

A COMMERCIAL APPLICATION OF
VIROMINE™ TECHNOLOGY

CASE STUDY CSA COBAR MINE, NEW SOUTH WALES, AUSTRALIA

“Results after treatment showed that Terra B™ was able to outperform lime in regards to pH and TCLP of heavy metals. More importantly, the data collected four years after treatment show clearly that Terra B™ was able to sufficiently bind heavy metals and maintain a pH ideal for plant growth... I would recommend Virotec for any contaminated soils project.”



PROBLEM

The CSA copper mine in central-western New South Wales produces in excess of 145,000 tonnes of copper concentrate per annum, and generates a large amount of potentially acid generating metal-rich (arsenic, copper, lead and zinc) waste rock. The mining process also contributes to salinity in the area, producing a barren landscape.

CSA was interested to compare the ability of lime and Virotec's Terra B™ to increase soil reaction pH and bind metals, thereby allowing successful revegetation of metal contaminated soils at the site.



The CSA copper mine is at Cobar, approximately 600 kilometers north-west of Sydney.

VIROTEC TOTAL SOLUTION

ViroMine™ Technology, using the Terra B™ reagent has demonstrated its ability to remediate acidic metal contaminated waste rock by “*in-situ* remediation” techniques that utilise “*surfacial reactive permeable covers (SRPC)*”.

The principle of *in-situ* immobilisation is to add soil amendments to the root zone of contaminated waste rock dumps or, where possible, throughout the entire contaminated profile. The main objective of immobilisation techniques is to reduce both the immediate and long-term environmental availability of contaminants in the environment. This is achieved by neutralising acid and immobilising toxic elements, thereby stopping them from being translocated into the adjoining environment or into plants and animals, while maintaining the necessary organic carbon and nutrient reserves necessary for sustainable habitat restoration.

Terra B™ is largely insoluble resulting in increased metal binding under various soil and weather conditions; Terra B™ cannot be flushed from the site where it is applied by rainwater or groundwater. Used or spent Terra B™ cannot result in the release of any trace elements at potentially environmentally hazardous concentrations. Terra B™ is non-dispersive and its addition to some sulphidic soils or sediments can increase their strength as well as eliminating their potential acid generating or metal release capacity.

In contrast, lime is slightly soluble and metals are progressively flushed from its place of application so that it is no longer available to maintain effective treatment; metals can also be leached out at the same time.

Terra B™ is an *in-situ* soil amendment that can be used to:

- > Create a healthy soil horizon to allow revegetation by adding essential elements to the soil and immobilising potentially toxic trace elements to allow sustainable habitat development;
- > Neutralise soil acidity in the application zone;
- > Neutralise soil acidity below the application zone;
- > Bind inorganic metal contaminants in non-bioavailable environmentally inert forms;
- > Retain phosphate, ammonium, calcium, magnesium, potassium and other essential macro and micronutrients in the soil to



ViroMine™ Reagent Terra B™ is designed to treat sulphidic waste rock and soil.

- support healthy plant growth; and,
- > Increase soil moisture retention.

The primary mechanism of acid neutralisation in TerraB™ involves reaction with low solubility hydroxide, carbonate and hydroxy carbonate minerals. Metals are bound by precipitation of new low solubility minerals, co-precipitation, crystal growth of existing minerals, isomorphous substitution, adsorption and solid state diffusion.

The ability of TerraB™ to trap trace metals increases with time. Most metals bound by TerraB™ are held as structural components of very low solubility minerals and therefore cannot be easily removed. Most trace metals are initially trapped by adsorption; TerraB™ is dominated by particles with a high surface area-to-volume ratio and high charge-to-mass ratio. During aging, elements are redistributed to become structural components of new minerals.

BACKGROUND

The scale of problems associated with contaminated soil at mine sites is highlighted by the number of documented contaminated sites throughout the world. There are 150,000 to 400,000 sites in the European Union alone containing more than 100,000,000 m³ of highly contaminated waste rock and tailings and some 110,000 contaminated sites in Australia.

The most common techniques for the remediation of acid waste rock dumps involve encapsulation, topsoil addition and liming. The cost of waste rock dump encapsulation techniques varies, however costs in Australia range between \$10,000 per ha for simple vegetative covers to \$100,000 per ha for multi-layer barrier covers. Unfortunately, these simple treatments seldom remain effective for more than a few years and have been described as a 'cover-up' rather than a 'clean-up' strategy.

One of the major problems with current encapsulation techniques is their failure to provide long-term treatment. Because no engineered structure can last forever, all lined and capped impoundments eventually fail and the resulting problems are compounded by the fact that their timing cannot be predicted.

There are currently no practical techniques for effectively removing acid from soil or spoil, however *in-situ* treatment (immobilisation) of acid and metals is gaining increased acceptance by the scientific and regulatory communities.

Waste rock and tailings constitute the largest volume of material that must be stabilised and remediated at mine sites and are often the hardest to remediate because of their chemical and physical properties. The waste rock and tailings can have both immediate (actual) contamination problems and future (potential) contamination problems that will develop as sulphide minerals



Area C Plots depicting the barren landscape to be remediated.



ViroMine™ Technology is alleviating past issues with *in-situ* immobilisation of metals and neutralisation of acid mine drainage.

continue to oxidise; both the actual and the potential problems must be addressed as part of any long term solution. The leaching of acid mine drainage (AMD) from these dumps and dams can lead to adverse environmental effects including contaminated waterways and adjoining terrestrial habitats.

The problems associated with remediating and revegetating potentially acid generating waste rock and tailings are well documented and include metal toxicity, inherent acidity, high salt concentrations, poor nutrient content and poor physical structure. The chemical condition of acid waste rock and tailings also inhibits fungal and bacterial ammonification processes and presents an ongoing obstacle to plant growth and natural regeneration and may do so for many years or decades until oxidation of the material ceases, acid generation is halted, and the material is neutralised.

TREATMENT METHODS

> Remediation of waste rock dumps under construction

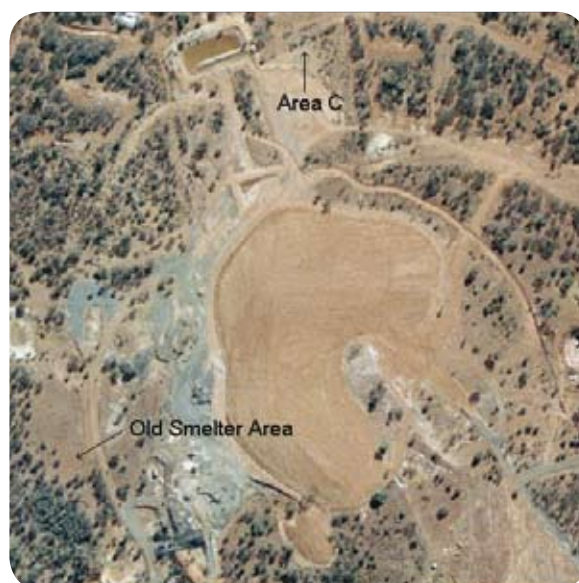
This is the preferred option for implementing ViroMine™ technology using Terra B™ reagent because it allows complete treatment of the waste rock dump, offering a long term, one-off solution. This can be achieved by mixing Terra B™ throughout the entire waste rock dump as the waste rock is emplaced. The Terra B™ reagents used for the remediation of waste rock dumps under construction can be applied as slurries, water soluble pellets or as powdered products, whichever is more convenient, but the goal is *in-situ* remediation of the entire profile. This strategy spreads the cost of remediation over the operating life of the mine so that all treatment costs are not incurred near the time of mine closure.

> Remediation of existing waste rock dumps.

Although existing waste rock dumps are harder to remediate, they can also be effectively treated using ViroMine™ Technology with Terra B™ using SRPC's. Extensive laboratory, bench and field trials, and project implementation have demonstrated that the application of Terra B™ in highly acidic metal contaminated waste rock dumps offers an economically viable and environmentally sound alternative to clay capping and acid neutralisation using lime or magnesium reagents. As with the remediation of waste rock dumps under construction, Terra B™ can be applied to existing waste rock dumps using slurry, pelletised and powdered reagents.

Where necessary, ViroMine™ reagent slurries can also be pressure injected into waste rock piles and exposed tailings to increase reagent penetration in thick deposits.

The treatment method for CSA consisted of three plots in each area: 7.5m X 16m in Area C and 10m X 20m at the Old Smelter Site. The plots consisted of control, lime and Terra B™ dosed areas. Lime and Terra B™ was spread on the surface of the appropriate plots and then mixed into the soil to an approximate depth of 300



Location of Plots at CSA Cobar mine.

mm using a backhoe. The control site had no further treatment.

The dosing rates for Terra B™ were calculated based on previous sampling carried out by Coffey Geosciences Pty Ltd, the environmental consultancy which was contracted to oversee the project independently. Lime dosing rates were determined on-site by mixing soil samples with lime to obtain a final pH of approximately 7.5.

> Evaluating soil treatment

Soil samples were collected from all plots prior to treatment and post-treatment from the lime and Terra B™ dosed plots. Samples were collected by pooling aliquots of soil (minimum of 10) that were collected in a grid pattern. These samples were analysed for a range of parameters including Toxicity Characterisation Leaching Procedure (TCLP) which assesses the effect of treatment on metal leaching. The TCLP was carried out at a pH of 2.88 (US EPA TCLP protocol). Results are presented in Table 3 (Old smelter area) and Table 4 (Area C).

> Leachate Analysis

Lysimeters were installed in each plot to enable pH, electrical conductivity and metal concentrations in water percolating through the soil to be measured.



Old smelter pots



Area C Plots

RESULTS

Table 1 details the total metal loads in the contaminated soil at the two trial sites before treatment. Tables 2 and 3 record the TCLP and acidity data before and after treatment. Results are compared to data for a control plot and a lime treated plot.

> Old Smelter

As shown in Table 2, the effect of Terra B™ is clearly demonstrated when concentrations of copper in the leachate are compared to those in leachate from the lime treated plot. There was a 90% reduction in copper concentrations in leachate from the Terra B™ plot compared with the control, whereas there was only a 55% reduction in copper concentrations in leachate from the lime treated plot (compared with the control).

> Area C

When total copper and leachate copper concentrations in the control plot were compared with the lime treated plot and the Terra B™ treated plot, a further reduction in copper leaching of about 85% was found for the Terra B™ treatment when compared to the lime dosed plot.



Old smelter plots: Control (foreground), Lime (centre) and Terra B™ treated (background).

Table 1: Results of soil pre-treatment total metal load analyses (mg/kg)

Analyte	Site	
	Old Smelter	Area C ²
EC (1:5 in water µS/cm)	220	1100
pH (1:5 in water)	5.6	3.4
Arsenic	100	88
Cadium	3	2.3
Chromium	17	24
Copper	2200	2000
Lead	7500	2300
Manganese	500	96
Nickel	10	4.8
Zinc	360	1500

Table 2 – Old Smelter Area, Soil TCLP & Acidity Data

Analyte	Control	Lime Untreated	Lime Treated	Terra B™ Untreated	Terra B™ Treated
pH	4.47	4.97	7.99	5.03	9.57
EC	456	107	266	750	507
TAA pH (KCl) ¹	4.36	4.19	7.98	4.25	9.26
TAA Moles H ⁺ / tonne (to pH 6.5)	34	34	0	30	0
TPA pH (ox) ²	4.64	4.31	8.56	6.41	8.23
TPA Moles H ⁺ / tonne (to pH 6.5)	19	23	0	7	0
Arsenic (mg/L)	0.006	0.005	0.008	0.011	0.003
Cadium (mg/L)	0.068	0.055	0.066	0.042	0.014
Chromium (mg/L)	0.051	0.045	0.024	0.049	0.022
Copper (mg/L)	17.760	7.700	12.470	8.449	1.440
Manganese (mg/L)	1.016	1.054	0.802	1.237	0.806
Nickel (mg/L)	1.151	0.023	0.020	0.074	0.027
Lead (mg/L)	0.529	0.740	0.664	0.380	0.291
Zinc (mg/L)	5,243	3.883	4.619	3.531	2.237

1) pH determined after using KCl to displace any adsorbed hydrogen ions.

2) pH determined after using hydrogen peroxide to oxidise sulphides and any other reduced species.

Table 3 – Area C, Soil TCLP & Acidity Data

Analyte	Control	Lime Untreated	Lime Treated	Terra B™ Untreated	Terra B™ Treated
pH	4.08	4.31	6.71	3.66	7.73
EC	1237	1300	2400	1322	1860
TAA pH (KCl) ¹	4.08	4.27	6.88	3.73	8.49
TAA Moles H+/ tonne (to pH 6.5)	40	30	0	96	0
TPA pH (ox) ²	3.36	4.58	7.19	3.02	7.09
TPA Moles H+/ tonne (to pH 6.5)	55	23	0	132	0
Arsenic (mg/L)	0.005	0.007	0.018	0.019	0.006
Cadium (mg/L)	0.025	0.049	0.092	0.045	0.015
Chromium (mg/L)	0.044	0.026	0.045	0.027	0.024
Copper (mg/L)	3.123	8.257	14.110	10.350	2.789
Manganese (mg/L)	2.368	2.173	2.739	2.306	2.111
Nickel (mg/L)	0.055	0.052	0.101	0.091	0.078
Lead (mg/L)	0.216	0.682	1.413	0.392	0.165
Zinc (mg/L)	19.125	15.728	33.922	19.420	10.060

1) pH determined after using KCl to displace any adsorbed hydrogen ions.

2) pH determined after using hydrogen peroxide to oxidise sulphides and any other reduced species.

> **Leachate Analysis Results – One year and four years post-treatment.**

Lysimeters were installed in each plot to measure the pore water pH and dissolved metal concentrations after rainfall events. The samples were collected approximately one and four years after the treatment was applied. The results are presented in Table 4 are only available for the Old Smelter Area.



Installation of ViroMine™ Lysimeters in acid waste rock.

**Table 4 - Lysimeter Results -
One and four years after treatment applied - Old Smelter Area**

Analyte	Control	2005		2009	
		Lime (mg/L)	Terra B™ Reagent (mg/L)	Lime (mg/L)	Terra B™ Reagent (mg/L)
pH	5.59	6.41	8.95	-	-
Arsenic	0.014	0.007	0.003	0.010	<0.005
Cadmium	0.043	0.007	<0.001	0.009	<0.001
Chromium	0.002	0.004	0.002	0.06	0.02
Copper	5.865	1.796	0.092	9.19	1.56
Manganese	1.035	0.118	0.097	2.63	2.10
Nickel	0.031	0.003	0.003	0.06	0.02
Lead	0.482	0.618	0.001	4.61	0.72
Zinc	4.743	0.507	0.012	66.00	15.00

The results in Table 4 clearly demonstrate that Terra B™ reagent is superior to lime in providing long-term metal binding and pH control for rainfall leachate.

CONCLUSION

ViroMine™ Technology has proven to be highly effective in contaminated soil remediation at the CSA Cobar Mine. The results show that Terra B™ is an effective *in-situ* soil amendment that is suitable for the development of surface reactive permeable barriers that neutralise surface and subsurface soil acidity, immobilise toxic elements thereby stopping their translocation from the site, and allow sustainable habitat development through the creation of a healthy soil ecosystem.

A great advantage of using Terra B™ reagent is that while the neutralisation of soil acidity and the immobilisation of toxic metal are undertaken, the sites can be simultaneously revegetated, thereby decreasing site disturbance and remediation and maintenance costs.

Furthermore, the results show that the longer time elapses after the treatment is applied, the better the Terra B™ performs and the more it outperforms lime.

TESTIMONIAL

“Coffey Geosciences were contracted as a third party environmental consultant to oversee the trial at CSA Cobar Mine. The goal of the trial was to compare lime against ViroMine™ Technology using Terra B™ Reagent to remediate heavily contaminated soils.

The initial results after treatment showed that Terra B™ was able to outperform lime in regards to pH and TCLP of heavy metals. More importantly, the data collected four years after treatment show clearly that Terra B™ was able to sufficiently bind heavy metals and maintain a pH ideal for plant growth.

We look forward to working with Virotec throughout the remainder of this important project. Virotec proved to be professional at all times and therefore I would recommend Virotec for any contaminated soils project.”

JOHN GORRIE

Consultant

Coffey Geosciences Pty Ltd