Full Paper

Green et.al. Impact of coalmine wastewater discharge on river water quality

Community triggers EPA action on coal mine river pollution

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Key Points

- Waste discharges from an underground coal mine has caused long-term water pollution of a river.
- The pollution triggered community action, a court case, media coverage and political intervention.
- The composition and impact of the colliery waste discharge has changed over a five-year period.
- New waste regulations have had a limited impact on the nature and magnitude of water pollution.
- Five pollutants have increased over five years (salinity, pH, nickel, arsenic and sodium)
- Five pollutants have decreased over five years (turbidity, bicarbonate, zinc, copper and aluminium)
- Low river flows have reduced the degree of dilution and magnified the impact of the mine wastes.
- The pollution plume for this mine extends further than 22 km below the waste inflow.

Abstract

In 2012 the upper Georges River was polluted due to coal mine wastewater inflows from the Westcliff Colliery. A local community group launched legal action against the mine. Evidence for the court case showed pollution involved elevated salinity and a suite of metals (zinc, nickel, copper and aluminium) at concentrations higher than recommended in the ANZECC guidelines. The pollution plume extended at least 22 km downstream. Macroinvertebrate samples confirmed that the river ecology was adversely affected by the coal mine wastes. The EPA license that authorised the waste discharge did not provide limits for any of the key pollutants (in 2012). Through the media the NSW Environment Minister intervened in the case and demanded action from the EPA to stop the pollution. In 2013 the EPA issued the mine with a revised license. It provided discharge limits for pollutants present in the wastes discharged from the mine, including salinity and numerous metals. Water samples collected in 2018 show that the water quality of the wastewater discharge has partially improved as a result of the new EPA license. However, low river flows have reduced dilution and increased the magnitude of the downstream plume for some pollutants in the Georges River.

Keywords

Underground coal mining, heavy-metal pollution, salinity, pollution regulation, drought, dilution

Introduction

In June and July 2012 water quality in the upper Georges River was investigated to assess any impact from Brennans Creek, which contains wastewater discharged from an active underground coal mine (West Cliff Colliery). The study was undertaken to collect evidence for an expert witness report for a court case. The flow in Brennans Creek is from the West Cliff coalmine wastewater discharge. It is licensed by the NSW Environment Protection Authority (EPA) under the NSW *Protection of the Environment Operations* Act (NSW) 1997 (POEO, 2018) using an '*Environment Protection Licence* (EPL)' that specifies the permitted concentrations of pollutants that can be discharged to the environment. The mine wastes flow to the Georges River via a very small tributary, Brennans Creek.

The 2012 report concluded that salt, copper, nickel, zinc, aluminium and pH all exceeded guideline levels for ecosystem protection and each was at risk of contributing to toxic conditions for downstream aquatic ecosystems (Wright, 2012). All results were assessed against the ANZECC (2000) water quality guidelines (where applicable), particularly using guidelines for protection of aquatic ecosystems. The NSW EPA licence in

2012 did not specify discharge limits for key pollutants (salinity, copper, nickel, zinc, or aluminium). The 2012 EPA licence only specified pollutant limits for pH, oil & grease and suspended sediment for the Westcliff mine.

In 2013 the NSW EPA imposed an updated, EPL on the coal mine in efforts to reduce pollution from the mine in the Georges River. This current study was conducted in April 2018, nearly six years after the previous study, and five years since the new licence was issued to test whether this action has resulted in improved water quality in the mine wastewater or to the waterway that received its waste, the upper Georges River. The exact same sites and same water quality tests used in the 2012 study (Wright, 2012) were repeated in 2018.

Methodology

Study sites

Samples were collected from five sampling sites on the upper Georges River (G1, G2 and G3) and also from two tributaries, Brennans Creek and O'Hares Creek (Figure 1). The Westcliff colliery discharges wastewater to the environment under specified conditions contained in NSW EPA EPL issued to Endeavour Coal (EPL, 2504; South32, 2018). Of particular concern is the discharge from the coal mine (of about two to three ML/day) to Brennans Creek, a small tributary of the Georges River (South32, 2018; Figure 1). The flow in dry weather in Brennans Creek is attributed to the colliery waste discharge. It has been estimated that the wastewater flows from the mine generally contribute about 90% of the flow of the upper Georges River (Price & Wright, 2016).

The study area includes the Georges River and two tributaries (Brennans Creek, O'Hares Creek) in the upper Georges River sub-catchment (Figure 1). The area of particular interest in this investigation is the section of the Georges River downstream of Brennans Creek. Two reference sites are the upper Georges River (G1) above Brennans Creek, and O'Hares Creek. O'Hares Creek flows into the Georges River about 22 km downstream from the Brennans Creek inflow. Both sites represent water quality in the most undisturbed waterway 'reference sites' available in the area. However, the site at the upper Georges River (G1) should not be considered as 'pristine' as it occasionally receives a small volume of waste water discharge from the Appin Colliery and urban runoff from the Appin township.

Uses of the upper Georges sub-catchment waterways include heritage protection, conservation and public recreation. A large percentage of the upper Georges River catchment is protected and valued for conservation purposes (flora and fauna, endangered species and cultural heritage) as National Park reserves (Tippler et al. 2012), Commonwealth Defence land and drinking water catchment. Its lower reaches are one of the most urbanised catchments in Australia and it is reported to house approximately 1.2 million people (Tippler et al. 2012). This makes the relatively undisturbed upper Georges catchment of great value.

Water quality sampling

Water was collected from five sites, four of which are closely related to Brennans Creek and are the basis of this report (Table 1; Figures 1). Water samples in 2012 were collected in duplicate on three occasions (19 June 2012; 26 June 2012 and 3 July 2012; Wright, 2012). Water samples in 2018 were collected in duplicate on two occasions (6 April 2018; 20 April 2018). Water samples were tested by the ALS laboratory (2012 samples) and the Envirolab laboratory (2018 samples). Both laboratories are National Association of Testing Authorities (NATA) endorsed commercial laboratory for analysis of water and sediment chemistry samples. They have NATA accreditation based on using appropriate sample analysis methods within a quality assured analytical chemistry environment.

At each sampling site, field meter results were obtained for stream pH, EC (electrical conductivity) and turbidity using a handheld TPS Model Aqua CD TPS Instrument (in 2012; Wright, 2012). The meter was tested for calibration (and adjusted if necessary) on each day of testing with reference solutions for pH and EC. In 2018 pH and EC were measured using a TPS Aqua-CP/A meter and turbidity was measured using a HACH 2100P portable turbidity meter. At each site the meter was allowed to equilibrate before recording five replicate measurements. Weather conditions were assessed prior to collecting water samples to avoid periods of heavy rain, which could have caused confounded results.

Results

Water quality results show that waste discharges from the Westcliff mine continue to pollute the upper Georges River (Table 1; Figure 2). The nature and magnitude of the pollution has changed from July 2012 to April 2018. The concentration of some pollutants in the coal mine waste have changed (Table 1). Of the 10 water quality variables examined, five have increased levels / concentrations (salinity, pH, sodium, nickel and arsenic) and five have decreased (turbidity, bicarbonate, zinc, copper and aluminium; Table 1).

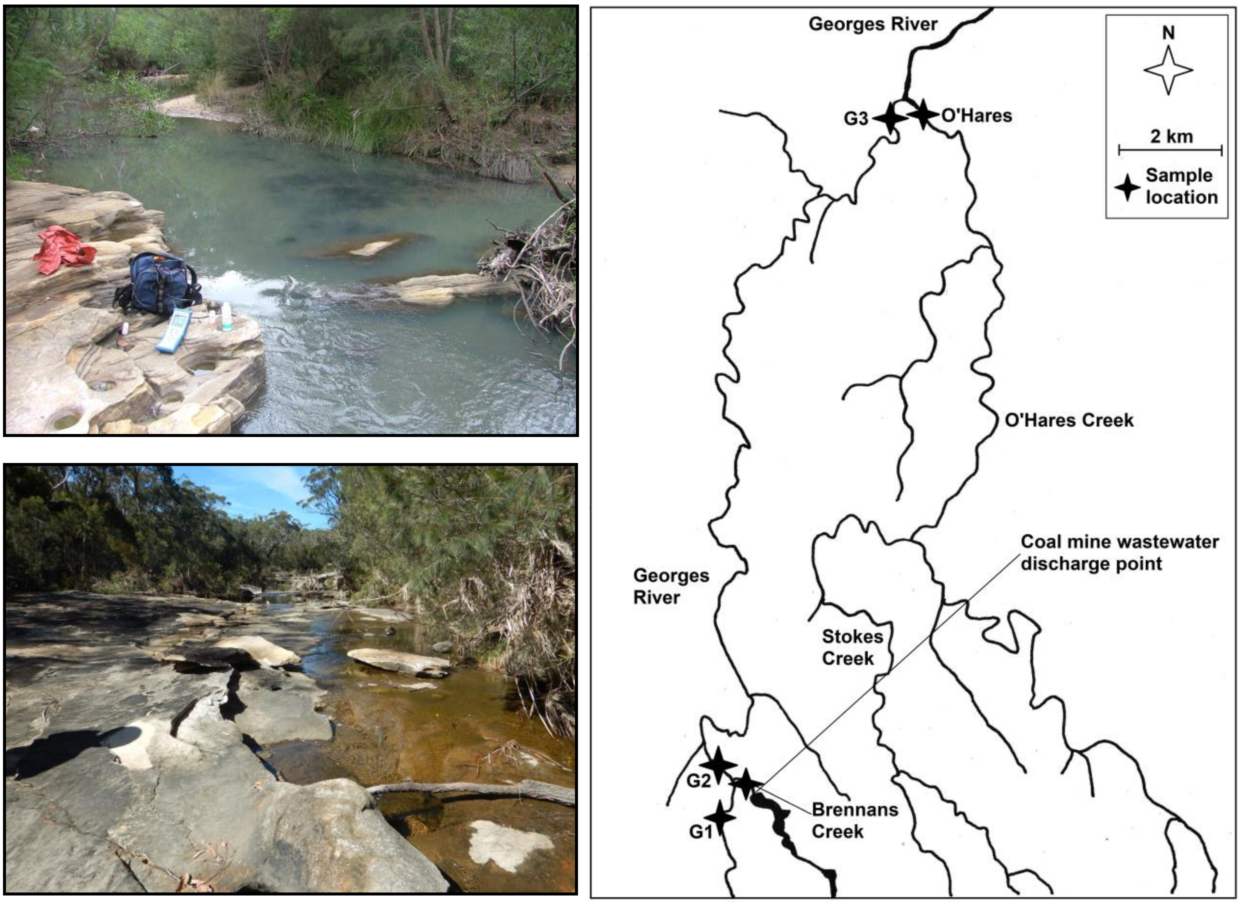


Figure 1. (top left) Brennans Ck (Westcliff Colliery waste water in June 2012 about 50 m upstream of its discharge to the Georges River). (right) map showing the upper Georges River Catchment. (bottom) Georges River about 5 km below Brennans Ck with subsidence fractures caused by mining.

The impact of the Westcliff waste discharges on the upper Georges River has also changed from July 2012 compared to April 2018. This change was influenced by a prolonged period of very low rainfall and much lower flow in the upper Georges River in April 2018. The sampling site G1, which is the Georges River above Brennans Creek, was pooled and was not flowing on either 2018 sampling occasion. Consequently, the flow of approximately 2 to 3 ML a day of mine waste water to the Georges River was largely undiluted (South32, 2018). This increased the magnitude of the discharge plume, for many pollutants from Brennans Creek to the Georges River (Table 1; Figure 2).

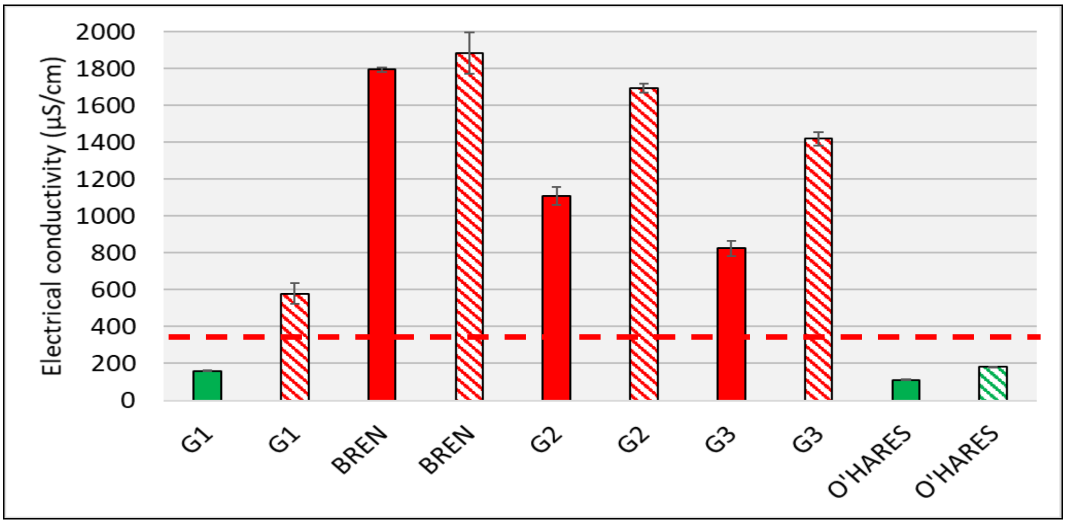
The salinity in Westcliff mine drainage (in Brennans Creek) was slightly higher in 2018 (mean 1885 µS/cm) compared to 2012 (mean 1795 µS/cm; Table 1; Figure 2) but was not statistically different (t=1.13). However, the lack of flow and dilution in the Georges River created higher salinity levels downstream from the Brennans Creek inflow. For example, between 2012 and 2018 salinity in the Georges River at site G3 (22 km below the inflow of the mine drainage) increased significantly (t=11.2; p<0.0001) from 825 to 1419 µS/cm.

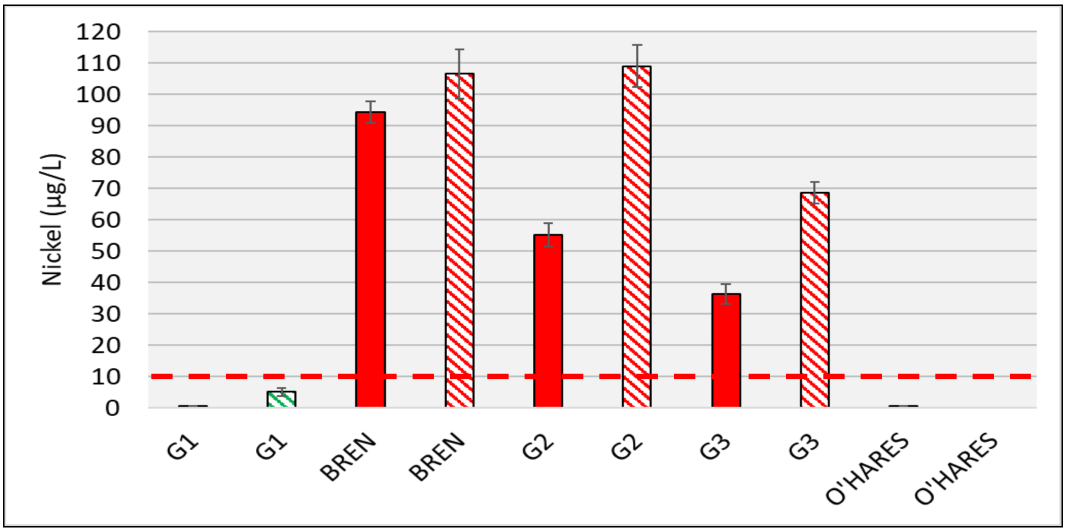
Table 1. Summary statistics (range and mean) of water quality resulted collected from five sites within the Georges River catchment in 2012 and 2018.

	Upstream	Mine Discharge	Downstream	Downstream	Reference
	Georges 1	Brennans Creek	Georges 2	Georges 3	O'Hares
Variables (units) and year	Range (Mean)	Range (Mean)	Range (Mean)	Range (Mean)	Range (Mean)
Turbidity (NTU) 2012	1.4 – 2.5 (1.9)	15.7 – 33.4 (25.0)	13 – 17 (14.8)	3.7 – 17.2 (10.9)	Bd. – 1.5 (0.84)
Turbidity (NTU) 2018	1.7 – 3.0 (2.3)	4.4 - 7.5 (6.1)	4.7 – 6.8 (5.8)	2.5 – 3.2 (2.9)	0.8 – 2.4 (1.6)
Salinity (µS/cm) 2012	142 – 180 (160.3)	1733 – 1851 (1795)	913 - 1338 (1109)	642 - 1029 (825)	100.4 - 121 (110.6)
Salinity (µS/cm) 2018	412 - 748 (580)	1548 - 2221 (1885)	1623 - 1766 (1695)	1314 - 1525 (1419)	178 - 188 (183)
pH (pH units) 2012	7.04 – 7.74 (7.34)	8.51 – 8.80 (8.62)	8.56 – 8.68 (8.63)	8.21 – 8.54 (8.37)	6.52 – 6.64 (6.58)
pH (pH units) 2018	6.68 – 6.77 (6.75)	8.81 – 8.84 (8.82)	8.92 – 8.93 (8.92)	8.43	7.33 – 7.36 (7.34)
Sodium (mg/l) 2012	18 - 21 (20)	431 – 478 (461)	217 – 328 (255)	180 - 254 (228)	15 – 16 (15.7)
Sodium (mg/l) 2018	49 – 80 (64.5)	520 – 680 (612)	510 – 670 (590)	360 – 440 (408)	23 - 25 (23.8)
Bicarbonate (mg/l) 2012	6 – 10 (8.7)	619 – 680 (658)	331 – 469 (378)	282 – 358 (324)	4 – 5 (4.7)
Bicarbonate (mg/l) 2018	35 – 59 (46.8)	620 – 820 (720)	620 – 820 (720)	480 – 590 (532)	10 – 13 (11.5)
Zinc (µg/l) 2012	Bd. – 9 (5.9)	26 – 35 (29.8)	14 – 26 (20.5)	13 - 21 (15.5)	Bd. – 12 (1.7)
Zinc (µg/l) 2018	18 – 26 (21.8)	14 – 17 (15.5)	13 – 16 (14.6)	3 – 5 (3.4)	3 – 13 (7.8)
Nickel (µg/l) 2012	Bd. – 1 (0.6)	86 – 105 (94.3)	44 – 65 (55.2)	27 – 47 (36.3)	Bd. – 1.0 (0.6)
Nickel (µg/l) 2018	3 – 7 (5)	93 – 120 (106.5)	92 – 120 (109)	61 – 79 (68.6)	Bd.
Copper (µg/l) 2012	Bd. – 6.0 (1.4)	5.0 – 8.0 (6.5)	3.0 – 9.0 (5.0)	Bd. - 7 (2.75)	Bd. – 1.0 (0.6)
Copper (µg/l) 2018	2 – 6 (3.5)	Bd. – 2.0 (1.25)	Bd. – 2.0 (1.3)	Bd. – 2 (1.0)	Bd. – 6.0 (1.83)
Aluminium (µg/l) 2012	90 – 170 (125)	520 – 860 (732)	450 – 590 (513)	290 - 670 (423)	150 – 700 (117)
Aluminium (µg/l) 2018	50 – 110 (75)	440 – 560 (507)	470 – 540 (498)	70 – 90 (76)	30 – 40 (32.5)
Arsenic (µg/l) 2012	Bd.	5.0 – 6.0 (5.8)	2.0 – 5.0 (3.3)	Bd.– 2.0 (1.0)	Bd.
Arsenic (µg/l) 2018	Bd.	10.0 – 13.0 (11.5)	10.0 – 13.0 (11.8)	1.0 – 2.0 (1.8)	Bd.

The metals zinc and nickel in Westcliff mine wastewater discharge (Brennans Creek) were both at ecologically hazardous concentrations in 2012 (mean zinc = 29.8 µg/L; mean nickel = 94.3 µg/L; Table 1). In 2018 the zinc concentrations in the mine discharge (mean=15.5 µg/L) have significantly (t 9.17, p<0.0001) dropped to levels lower than upstream levels (mean=21.8 µg/L). In contrast, in 2018 slightly higher, but statistically similar (t 1.43, p = not significant) nickel concentrations were found in the Westcliff mine wastewater (mean nickel = 106.5 µg/L). Due to the absence of upstream flow, the plume of elevated nickel concentrations extended at least 22 km below the mine wastewater discharge point (Figure 2). At site G3 the nickel concentration increased significantly (t 6.89, p<0.0001) from a mean of 36.3 µg/L in 2012, to 68.6 µg/L in 2018.

The mean bicarbonate concentration of Westcliff mine drainage (in Brennans Creek) was marginally higher in 2018 (mean=720 mg/L) compared to 2012 (mean=658 mg/L) but was statistically similar (t 1.01, p = not significant). However, the lack of dilution in the Georges River caused higher levels downstream. For example, between 2012 and 2018 the bicarbonate concentrations in the Georges River at site G3 (22 km below the inflow of the mine drainage) increased significantly (t 5.54, p=0.0026) from 324 to 532 mg/L (Figure 2).





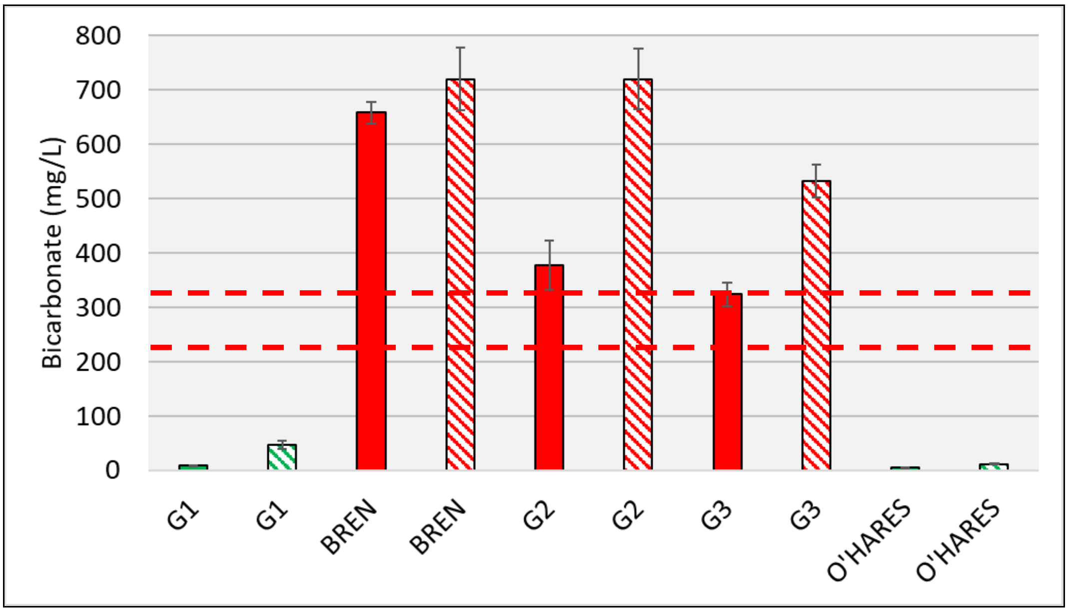


Figure 2. Summary of mean (plus/minus standard error of mean) results from the sampling sites: G1=Georges upstream, G2=Georges immediately downstream, G3=Georges 22km downstream, Bren=Brennans Creek (Westcliff Colliery waste water) and O'Hares Creek. 2012 (first bar – solid) versus 2018 (second bar cross-hatched).
Top: Salinity; Middle: Nickel; Bottom: Bicarbonate. The dotted red lines are the trigger value guidelines based on ANZECC (2000). The bicarbonate trigger values are from NSW OEH (2012). Columns are coloured based on their mean value and compliance (green) or exceedance (red) of the trigger value guidelines.

Discussion

Coal mines are frequently associated with pollution of waterways (Brake et al. 2001) and this study adds further information showing that water quality of the Georges River continues to be impaired due to the Westcliff Colliery discharge (OEH, 2012; Wright, 2012; Price & Wright, 2016). This study found that there had been many changes to Westcliff Colliery waste water quality and its impact on the Georges River. Some changes were positive as they showed a reduction in the level of several pollutants in the mine wastes. Others showed the opposite and revealed an increase in the level of pollutants. It also needs to be acknowledged that the sampling in April 2018 was conducted in a period of drought and mine wastewater discharge was largely undiluted by natural flow.

In 2012 and 2018 there were numerous pollutants present in the Georges River at elevated levels, due to the mine waste discharge, which were hazardous for stream biota. Salinity in the Georges River below the mine discharge increased by 50% from a mean level (in 2012) of 1109 µS/cm (G2) to 1695 µS/cm (in 2018). Such levels of elevated salinity are many times higher than ANZECC (2000) guideline (350 µS/cm). Horrigan et al. (2005) found that aquatic macroinvertebrate communities declined at salinity levels above 1000 µS/cm. The EPA licence for the colliery specifies a discharge limit of 2500 µS/cm for salinity (EPL 2504).

Nickel remains a pollutant of concern. In the mine wastewater (Brennans Creek) it had a mean concentration in 2012 of 94.3 µg/L and this increased by 13% to 106.5 µg/L in 2018. Coupled with the lack of dilution the concentration of nickel in the Georges River increased from 55.2 µg/L (at G2) and 36.3 µg/L (at G3) in 2012 to 109 µg/L (G2) and 68.6 µg/L (G3) in 2018. As the water hardness of the Georges River is classified as 'soft' the appropriate ANZECC (2000) guideline is 8 µg/L for 99% species protection or 11 µg/L for 95% protection. Site G3 is 22 km below the mine inflow and is more than six times higher than the 90% species protection guideline. The actual extent of the ecologically hazardous nickel plume from the mine is unknown. The EPA licence for the colliery (EPL 2504) currently specifies a 90th percentile concentration limit of 200 µg/L discharge limit for dissolved nickel. Elevated nickel is a continuous pollutant issues as monthly data (March

2017 to March 2018) reported by South32 (2018) show that the monthly dissolved nickel in the mine discharge varied in the range 68 -114 µg/L.

In contrast, zinc concentrations have dropped since 2012. The mine wastewater (Brennans Creek) had a mean concentration in 2012 of 29.8 µg/L and this decreased by nearly 50% to 15.5 µg/L in 2018. Mean zinc levels in the Georges River decreased from 20.5 µg/L (at G2) and 15.5 µg/L (at G3) in 2012 to 14.6 µg/L (G2) and 3.4 µg/L (G3) in 2018. As the water hardness of the Georges River is classified as 'soft' the appropriate ANZECC (2000) guideline for zinc is 2.4 µg/L or 8 µg/L for 99% or 95% species protection. The EPA licence for the colliery (EPL 2504) currently has a 90th percentile limit of 84 µg/L for dissolved zinc. Monthly data on zinc in the mine discharge (March 2017 to March 2018) varied from 7 -21 µg/L (South32, 2018).

Our results show that the Westcliff Colliery discharge continues to increase the bicarbonate concentration of the Georges River. The mean bicarbonate concentration from the mine fell from 738 mg/L to 720 mg/L (2012 compared to 2018). However, the lack of dilution has increased the magnitude of the downstream plume of elevated bicarbonate in the Georges River (Figure 2). The mean bicarbonate concentration at G2 and G3 increased from 408 and 344 mg/L, in 2012, to 720 and 532 mg/L (at G2 and G3) in 2018. These levels are considerably higher than trigger values recommended by NSW OEH (2012). An ecotoxicology investigation by NSW OEH (2012) identified elevated bicarbonate in Westcliff mine wastewater as a key pollutant of concern in 2012. The OEH report referred to research by Farag and Harper (2012) on bicarbonate and recommended trigger values for 80% to 95% protection of aquatic species of 225 to 319 mg/L (NSW OEH, 2012). The EPA licence for the colliery does not currently specify a discharge limit for bicarbonate.

There are two key management implications from this research. Firstly, it demonstrates the importance of effective regulation of water waste discharges. We suggest that regulation should drive industry to appropriately treat wastes to a level that has negligible impact on river water quality. Secondly, our research also highlights how climate extremes, such as drought and lack of flow to dilute wastes, can influence the downstream plume of water pollution.

Conclusions

This case study demonstrates how disposal of waste water from an underground coal mining operation can cause long-term water pollution associated with its disposal to a nearby river. We collected samples covering 22 km of the Georges River, but the pollution plume for some pollutants (salinity, bicarbonate and nickel) was likely to extend further downstream. The imposition of a revised EPA licence five years ago appears to have reduced the level of some pollutants in the colliery waste water. However, an extended period of dry weather prior to, and during the 2018 sampling stopped the upstream Georges River from flowing. This has reduced the dilution of the coal mine discharge and extended the downstream pollution plume from the mine. Questions remain about how appropriate the pollutant concentrations in the EPL licence are for protecting the water quality of the Georges River, given that this study has concluded that the river is still highly polluted.

Acknowledgments

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