AN APPLICATION OF
VIROMINE™ TECHNOLOGY

CASE STUDY: ACID WASTE ROCK REMEDIATION AT MT CARRINGTON

"After five years the leachate data, collected from three lysimeters within each plot, show that Terra B™ reagent has markedly outperformed the other treatments and continues to get better over time."

Plant growth achieved on Acid Rock Waste after application of ViroMine™ Technology

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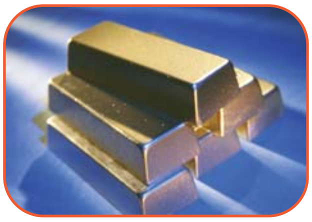
PROBLEM

The Mt Carrington mine site in northern NSW, Australia, covers an area of 300 hectares and contains as many as 1,800 adits and shafts that are a legacy of more than 150 years of gold and silver mining; minor quantities of copper, zinc and antimony have also been extracted. The last commercial operations stopped about 14 years ago and at the time there was little effort undertaken to remediate and revegetate the site.

The remediation and revegetation that was undertaken on the acid waste rock dumps and haul road verges included clay capping and the addition of lime before planting. Most of these remediation attempts failed due to the presence of acid generating minerals such as pyrite and chalcopyrite, the high actual acidity already generated within the waste rock dumps and the high concentrations of toxic elements.



Mining for gold at Mt Carrington covers a period of over 150 years.

VIROTEC'S TOTAL SOLUTION

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 pedogenic 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.

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

Terra B™ reagent is largely insoluble resulting in increased metal binding under various soil and weather conditions. In contrast, lime treatment is slightly soluble and metals are easily leached out.

Terra B™ reagent 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 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;

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- Bind phosphate, ammonium, calcium, magnesium, potassium and other essential macro and micronutrients in plant available forms; and
- Increase soil moisture.

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 m^3 of highly contaminated waste rock and tailings*** (Mule & Melis, 1999) and some ***110,000 contaminated sites in Australia*** (Hill & Naidu, 1999). In 1998 Lombi, et al., (1998) estimated the number of highly contaminated ***sites in the USA*** at ***35,000*** and by 1999 there were 1,206 contaminated sites on the US Superfund National Priority List (Pierzynski, 1999).

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 (Wilson et al., 2003). However, 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; Vangronsveld et al. (1999) and Wilson et al. (2003) estimate that the integrity of encapsulation methods is limited to 20-30 years at best.

There are currently no practical techniques for the *in-situ* removal of heavy metals from soil or spoil, however *in-situ* treatment (immobilisation) of heavy metals is gaining increased acceptance by the scientific and regulatory communities (Vangronsveld et al., 1995; Vangronsveld et al., 2000; Friesl et al., 2001; Lombi et al., 2001 and Hamon et al., 2002).

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 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. Kleinman (1989) estimated that ***in the US in 1989 there were 19,500 km of waterways adversely affected by AMD.***

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 (Kabata Pendias & Pendias, 1992; Alloway, 1995; Dollhopf, 1998; Miekle et al., 1999 and Brown et al., 2000). The chemical condition of acid waste rock and tailings also inhibits fungal and bacterial ammonification processes and

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presents an ongoing obstacle to plant growth and natural regeneration (Bengson & Thompson, 1998) 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™ reagent 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.

> *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™ reagent using SRPC's. Extensive laboratory, bench and field trials have demonstrated that the application of Terra B™ reagent 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™ reagent can be applied to existing waste rock dumps using slurry, pelletised and powdered reagents.

This case study examines the main results of the *in-situ* remediation of an acidic, metal contaminated Haul Road verge that had been unsuccessfully treated and revegetated 12 years ago using lime. The study used 4 x 10 m wide x 40 m long plots. The plots were; (1) control, (2) Terra B™ reagent, (3) lime + biosolids, and (4) clay capping and topsoil addition.

Figure 1. The study site three years ago showing the failure of previous liming for remediation ten years before.

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Figure 2. This figure shows the steps taken during the addition of the Terra B™ reagent at Mt Carrington. The site was levelled using the excavator to allow access to the trucks. Terra B™ reagent was transported to the site by truck and deposited in piles. The piles were then spread and incorporated using an excavator. The haul road contained a range of size fractions, from fines to boulders greater than two metres in width (far right).

This study utilised the addition of a dry Terra B™ reagent product that was incorporated using a 20 tonne excavator fitted with a single ripping tine. There was no dust problem at the site and the operator said "it was an easy, clean job to do".

RESULTS

The waste rock in the Haul Road was both physically and chemically heterogenous. Table 1 below shows the initial soil chemistry taken from 25 samples at the beginning of the study. Physically the material ranged from clay size to boulders with a diameter of about one metre.

TABLE 1. SOIL CHEMISTRY OF THE WASTE ROCK TREATED USING TERRA B™ REAGENT.

	Minimum	Maximum		Minimum	Maximum
pH	2.65	5.83	Cu (mg kg^{-1})	166.29	675.31
EC(μS cm^{-1})	110.00	1150. 00	Fe (mg kg^{-1})	19987.07	29525.54
TAA (mmol kg^{-1})	42.00	132.00	Mn (mg kg^{-1})	219.62	1436.13
CRS (%)	0.35	1.05	Ni (mg kg^{-1})	3.36	34.90
Al (mg kg^{-1})	3527.29	7624.52	Pb (mg kg^{-1})	168.15	1024.03
Cd (mg kg^{-1})	7.10	21.42	Zn (mg kg^{-1})	380.36	1210.82
Cr (mg kg^{-1})	6.50	41.26			

pH refers to the 1:5 soil reaction pH; EC indicates electrical conductivity; TAA indicates actual acidity in the waste rock; CRS represents the chromium reducible sulphur concentration and is an indicator of potential future acid generation.

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> *Haul Road pH leachate data*

After five years the leachate data, collected from three lysimeters within each plot, show that Terra B™ reagent has markedly outperformed the other treatments and continues to get better over time. Figure I shows the results, relative to a control site, of using Terra B™ reagent and lime for the *in-situ* neutralisation of soil acidity in a waste rock haul road verge.

Leachate was collected by lysimeters 50cm below the application depth for the amendments. In Figure 3 it can be seen that Terra B™ reagent has the capacity to neutralise acid in the application zone, that it neutralises sub-surface acidity and that leachate pH is maintained over time. In contrast, the data show that not only has leachate pH in the lime plot decreased over time, but the lime only had a mild effect on the neutralisation of soil acidity below the application depth (indicated by an increase in leachate pH relative to the control).

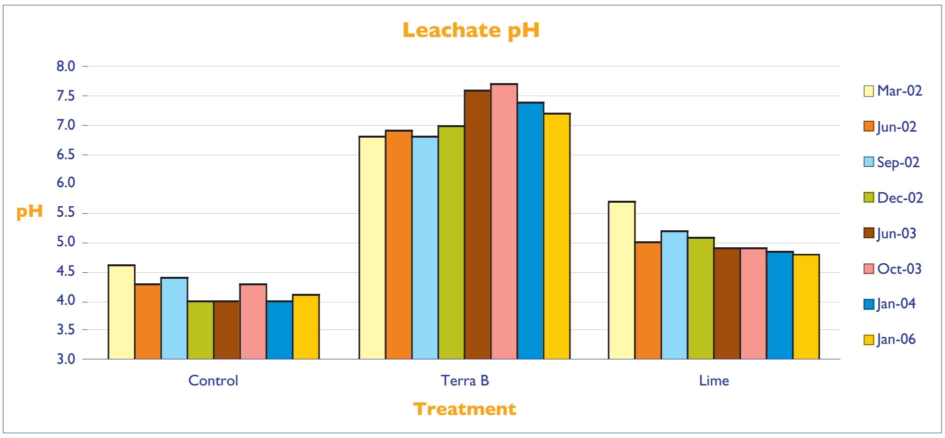

Figure 3. Acid neutralisation in a waste rock dump using TerraB™ reagent and lime.



Figure 4. Average tree growth from left to right in the control, lime and Terra B™ reagent plots after 24 months.

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> *Haul Road leachate data*

This study has also demonstrated that both Terra B™ reagent can lime will immobilise metals in and below the application zone but that the effectiveness of Terra B™ reagent is far greater than that of lime (see Figure 5).

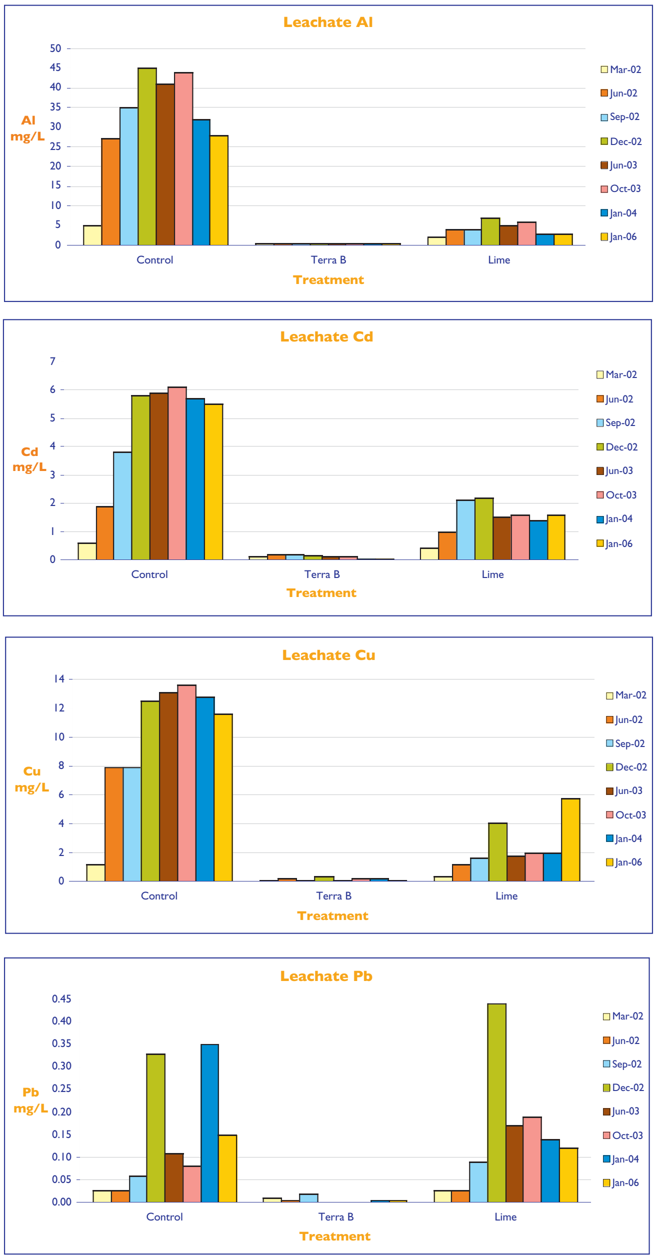

Figure 5. Metal immobilisation using Terra B™ reagent and lime. This figure shows that Terra B™ reagent is superior to lime for the immobilisation of metals using in-situ remediation.

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> *Haul Road plant growth*

A great advantage of using Terra B™ reagent is that while the neutralisation of soil acidity and the immobilisation of toxic metal is undertaken the sites can be simultaneously revegetated, thereby decreasing site disturbance and remediation and maintenance costs. The study has found that plant growth of Australian native grass and tree species grown in this acid waste rock dump is superior to that of test plots treated with lime and plots treated using clay capping encapsulation (Figure 5 and Figure 6). Furthermore, the data indicate that the longer that time elapses once the treatment is applied, the better Terra B™ reagent performs and the more it outperforms alternative

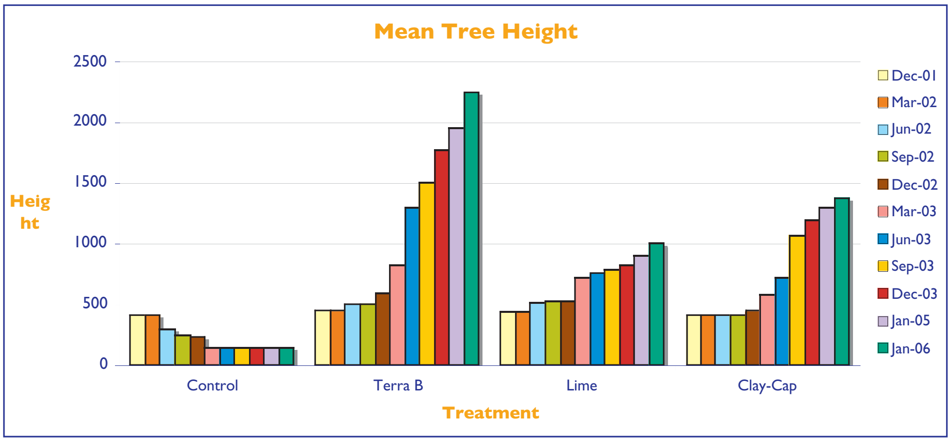

Figure 6. Average tree growth in cm of the trees in the 4 plots over 5 years.

CONCLUSION

After 5 years of monitoring ViroMine™ Technology has proven to be highly effective in acid rock remediation at Mt Carrington, Australia. The results show that Terra B™ reagent is an effective *in situ* soil amendment that is suitable for the development of surface reactive permeable barriers that neutralise surface and sub-surface 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.

Left: Plant growth in acidic mine waste with Terra B™ reagent.
Right: Growth in control (without application of Terra B™ reagent).

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