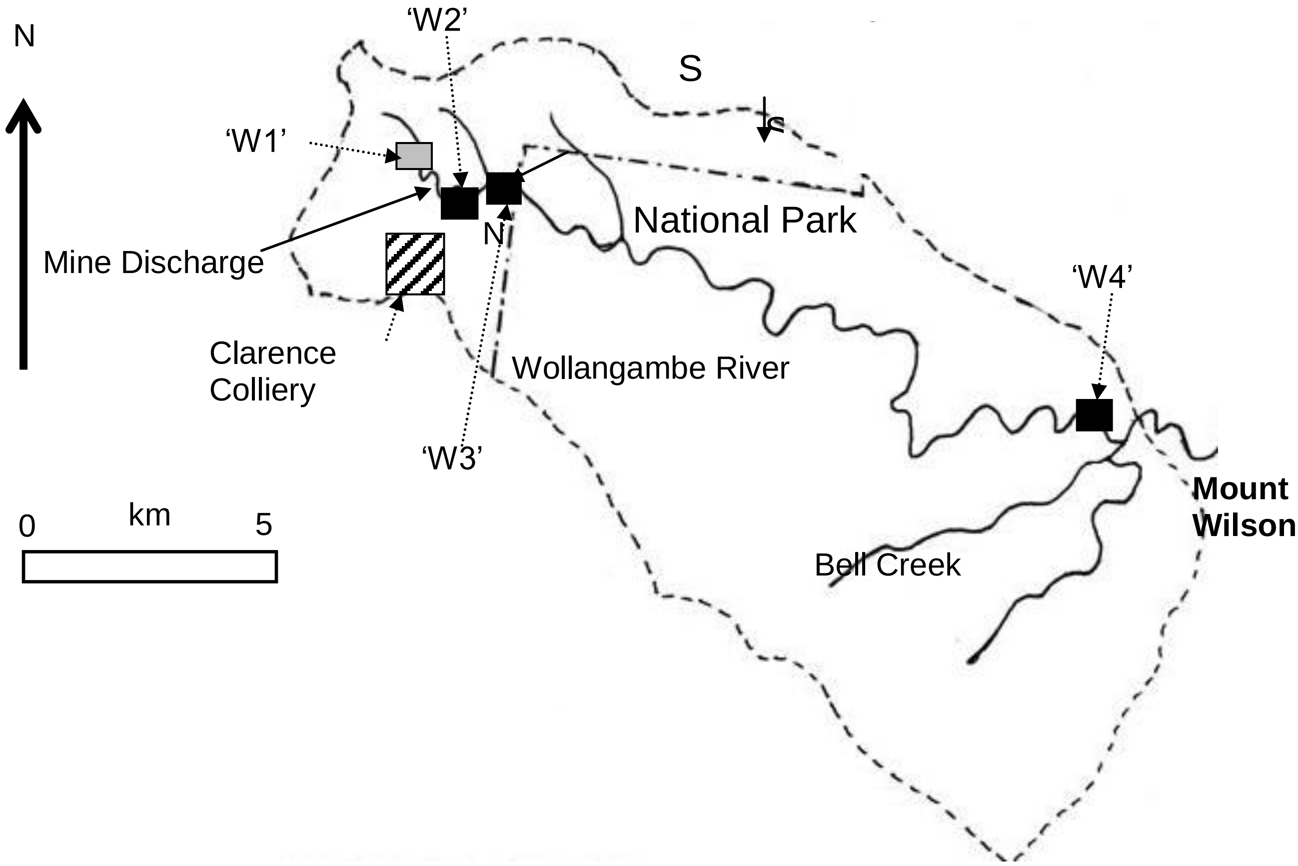

Figure 1. Map of stream sampling sites, waterways and waste discharge point in the upper Wollangambe River. Approximate catchment boundary is dashed line. Gray symbols represents the upstream reference site and black symbol the Wollangambe River below the coal mine waste discharge. The Blue Mountains National Park/State Forest Boundary is indicated.

In the laboratory, each sample was sorted under a dissecting microscope (X 10 to X60) to extract macroinvertebrates. Macroinvertebrate identification was determined using the identification keys recommended by Hawking (1994). All insect groups were identified to family as these data have been demonstrated to provide adequate taxonomic resolution for impact assessment (Wright et al., 1995). Three commonly used invertebrate indices were calculated for each sample; taxa richness, abundance (Resh and Jackson, 1993) and %EPT (Ephemeroptera, Plecoptera and Trichoptera taxa) (Lenat, 1988).

Water quality sampling

Water quality was sampled at each site on four occasions (Dec 2012, early and late Feb 2013 and May 2013). Physical and chemical water quality attributes of pH, electrical conductivity (EC) and water temperature were measured in-situ using a calibrated TPS AQUA-Cond-pH meter (for pH and electrical conductivity) and a calibrated YSI ProODO meter (water temperature). Water grab samples for total nickel, zinc and hardness were collected in unused sample containers provided by a commercial testing laboratory. Samples were chilled and delivered to the laboratory for analysis. All grab samples were analysed using standard methods (APHA 1998) by a National Associations of Testing Authorities (NATA) accredited laboratory. QA/QC procedures were implemented in the field and laboratory to ensure data integrity. Replicated measurement of water quality was conducted in-situ.

Results and discussion

A total of 605 macroinvertebrates from 19 taxa (mostly families) were collected during the sampling period (Table 1.). 80.5% of all invertebrates were collected from the reference site above the mine. Mean family richness at the three sites downstream of the mine discharge (3.6 families) was less than one third of that recorded at the upstream reference site (mean 11.4 families) (Table 1). Mean abundance was much higher at the upstream reference site (mean= 97.4 individuals) and was more than 90 % lower downstream of the coal mine discharge point (mean = 7.9 individuals)(Table 1, Figure 2a). The data clearly points to a significant impact of the wastewater discharge on ecological health. Unpublished data from additional local unimpacted reference sites provide additional support that the changes in macroinvertebrates was unnatural and was due to the coal mine waste discharge. The pollution license does not protect the Wollangambe river ecosystem from the colliery waste discharge, and given the order of magnitude of the influence, it is recommended that ongoing monitoring of macroinvertebrates should be included as part of the assessment of the mine's operations.

The effect of mine wastewater discharge on the water chemistry of the Wollangambe River is illustrated in Figure 2 b, c, d, e and f). All water quality attributes varied highly significantly according to location of sampling site (Table 1).

Salinity was very low at the upstream reference site (mean 30 μS/cm; Table 1) and was significantly higher at impacted sites increasing by more than 12 times at W2 (mean 417 μS/cm) (Figure 2b). Mean salinity at impacted sites W3 to W4, declined (378 - 231 μS/cm) with distance downstream of discharge point (Figure 2b) but 18 km downstream salinity was still more than 7.5 times higher than the salinity level upstream of the mine. Salinity at sites W2 and W3, below the coal mine, were above the upper trigger value recommended for ecosystem protection (350 μS/cm) (ANZECC, 2000).

The reference site on the Wollangambe River was acidic with a mean pH 5.6, in contrast the site W2 (immediately below the mine discharge) was alkaline with a mean pH of 7.9 decreasing to 6.5 at W4, 16 km further downstream (Figure 2c). Under the ANZECC trigger values (ANZECC, 2000) for slightly disturbed ecosystems, the reference site (W1) would fail to comply with the recommended trigger value range (pH 6.5-7.5). However, low pH is typical of naturally vegetated catchments on sandstone streams in the Sydney basin (Davies et al. 2010; Tippler et al. 2012). The mean pH at W2 of 7.9 was higher than the upper ANZECC trigger value of 7.5. Elevated pH of the Clarence Coal mine waste has been attributed to colliery treatment of the acidic mine water (pH 4.2) using lime dosing prior to discharge (Cohen, 2002). This would appear to be an overcorrection based on reference water conditions. From a licensing perspective the treatment is consistent with that set by the regulator range 6.5 – 8.5 (EPL 726) although represents a clear example of how the ANZECC guidelines need to be applied in a site specific manner and therefore a change in the pollution license for pH should follow.

Under the ANZECC guidelines water hardness at W2 and W3 was classified as 'very hard' (with a mean hardness of 200 and 186 mg/L $CaCO_3$, respectively). This level of hardness corresponds to a hardness-modified trigger (HMTV) for protecting 99% of species in waterways for zinc of 12.5 μg/L and for nickel of 41.6 μg/L (ANZECC, 2000). Reference concentrations of nickel and zinc concentrations were generally below or just above the laboratory limits of detection at the upstream reference site (nickel 1 µg/L and zinc 5 µg/L). Both zinc and nickel concentrations below the discharge point exceeded the ANZECC guidelines that suggest the levels would be hazardous for aquatic ecosystems (ANZECC, 2000) (Table 1 and Figure 2d & e). Mean zinc concentrations downstream of the discharge point peaked at 126 µg/L reducing to 55.8 µg/L, at the most downstream site (W4). Mean Nickel was 108 µg/L at W2 downstream of the discharge site falling to a mean of 44.2 µg/L at (W4) the furthest downstream site.

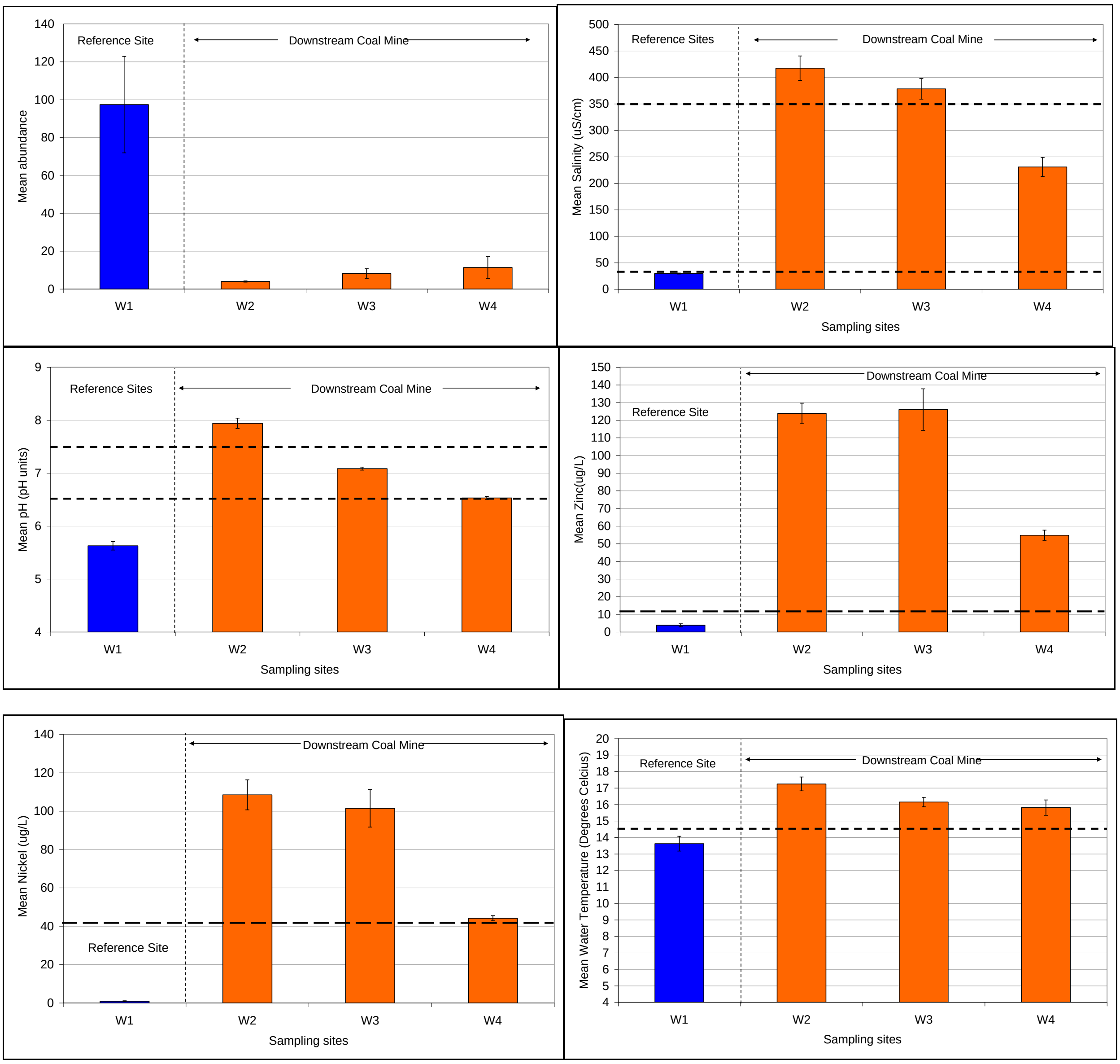

Figure 2. (a) *upper left*: mean invertebrate abundance (+/- SE) (b) *upper right*:. mean salinity (+/- SE) measured as electrical conductivity (µS/cm) the dotted line represents ANZECC (2000) EC ecosystem protection guidelines. (c) *middle left*: mean pH (+/- SE) the dotted line represents ANZECC (2000) pH ecosystem protection guidelines. (d) *middle right*: mean total zinc (+/- SE) concentration the dotted line represents the ecosystem protection guideline. (e) *bottom left:* mean total nickel (+/- SE) concentration the dotted line represents the ecosystem protection guideline. (f) *bottom right:* mean (+/- SE) water temperature collected from each site in the upper Wollangambe River, December 2012 to May 2013. Site W1 is a reference site on the Wollangambe above the mine.

The measured results suggest that the pollution licence for zinc is completely ineffective in terms of its limit with respect to protecting the health of Wollangambe River ecosystems. The maximum permitted concentration under the EPL is 2500 µg/L, 200 times greater than the level for protecting ecosystem health, as recommended under ANZECC guidelines. Monthly monitoring data for 2012 reported by the Clarence Colliery showed zinc concentrations in mine waste discharges ranging from 147 to 712 µg/L (Clarence Coal, 2013); compliant yet ecologically hazardous. For nickel, the pollution licence is silent. Arguably the discharge limits would qualify as pollution under the *Protection of the Environment Operations Act 1979.*

Water temperature results indicate sites below the wastewater discharge point were considerably warmer than at the W1 reference site, indicating the occurrence of thermal pollution (Figure 2f). Mean water temperature at the upstream reference sites was 13.6°C compared to 17.2°C at the site W2 below the mine (Table 1). ANZECC trigger values do not exist for temperature impacts however the ANZECC (2000) guidelines provide a framework for calculating regionally specific water quality trigger values from local reference data. By following this approach a local guideline (based on 80^{th} percentile of reference site water temperature) provides a derived temperature of 14.5°C for aquatic ecosystems for the current study. The results of this study show mean water temperature at W2 (17.2°C) was 2.7°C higher than the calculated local trigger value.

Table 1. Summary of stream physical, chemical and macroinvertebrate data indicating the range (and mean) for each water physical and chemical variable, according to site collected on three occasions between December 2012 and May 2013. (see Figure 1 for map of sites). BD=below detection limits. The EPL 726 discharge limits are also provided where they are included in the licence (EPL 726).

Macroinvertbrate (MI) and water quality variables	t-statistic; probability (*p*)	Upstream Mine (Reference) Range (mean)	Downstream Mine Range (mean)	EPL 726
Abundance (MI)	*t*=3.5, *p*=0.025	52-166 (97.4)	3-34 (7.9)	Not in EPL
Family Richness (MI)	*t*=11.0, *p*<0.0001	10-13 (11.4)	2-10 (3.6)	Not in EPL
% EPT (MI)	*t*=1.3; *p* =0.21	23.1 – 62.7 (39.7)	0 – 66.7 (26.6)	Not in EPL
pH (pH units)	*t*=13.4; *p* <0.0001	5.27 – 6.07 (5.63)	6.4 – 8.7 (7.2)	6.5-7.5
Electrical Conductivity (uS/cm)	*t*=20.0; *p* <0.0001	23.5 – 36 (29.6)	113.5 – 503 [illegible]	Not in EPL
Water Temperature (º Celcius)	*t*=5.1; *p* <0.0001	10.5 – 15.1 (13.6)	9.4 – 18.6 (16.4)	Not in EPL
Nickel (ug/L)	*t*=10.4; *p* <0.0001	40 – 141 (84.7)	BD – 2 (0.9)	Not in EPL
Zinc (ug/L)	*t*=10.7; *p* <0.0001	46 – 180 (101.5)	BD – 7 (3.8)	Max. 2500
Hardness (as CaCO3) (mg/L)	*t*=12.7; *p* <0.0001	BD	37 – 223 (160.2)	Not in EPL

Conclusion

The disposal of mine waste water from the Clarence Colliery is associated with pollution-related changes to the physical and chemical water quality properties and macroinvertebrate communities of the Wollangambe River. The physical and chemical changes to the Wollangambe River are due to the waste discharge from the mining operation and include elevated water temperatures, salinity, pH, modification of ionic composition and introduction of potentially toxic levels of zinc and nickel. Associated with the cumulative effect of the multiple changes in river water quality, due to the coal mine wastes discharges, was a clear and marked ecological degradation of stream invertebrate communities in the river below the discharge. The Clarence Coal mine is located in a highly sensitive location, adjacent to the Blue Mountains World Heritage area. It currently has the approval of both the NSW Government and the Commonwealth Government to operate. The NSW EPA licence for releasing the mine waste provides inadequate regulation for protecting the river and its ecosystems from pollution. The result of this study suggests (a) the licence conditions need to be reviewed for this extremely sensitive site (b) the effectiveness of the licensing system needs to be reviewed more generally.

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