



*A COMMERCIAL APPLICATION OF  
VIROSOIL™ TECHNOLOGY*

**CASE STUDY  
CONTAMINATED SOIL REMEDIATION  
MT CARRINGTON**

*“This study has shown that the ViroBind™,  
Terra B™ and ViroGrow™ reagents offer  
superior acid neutralisation to lime and that  
the reagents continue to neutralise pH and  
promote tree growth over time...”*

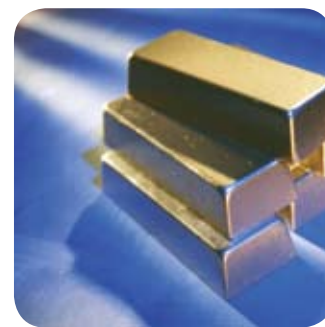


*Planting pots after Terra B™ reagent  
application.*

## PROBLEM

The Mt Carrington mine site in northern New South Wales, Australia, carries a legacy of more than 150 years of gold and silver mining. Within the site was a large quantity of sulphidic waste rock in urgent need of remediation.

Previous attempts at remediation had shown that lime had limited success in that plant growth was sustainable for periods of only up to two years. There was a need for a long-term sustainable solution.



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

## VIROTEC'S TOTAL SOLUTION

Virotec has recently developed a suite of reagents to remediate acidic trace element (particularly heavy metals) contaminated soils and is developing reagents that can immobilise some organic contaminants. The methods used to remediate contaminated soils allow *in situ* remediation and the reagents can be added to the soil profile using dry powdered, water soluble or slurried forms of the reagents depending on which form is most convenient and appropriate for each site.

## VIROTEC'S TOTAL SOLUTION

When these reagents are added to the soil they neutralise soil acidity and “immobilise” heavy metals. Immobilisation is seen as the most effective and environmentally sustainable technique for soil remediation and works by binding contaminants in the soil profile as non-bioavailable, chemically inert forms thereby limiting their potential for translocation into the adjoining environment or their absorption by plants and animals. Because complete removal of the contaminants is not possible and encapsulation can never provide a permanent solution, immobilisation offers the most practical long term solution.

In this study, the ViroMine™ Technology and ViroSoil™ Technology reagents Terra B™, ViroBind™ and ViroGrow™ were tested and although each reagent has unique properties, they are all effective at:

- > Creating or maintaining a healthy, sustainable soil horizon to allow revegetation by controlling trace element availability in a way that promotes sustainable plant growth and soil microbiota;
- > Neutralising soil acidity in the application zone;
- > Neutralising soil acidity below the application zone;
- > Immobilising inorganic metal contaminants as non-bioavailable environmentally inert forms;
- > Retaining phosphate, ammonium, calcium, magnesium, potassium and other essential macro and micronutrients in plant available forms, and;
- > Increasing soil moisture retention.

These reagents have been tested extensively in the laboratory, and in large-scale pot trials in Australia.



*The mine opening at Mt Carrington.*

Virotec's reagents immobilise inorganic metal contaminants but make macro and micronutrients available for plant growth.

## BACKGROUND

The contamination of soils by acidity or inorganic contaminants, or both, is common at mine sites as a result of sulphide mineral oxidisation, in agricultural soils through the addition of biosolids and some fertilisers, in soils contaminated by fallout from smelters and refineries, in natural acid sulphate soils, and at sites where sediment is dredged from harbours, estuaries lakes or dams and then stored in subaerial conditions.



Tailings from an industrial smelter.

The magnitude of the problems associated with soil contamination is highlighted by the data for the European Union where there are 150,000 to 400,000 heavy metal contaminated sites containing more than 1,000,000,000 m<sup>3</sup> of highly contaminated soil, waste rock and tailings (Mule and Melis, 1999). Much of this contaminated material is a result of human activity undertaken between 1800 - 1945 (Lepp, 1999) and the conservatively estimated cost to remediate these sites is in excess of US\$100 billion (Lombi *et al.*, 1998).

The contamination of farmland by the addition of sewage effluent and biosolids is also now acknowledged as a possible environmental source of metal contaminants, pesticides, nutrients and potentially hazardous compounds such as polychlorinated biphenyl (Phillips, 1994). The soluble fraction in biosolids is usually only 0.5 – 7 % of the total amount of sludge-borne heavy metals but can be a major contributor to the total metal flux through the soil or metal uptake by plants following application. Whatmuff, (1999) found that under conditions where the soil pH is <5 cadmium (Cd) and zinc (Zn) remain highly bioavailable even when the concentrations in the biosolids are very low.

These findings are corroborated by Balik *et al.*, (1999) who found a substantial increase in Cd and Zn in above ground biomass after biosolids application. Metal contamination can also occur as a result of the application of agricultural fertiliser and Ross, (1994) states that phosphatic fertilisers are a major source of cadmium in agricultural soils. The problems associated with smelter fallout and contamination of soil and water from mining are also well documented in the scientific literature and such contamination contributes to excessive and often uncontrolled pollution.

Several remediation methods were investigated to determine the most effective, sustainable solution. In particular, encapsulation of permeable cells does not work because they are not sustainable. Additionally, when encapsulated cells are disturbed there is a potential for leaching of heavy metals and sulphidic waste.

The minerals used in ViroMine™ Technology and ViroSoil™ Technology reagents are largely insoluble under all likely soil conditions and consequently, unlike lime, cannot be leached out.

## TREATMENT METHODS

*Ex situ* and *in situ* remediation techniques can be used to remediate contaminated soil. However, *ex situ* techniques generally involve civil engineering work and are expensive, environmentally invasive, labour intensive and they pose ongoing problems with the removal, transportation and subsequent redistribution of contaminants into the environment at landfill sites. In contrast, *in situ* remediation techniques combined with sustainable revegetation practices offer a viable alternative to the invasive and expensive practices that are currently being used.

The principle of immobilisation seeks to add soil amendments to the root zone of contaminated soils or, where possible, throughout the entire contaminated profile, in order to bind metals in nonbioavailable forms thereby limiting their environmental availability, while maintaining the availability of essential plant nutrients. The main objective of *in situ* remediation techniques is to reduce the long-term environmental availability of contaminants in soil and aquatic environments through the incorporation of site specific reagents thereby creating a permeable reactive barrier within the soil profile. Such an approach modifies the geochemical availability of potential contaminants without removing them from natural geochemical cycles and risking creating new disequilibrium conditions.



*Overview of the pot trial site at Mt Carrington.*

To test *in situ* techniques, one ViroMine™ Technology and two ViroSoil™ Technology reagents were applied in extensive pot trials at the Mt Carrington mine site using the *in situ* permeable reactive cover methodology described above. Plastic drums (150 x 200 L) were used for tree growth trials. All potting containers were filled with contaminated soil and waste rock. Three Australian native tree species (Eucalypt, acacia and casurina) from three genera were tested together with an approved pasture grass and a native pasture grass. Terra B™, ViroBind™ and ViroGrow™ reagents were tested in this study and compared with applications of lime, lime + biosolids, biosolids, NPK soluble fertiliser and a control.

## RESULTS

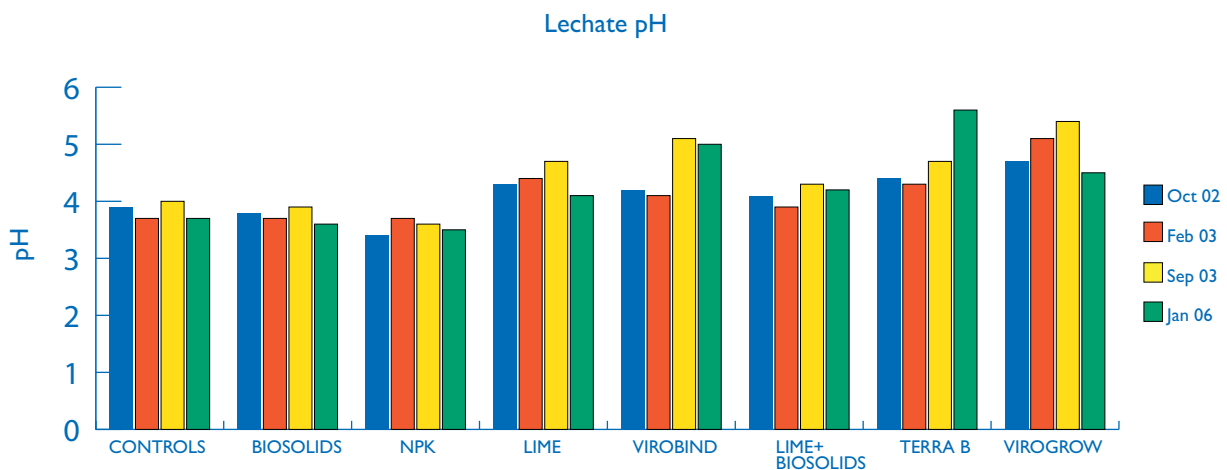
Leachate from each of the test pots was collected and analysed for metals, pH, electrical conductivity, salts and nutrients over four years. The data show that in these trials the capacity of the ViroMine™ Technology and ViroSoil™ Technology reagents to neutralise soil acidity is greater than that of lime and the other additives, and continues to improve over time.



*Haul road after treatment.*

Furthermore, the ViroMine™ Technology and ViroSoil™ Technology reagents appear to continue neutralising acidity whereas lime and the other additives appear to lose their capacity to neutralise soil acidity within a short period of time. The data (in Figure 1 below) also show that the addition of biosolids and NPK fertiliser has no significant effect on leachate pH and curiously, biosolids combined with lime appear to consume alkalinity in the soil profile.

Figure 1. Average leachate pH collected from five replicates within each treatment over four years.



The data from this study show that ViroBind™, Terra B™ and ViroGrow™ reagents are all very effective at immobilising metals within the soil profile indicating that *in situ* remediation is an effective method of soil remediation.

The metal leachate data also show that the ViroBind™, Terra B™ and ViroGrow™ reagents are even more effective after four years. Generally, the ViroMine™ Technology and ViroSoil™ Technology reagents removed most available metals from the soil profile immediately, and removed greater amounts of potentially available metal over time.

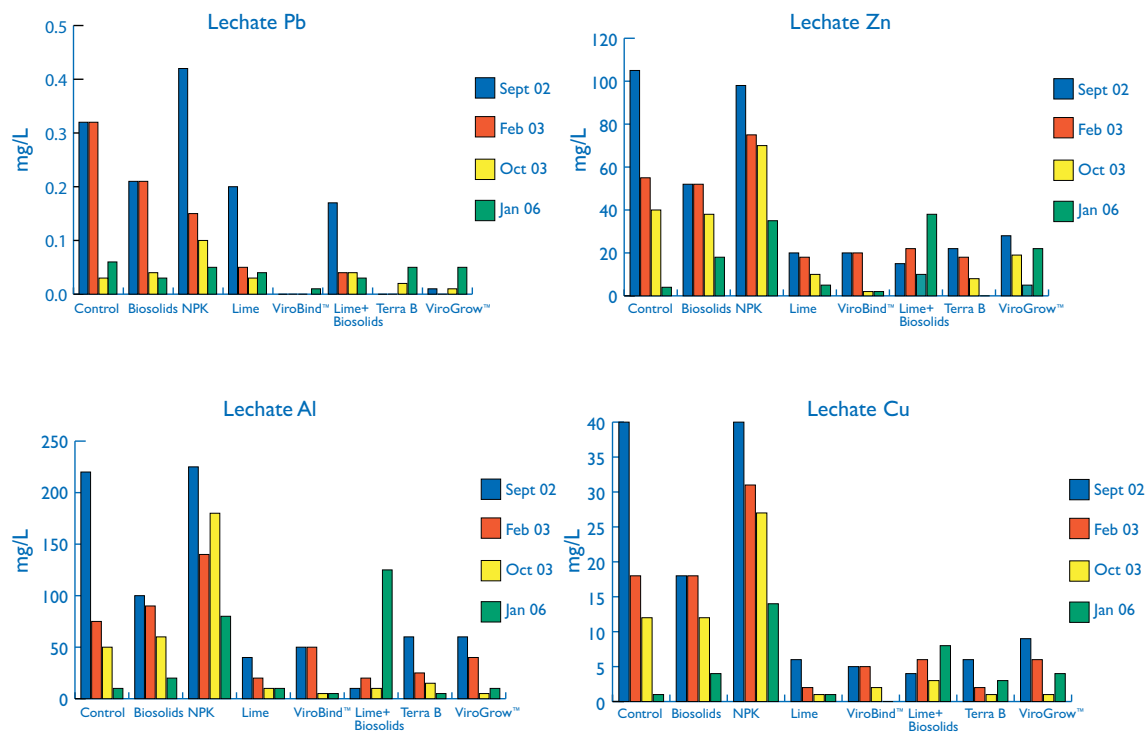
In contrast, biosolids and NPK fertiliser had little or no effect on metal availability, and lime or lime & biosolids had only modest ability to reduce metal availability.



Tailings dam revegetation.

Data from other studies also show that the metal immobilising potential of the ViroBind™, Terra B™ and ViroGrow™ reagents increases over time and that once the metals are immobilised they remain essentially non-bioavailable to soil biota such as earthworms or to plants grown in the remediated soil.

Figure 2. Average leachate Pb, Zn, Al and Cu concentrations taken from five replicates within each treatment over four years.



## TREE GROWTH

The best indicator of successful soil remediation is the establishment and growth of a healthy vegetation cover. This study used native Australian tree and grass species and has clearly demonstrated that the ViroBind™, Terra B™ and ViroGrow™ reagents are not only suitable and effective for contaminated soil remediation but that they provide better and more sustainable outcomes than the use of lime, which has been the most widely used soil ameliorant in the past.



Overview of the pot trial site at Mt Carrington.

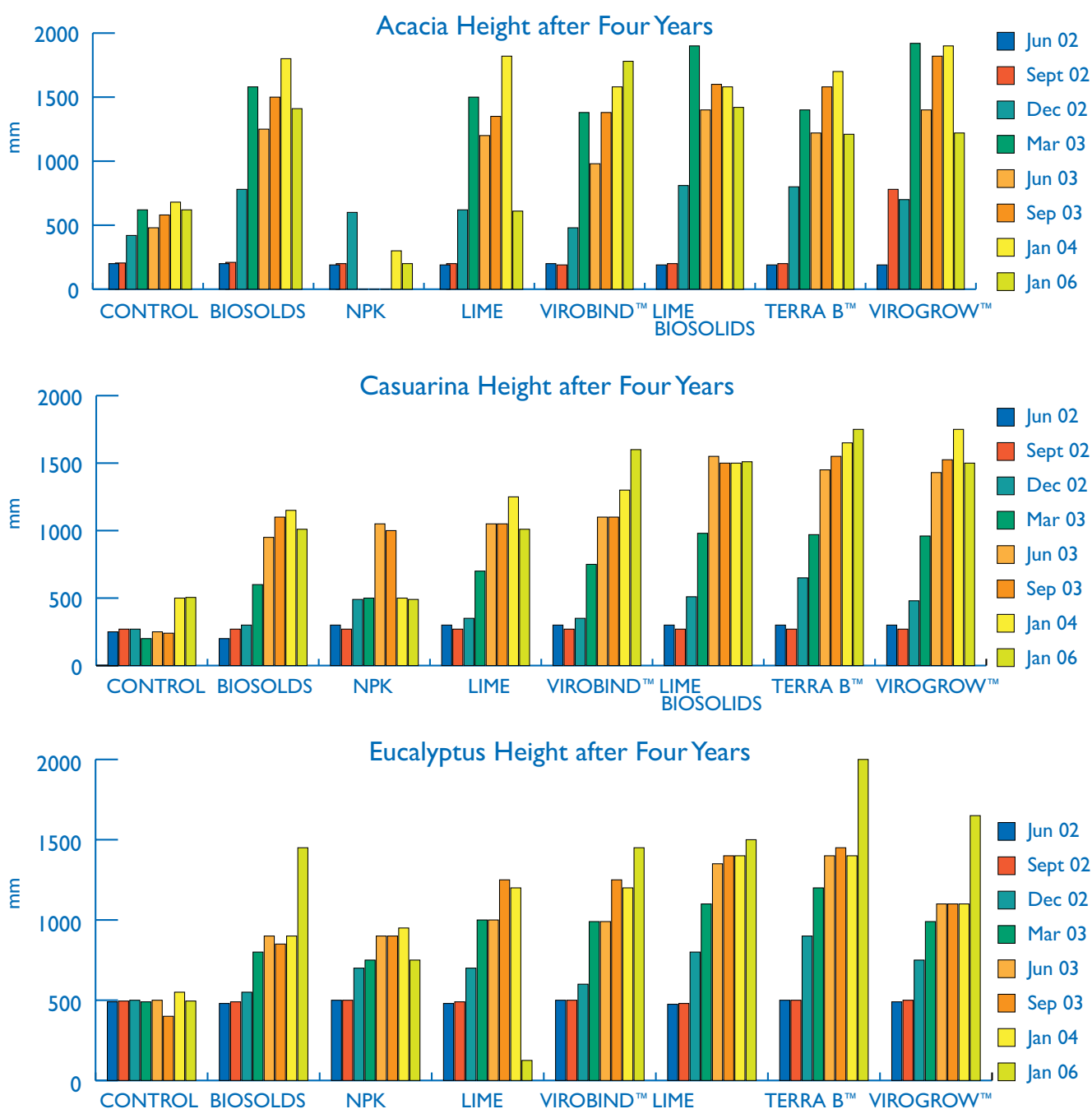
This study has also shown that the uptake of metals by the tree and grass species tested is substantially reduced by the use of ViroBind™, Terra B™ and ViroGrow™ reagents compared to the use of lime. The uptake in these treatments is directly related to the 0.01 M CaCl<sub>2</sub> soil extractable load for each metal indicating that only a very small proportion of the metals bound in the treated waste rock or tailings are available for uptake by plants.

When tree growth from this study is plotted as a graph the effectiveness of ViroBind™, Terra B™ and ViroGrow™ reagents is clearly highlighted. Figure 3 (overleaf) shows average tree height in the treatments over four years. Trees in the control and NPK fertiliser treatments have either died from metal toxicity or have shown very poor growth.

The addition of biosolids initially promoted tree growth but after four years the trees are now suffering from metal toxicity. The use of lime and lime + biosolids allowed good tree growth over the first 12 -14 months of the study, however at 16 -18 months the ability of lime to maintain soil pH at near-neutral conditions has failed and tree growth has slowed due to falling pH and increasing metal toxicity.

In contrast to these treatments, the ViroBind™, Terra B™ and ViroGrow™ reagent treatments show excellent tree growth over the entire four years. It is anticipated that tree growth will continue in these treatments because the reagents are able to maintain a suitable soil pH because the reactive minerals in the ViroMine™ Technology and ViroSoil™ Technology reagents are sparingly soluble and cannot be leached out before all acid that could be produced has been produced and neutralised.

Figure 3. Average growth in this study for each of the three native Australian trees over four years.



## CONCLUSION

This study has shown that the ViroBind™, Terra B™ and ViroGrow™ reagents offer superior acid neutralisation to lime and that the reagents continue to neutralise pH and promote tree growth over time. Because application of the ViroMine™ Technology and ViroSoil™ Technology reagents is simple and expensive treatment equipment is not required, these reagents offer an economic alternative to the invasive and expensive soil remediation techniques that are currently widely used.

Not only is soil acidity neutralised by the ViroBind™, Terra B™ and ViroGrow™ reagents but metals in the soil are immobilised as chemically inert and non-bioavailable forms. Furthermore, the use of these reagents allows the simultaneous remediation and revegetation of the contaminated soil, thereby offering additional cost efficiencies in implementation of the technology.

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