

## Passive treatment of mine drainage arsenic through adsorption by acid mine drainage precipitates, West Coast, New Zealand

Rachel RAIT<sup>1</sup>, Dave TRUMM<sup>1</sup>, James POPE<sup>1</sup>, Dave CRAW<sup>2</sup>, Nigel NEWMAN<sup>1</sup>, Hayden MACKENZIE<sup>1</sup>

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

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

**Abstract** The remediation properties of two iron oxides were tested on arsenic contaminated water from a gold mine in Waiuta, New Zealand. The iron oxides tested include sludge from an active AMD treatment plant (Stockton Mine) and a precipitate of goethite from AMD at an abandoned mine (Blackball Mine). Arsenic adsorption was determined in batch and column tests onto each iron oxide under laboratory conditions. Small-scale passive treatment field trials were completed at the Waiuta Mine to remove As from the water. Results confirm that the both AMD sludges were effective at As adsorption and can be used in a passive treatment system.

**Key Words** arsenic, AMD sludge, AMD precipitate, iron oxides, adsorption, acid mine drainage, gold mines, coal mines

### Introduction

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. To test this idea, AMD precipitate was sourced from (1) sludge from AMD neutralisation at the Stockton Coal Mine (ST), and (2) precipitate from untreated AMD at the abandoned Blackball Coal Mine (BB). The precipitate contained Fe<sub>2</sub>O<sub>3</sub> at concentrations of 13 wt% (ST; 2-line ferrihydrite) and 74 wt% (BB; goethite). Batch and column laboratory experiments were performed to determine the ability of the precipitate to remove arsenic from mine drainage through adsorption. Small scale field trials were completed at a gold mine at Waiuta using both AMD precipitates over 11 weeks. All three mines are located on the West Coast, New Zealand.

### Laboratory Experiments

Water for the experiments was obtained from the abandoned Waiuta Gold Mine, and contained up to 99 mg/L As (Table 1). The water collected from the lower wetland at Waiuta exhibits arsenic speciation that indicates the bulk of the of As is oxidised (As(V) > 97.5%; Haffert et al. in press). Rapid reduction in As concentrations occurred within 15 hr in all batch experiments, with BB precipitate reducing arsenic levels below that for ST sludge (Figures 1). After 48 hr at a ratio of 10 g

*Table 1 Waiuta mine water chemistry used in the laboratory experiments and field trials*

Parameter	Units	Lab	Field	Parameter	Units	Lab	Field
Dissolved Sodium	mg/L	4.2	2.4	Nitrate-N + Nitrite-N	mg/L	0.0078	0.25
Dissolved Potassium	mg/L	1.5	0.90	Dissolved Reactive Phosphorus	mg/L	21	
Dissolved Calcium	mg/L	15	13	pH	pH Units	4.1	7.4
Dissolved Magnesium	mg/L	3.6	14	Dissolved Aluminium	mg/L	0.5	0.16
Sulphate	g/m <sup>3</sup>	15	24	Dissolved Arsenic*	mg/L	61-99	2.4-2.5
Total Alkalinity	mg/L as CaCO <sub>2</sub>	<1.0	62	Dissolved Iron	mg/L	0.53	0.41
Chloride	mg/L	4.3	4.3	Dissolved Manganese	mg/L	0.11	0.016
Nitrite-N	mg/L	0.0037	0.0028	Dissolved Nickel	mg/L	0.013	0.0032
Nitrate-N	mg/L	0.0041	0.25	Dissolved Zinc	mg/L	0.41	0.038

(\*Arsenic concentrations from 3 analyses)

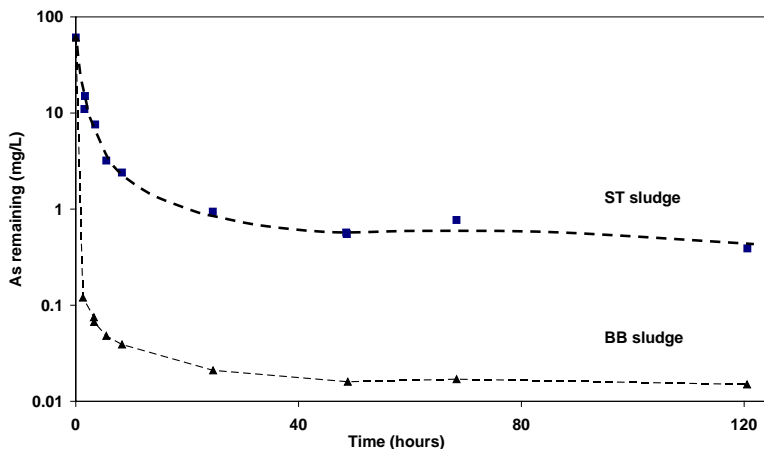


Figure 1 Arsenic concentration in water over time when in contact with ST and BB precipitate during batch experiments. Ratio of precipitate to water was kept constant at 10 g/L

sludge to 1 L water As concentrations were lowered to 0.016 mg/L (BB) and 0.55 mg/L (ST). At a ratio of 50 g sludge to 1 L water, As concentrations after 48 hr were lowered to 0.0017 mg/L (BB) and 0.008 mg/L (ST).

A column leaching experiment was conducted to determine long-term adsorption potential. Water was passed through columns, at an average flow rate of 1.8 L/day, with sand coated in the powdered AMD precipitate for 10 days at a constant contact residence time of 1 day. Two columns contained 50 g precipitate to 1 L water (ST and BB) and one at a ratio of 10 g precipitate to 1 L water (BB). All columns lowered As concentrations to <0.01 mg/L for the first 2 days. The columns with ST precipitate at a ratio of 50:1 and BB sludge at a ratio of 10:1 showed a steady increase in effluent As concentrations after 2 days, suggesting that adsorption sites were being exhausted (Figure 2). The column with the BB sludge at a ratio of 50:1 lowered As concentrations to <0.01 mg/L for 9 days, increasing to 0.04 mg/L on day 10, suggesting many more available adsorption sites on the

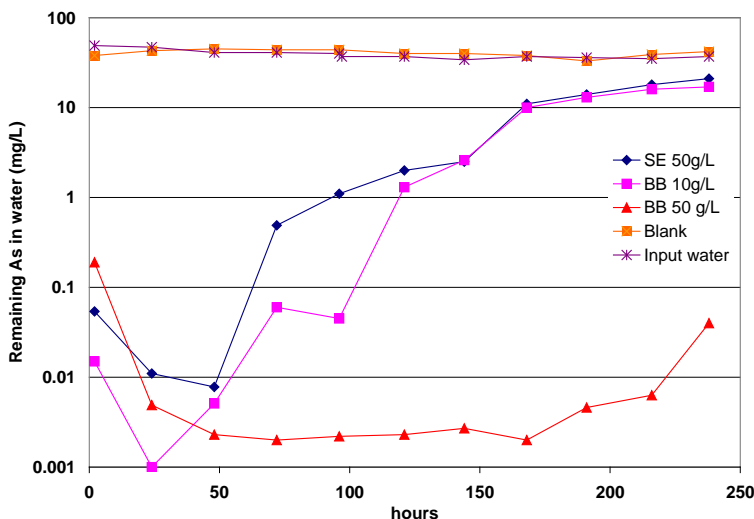
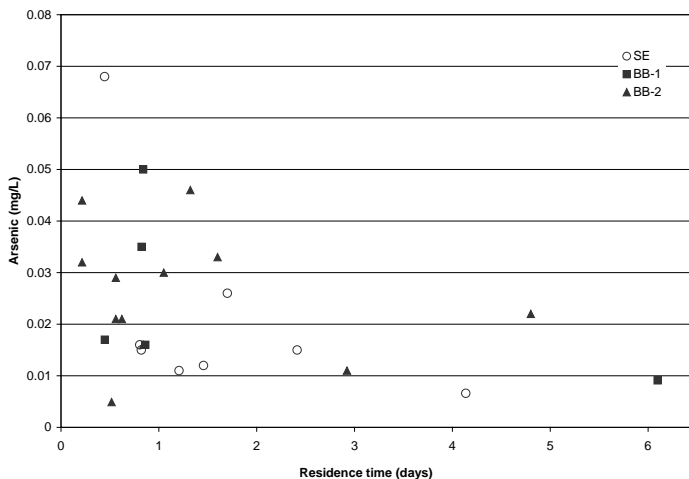


Figure 2 Arsenic concentration in effluent over time for column experiments. Col 1=ST precipitate 50 g/L input water, Col 2=BB precipitate 10 g/L input water, Col 3=BB precipitate 50 g/L input water, Col 4= No precipitate only sand, control

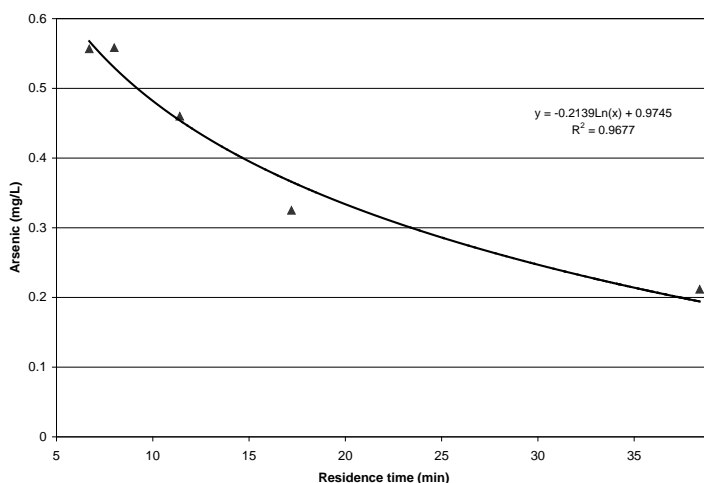


**Figure 3** Arsenic concentration versus residence time for field trials. Precipitate to water ratio, 119 g/L (SE) and 89 g/L (BB-1, BB-2)

naturally-precipitated AMD sludge (Figure 2). A toxicity characteristic leaching procedure test on the BB precipitate/sand mixture packed at the 50:1 ratio showed As <0.021 mg/kg, indicating relatively good stability of the adsorbed As. These results suggest that As can be treated with AMD sludge if ratio of sludge to water and contact residence time are optimised.

**Field Trials**

A small-scale field trial was conducted at the Waituta Site to remove As from the water. Water from the site flows through a large waste rock pile and emerges on the other side at a flow rate of about 2 L/s. The waste rock acts as a natural As removal system reducing concentrations from 52 to 2.4 mg/L (Haffert & Craw 2008). The field trials were constructed using 1000L plastic tubs (filled with sand/AMD precipitate mixtures), PVC piping and valves. Three tubs were setup; one with SE sludge and two with BB sludge (BB-1, BB-2) at loading ratios of 119, 89, and 89 g sludge/L water, respectively. Water inflow (Table 1) and outflow were sampled.



**Figure 4** Arsenic concentration versus residence time for BB-2 field trials

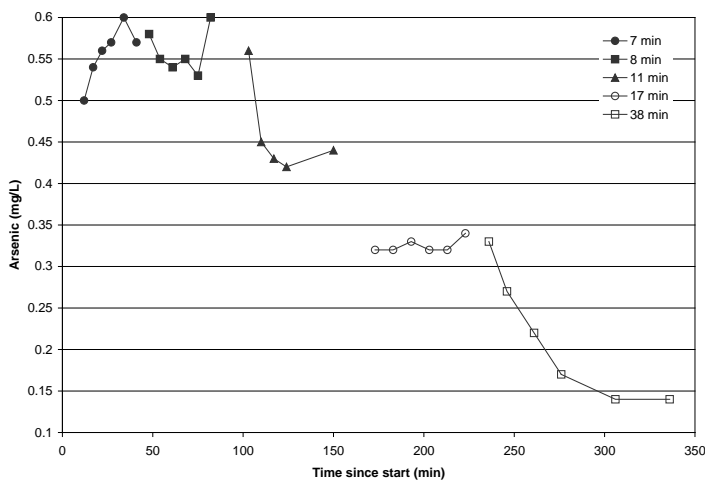


Figure 5 Arsenic concentration versus time since start at five residence times for BB-2 field trials

Arsenic was removed to lower levels at longer residence times (Figure 3, 4). Five residence times under 1 h were used in BB-2, with multiple samples collected at each residence time to determine consistency of removal. The data indicate that at these very short residence times, arsenic removal rate is often not constant, increasing initially but then decreasing (less effective removal) with time (Figure 5). One outcome yet to be addressed is how long the sludge can remain effective at longer residence times. Sampling will be continued over the next year to determine this. Analysis of results will provide information on the effectiveness of the treatment system and allow for later design of a full-scale remediation system.

**Conclusion**

Results confirm that the 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. 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. Support has also been provided from Dr Laura Haffert, University of Otago.

**References**

Haffert L, Craw D 2008. Mineralogical controls on environmental mobility of arsenic from historic mine processing residues, New Zealand. *Applied Geochemistry* 23: 1467–1483.  
 Haffert L, Sander S, Hunter K, Craw D, in press. Evidence for arsenic-driven redox chemistry in a wetland system: a field voltammetric study. *Environmental Chemistry*.