

Waiuta Gold Mine arsenic remediated in field trials with AMD iron oxides from Stockton and Blackball Mines

D. Trumm¹, R. Rait¹, J. Pope¹, D. Craw², N. Newman¹ and H. MacKenzie¹

¹CRL Energy Limited, PO Box 29-415, 123 Blenheim Road, Christchurch 8540, New Zealand; d.trumm@crl.co.nz; r.rait@crl.co.nz; j.pope@crl.co.nz; n.newman@crl.co.nz; h.mackenzie@crl.co.nz

²Geology Department, Otago University, Dunedin, New Zealand, dave.craw@stonebow.otago.ac.nz

Abstract

Dissolved As is strongly attracted to fine grained Fe(III) minerals, therefore Fe-rich minerals from acid mine drainage (AMD) may be useful for treatment of As-contaminated water. We tested the remediation properties of two hydrated Fe oxides on As from water at the Waiuta Gold Mine, West Coast Region. The Fe oxides tested include precipitate from the active AMD treatment plant at the Stockton Coal Mine and precipitate from AMD at the abandoned Blackball Coal Mine. Previous laboratory-work had determined the adsorption kinetics and adsorption capacity for each of the precipitates. This work applied these previous results to construction and operation of field trials. Three passive treatment systems were operated on site, treating water containing 2-4 mg/L As: one with Stockton precipitate and two with Blackball precipitate at loading ratios of 119, 89, and 89g precipitate/L water, respectively. Residence times in the systems were varied from 7 minutes to 6 days. Arsenic concentrations were lowered to 0.5 mg/L at the shortest residence times (7 min) and below 0.05 mg/L for residence times above 5 hours for the Blackball precipitate. The Stockton precipitate lowered As concentrations to below 0.12 mg/L at residence times above 5 hours. In all cases, Blackball precipitate is more effective at As removal than Stockton precipitate, likely due to the higher Fe content in the Blackball material. This work suggests that a full-scale system containing either of the Fe oxides can be successful at the Waiuta Gold Mine site. These results also show that waste material from coal mine AMD can be used as a treatment medium for gold mine sites.

Keywords: arsenic, AMD sludge, AMD precipitate, iron oxides, adsorption, acid mine drainage, gold mines, coal mines.

Introduction

Arsenic extraction from mine waters is commonly achieved by oxidation of As(III) to As(V) and coprecipitation of ferric arsenate with iron hydroxide ($\text{FeAsO}_4 \cdot \text{Fe}(\text{OH})_3$) in a high-density sludge process in active treatment systems (Lawrence and Higgs, 1999; Leist et al., 2000). Many workers have documented the removal of As from mine water by adsorption onto various iron compounds including ferric hydroxide (Dousova et al., 2005; K uchler et al., 2005), zerovalent iron (Wildeman et al., 2006), sulphate-ferrihydrite (Jia and Demopoulos, 2005), red mud produced during the extraction of aluminium from bauxite (Altundogan et al., 2000, 2002), and natural red earth (Vithanage et al., 2007). Treatment of As-contaminated mine water through adsorption and coprecipitation in a water treatment plant is reliable and appropriate at active mine sites where power is available and personnel are on site to operate the plant, however, active treatment can be prohibitively expensive at abandoned mine sites

that could continue to discharge As-contaminated water for many years post closure. Some research has explored the possibility of passive treatment systems to remove As from mine water through adsorption onto iron compounds (Küchler et al., 2005; Wildeman et al., 2006).

This study is based on a relatively unusual geological situation where gold mines, generating As-bearing waters, occur in close proximity to coal mines generating AMD with iron oxyhydroxide precipitates (HFO). In an ideal situation, the effluent AMD water from a coal mine could be directly combined with As-bearing water from a gold mine to produce HFO that adsorbs As. Unfortunately, this is not physically possible in this area, although some dispersed coal mine HFO does contribute to extraction of As discharged from historic gold mines downstream (Hewlett et al., 2005). In this study, we investigate the possibility of using HFO from coal mines for extraction of As in a passive treatment system at a nearby historic gold mine where waters with high dissolved As occur. Previous laboratory work by Rait et al. (2010) focused on the kinetics of As adsorption and the adsorption capacity of two HFOs, precipitate from AMD neutralisation at the Stockton Coal Mine, and precipitate from untreated AMD at the abandoned Blackball Coal Mine. Here, we apply these results by constructing and operating small-scale field trials for As adsorption at the historic Waiuta Gold Mine, near Waitua, South Island, New Zealand.

Previous results

The work by Rait et al. (2010) found that the precipitate from the Stockton Coal Mine neutralisation treatment contained Fe_2O_3 at a concentration of 13 wt% and was composed primarily of Fe and Al oxyhydroxy sulphate minerals, whereas the precipitate from the Blackball Mine contained 74 wt% Fe_2O_3 and was composed primarily of goethite and ferrihydrite. Batch experiments documented that As adsorption for both HFOs is rapid over the first 5 h reaching equilibrium after 24 h and that adsorption capacity is up to 12mg As/g of HFO (Stockton material) and 74mg As/g of HFO (Blackball material). Blackball HFO consistently lowered As concentrations lower than the Stockton HFO, primarily due to the higher Fe content. A column leaching experiment verified that both HFOs can adsorb As from a continuous waste stream.

Methods

Three small-scale treatment systems were constructed at the base of a large waste rock pile at the Waiuta Gold Mine site. Water from the site flows through the waste rock pile and emerges at a flow rate of about 2 L/s with As concentrations ranging from 2 to 4 mg/L (Table 1). The treatment systems were constructed using 1000 L plastic tubs filled with sand/AMD precipitate mixtures. Water flowed from a header dam through alkathene and PVC piping and gate valves into the base of each tub, flowed upward through each unit and out the top through PVC and alkathene piping. Upward flow was used to prevent plugging of the perforated PVC piping with AMD precipitate and to prevent loss of AMD precipitate out of each system. One tub contained Stockton material at a loading ratio of 119g precipitate/L water, and the second and third tubs each contained Blackball material at a loading ratio of 89g precipitate/L water.

Table 1. Waiuta mine water chemistry used in the field trials.

Parameter	Units	Result	Parameter	Units	Result
Dissolved Sodium	mg/L	2.4	Nitrate-N + Nitrite-N	mg/L	0.25
Dissolved Potassium	mg/L	0.90	Dissolved Reactive Phosphorus	mg/L	0.36
Dissolved Calcium	mg/L	13	pH	pH Units	7.4
Dissolved Magnesium	mg/L	14	Dissolved Aluminium	mg/L	0.16
Sulphate	g/m ³	24	Dissolved Arsenic	mg/L	2.5
Total Alkalinity	mg/L as CaCO ₂	62	Dissolved Iron	mg/L	0.41
Chloride	mg/L	4.3	Dissolved Manganese	mg/L	0.016
Nitrite-N	mg/L	0.0028	Dissolved Nickel	mg/L	0.0032
Nitrate-N	mg/L	0.25	Dissolved Zinc	mg/L	0.038

The systems have operated for a period of 5 months and continue to operate. Flow rates were varied to determine As removal for different residence times. One of the Blackball tubs (Blackball-2) was initially operated at high flow rates to determine As removal at very short residence times. Inlet and outlet samples were collected weekly from each tub or more often for the very short residence time experiment.

Results and discussion

Arsenic was removed to lower levels at longer residence times for both HFOs (Fig. 1). Arsenic was removed to below 0.05 mg/L for the Blackball HFO and to below 0.12 mg/L for the Stockton HFO at all residence times greater than 5 hours. Better performance by the Blackball HFO is likely due to the higher Fe content. Scatter in the data set is much greater for the Stockton treatment system compared to the Blackball treatment systems, resulting in much greater uncertainty when predicting treatment efficiency by Stockton HFO. Five residence times under 1 hour were used in one of the Blackball systems (Blackball-2) to determine treatment effectiveness at very short residence times (Fig. 2). The data show a good logarithmic trend, suggesting that removal rates at these residence times are somewhat predictable.

One outcome yet to be addressed is how long the precipitate can remain effective at short and long residence times, and if the laboratory-measured adsorption capacities match well with field trials. To address this, operation and sampling will be continued over the next year. Analysis of results will provide information on the effectiveness of the treatment systems and allow for later design of a full-scale treatment system.

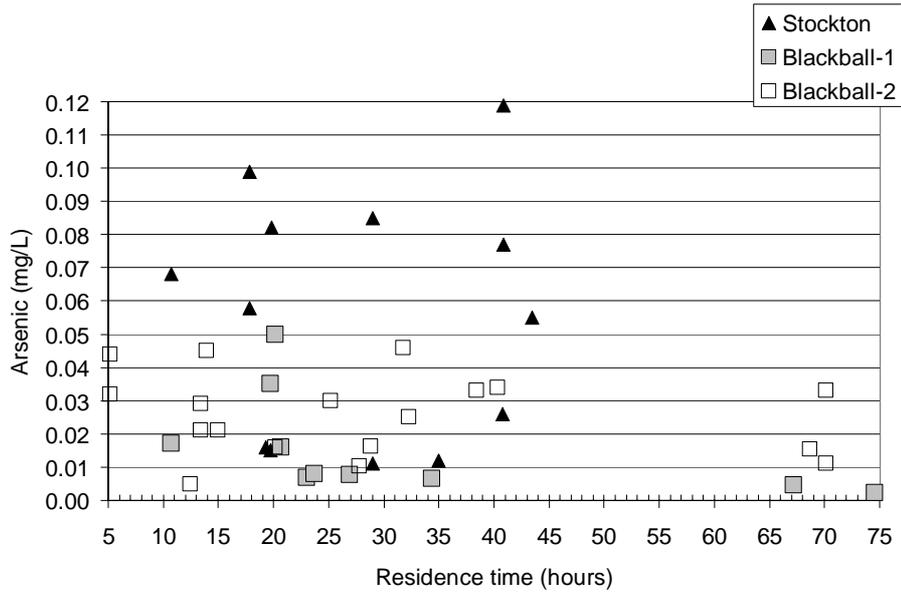


Figure 1. Arsenic concentration in outlet from field trials at residence times between 5 and 75 hours in treatment systems. Stockton, tub containing precipitate from Stockton Mine AMD treatment; Blackball-1 and Blackball-2, replicate tubs containing precipitate from Blackball Mine.

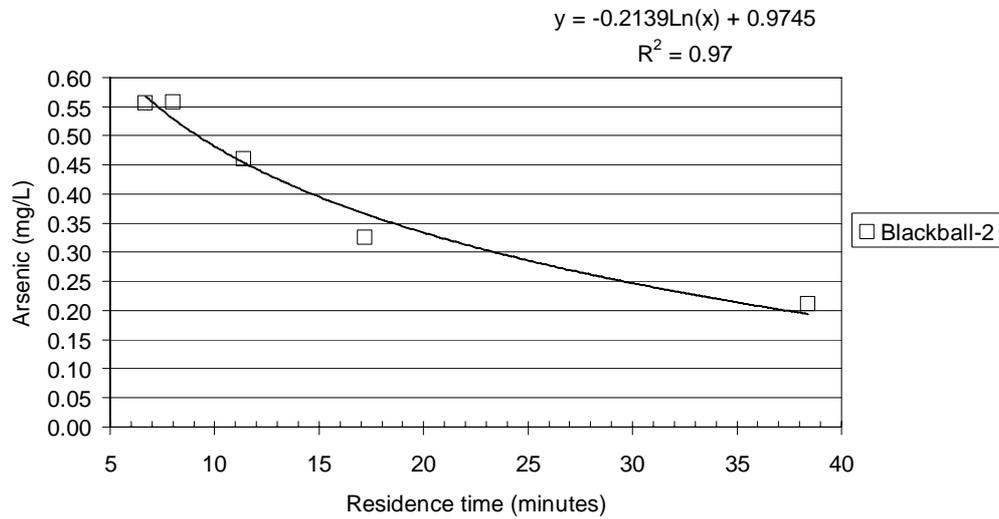


Figure 2. Arsenic concentration in outlet from field trials at residence times between 5 and 40 minutes in treatment system containing precipitate from Blackball Mine. Each data point is an average of 6 analyses.

Conclusions

Results confirm that both the Blackball precipitate and the Stockton precipitate are effective at As adsorption and can be used in a passive treatment system to remove As from gold mine drainage. Blackball precipitate can adsorb more As than Stockton precipitate likely due to a higher Fe content in the Blackball material. The use of AMD precipitate is practical if there is a nearby, abundant source to the remediation area.

Acknowledgements

This research was financed by the New Zealand Foundation for Science, Research and Technology (contract CRLX0401). Important support for this project is provided by several organizations including, the West Coast Regional Council, Environment Southland, Department of Conservation and Solid Energy New Zealand. The Department of Conservation provided helicopter support for system installations.

References

- Altundogan H., Altundogan S., Tumen F. and Bildik, M. 2000. Arsenic adsorption from aqueous solutions by adsorption on red mud. *Waste Management* 20: 761-767.
- Altundogan H., Altundogan S., Tumen F. and Bildik M. 2002. Arsenic adsorption from aqueous solutions by activated red mud. *Waste Management* 22: 357-363.
- Dousova B., Kolousek D., Kovanda F., Machovic V. and Novotna M. 2005. Removal of As(V) species from extremely contaminated mining water. *Applied-Clay-Science* 28: 31-42.
- Hewlett L., Craw D. and Black A. 2005. Comparison of arsenic and trace metal contents of discharges from adjacent coal and gold mines, Reefton, New Zealand. *Marine and Freshwater Research* 56: 983-995.
- Jia Y. and Demopoulos G. 2005. Adsorption of arsenate onto ferrihydrite from aqueous solution: Influence of media (sulfate vs nitrate), added gypsum, and pH alteration. *Environmental Science and Technology* 39: 9523-9527.
- Küchler A., Kiessig G. and Kunze C. 2005. Passive Biological Treatment Systems of Mine Waters at WISMUT. 9th International Mine Water Conference.
- Lawrence R.W. and Higgs T.W. 1999. Removing and stabilizing As in acid mine water. *Journal of Mining* 51: 27-28.
- Leist M., Casey R.J. and Caridi D. 2000. The management of arsenic wastes: problems and prospects. *Journal of Hazardous Materials B76*: 125-138.
- Rait R., Trumm D., Pope J., Craw D., Newman N. and MacKenzie H. 2010. Adsorption of arsenic by iron rich precipitates from two coal mine drainage sites on the West Coast of New Zealand. *New Zealand Journal of Geology and Geophysics*, Vol. 53:179-195.
- Vithanage M., Senevirathna W., Chandrajith R. and Weerasooriya R. 2007. Arsenic binding mechanisms on natural red earth: A potential substrate for pollution control. *Science of the Total Environment* 379: 244-248.
- Wildeman T.R., Pinto A.P., Tondo L.A. and Alves L.A. 2006. Passive Treatment of a Cyanide and Arsenic Laden Process Water at the RPM Gold Mine, Minas Gerais, Brazil. *Proceedings, 7th International Conference on Acid Rock Drainage*. St. Louis, MO. Pp. 2377-2384.