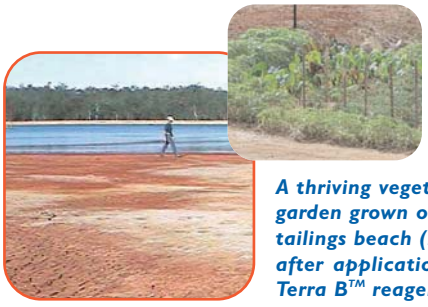
AN APPLICATION OF
VIROMINE™ TECHNOLOGY

CASE STUDY: TAILINGS DAM REVEGETATION AT MT CARRINGTON

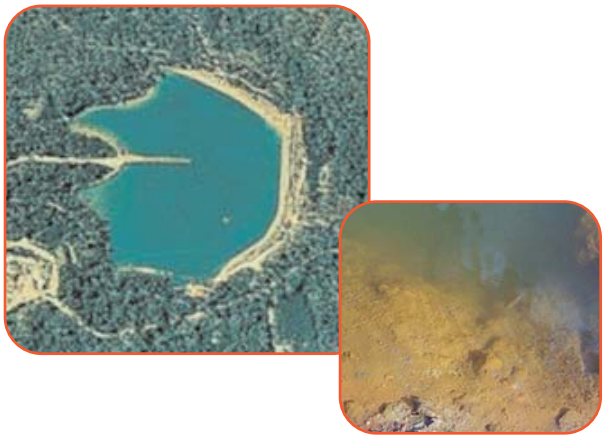
"After the treatment and discharge of the tailings dam water, wetland plants have been able to colonise the exposed tailings beach. Before treatment using Acid B™ and Terra B™ no vegetation was able to colonise the exposed tailings or exposed dam walls."



A thriving vegetable garden grown on a tailings beach (left) after application of Terra B™ reagent.

VIROTEC

>>> CASE STUDY: TAILINGS DAM REVEGETATION



Left: The tailing dams dam after treatment using ViroMine™ Technology.
Right: Contaminated tailings dam water prior to treatment.

PROBLEM

The Mt Carrington mine site in northern NSW, Australia, carries a legacy of more than 150 years of gold and silver mining (some copper, zinc and antimony were also recovered), but the last commercial operations stopped in 1989. Mineralogical recovery of gold and silver employed the carbon-in-pulp cyanide extraction method. After extraction of gold and silver the tailings were discharged at a pH of > 9.0 to a 14 ha tailings dam.

Since 1989 the water in the tailings dam progressively became acidic and enriched in heavy metals. largely as a result of the input of acid mine drainage water from oxidising waste rock, and in 2001 the tailings dam threatened to overflow because the increasing volume of water could not be treated using existing technology.

Virotec used ViroMine™ Technology to treat the water *in situ* in a world first demonstration of its new technology. After the water was treated to the stringent environmental discharge standards, 350 ML of water was released from the tailings dam into the local catchment. The decrease in the water volume left exposed areas of tailings (Figure 1), and in 2002 Virotec undertook trials using the Terra B™ reagent to revegetate the tailings.

Figure 1. This photo shows the exposed area of tailings that was used to grow vegetables and grass in this study. The photo also shows the very thin layer of the Acid B™ reagent that remained after the water had been released from the tailings dam.

VIROTEC

>>> CASE STUDY: TAILINGS DAM REVEGETATION

VIROTEC'S TOTAL SOLUTION

Virotec used *in-situ* remediation to treat the exposed tailings in order to reduce the long-term environmental availability of contaminants in the pedogenic environment. This was achieved by neutralising actual acidity in the oxidised tailings and immobilising potentially harzardous trace elements while adding the necessary organic carbon and nutrients required for the plant growth.

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

- Create a healthy soil horizon to allow revegetation by adding essential organic matter and nutrients 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;
- Bind phosphate, ammonium, calcium, magnesium, potassium and other essential macro and micronutrients in plant available forms; and
- Increase soil moisture.

BACKGROUND

At both active and derelict mines, waste rock and tailings constitute the largest volume of material that must be stabilised and remediated and are often the hardest to remediate because of their chemical and physical properties. The leaching of acid mine drainage (AMD) from waste rock and tailings often lead to adverse environmental impacts on waterways and adjoining terrestrial habitats.

The problems associated with remediating and revegetating 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; Brown *et al*., 2000). Acid waste rock and tailings also inhibit natural fungal and bacterial ammonification processes and 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.

The remediation of waste rock and tailings can also be complicated by the physical and textural properties of the material. Tailings are very fine grained and can remain waterlogged for extended periods of time particularly if the tailings dam has not been de-watered. Even if the tailings dam has been drained and de-commissioned, the tailings have poor drainage and micromorphology and are structurally unstable; they are commonly unable to support the weight of machinery that can be required for remediation work.

>>> CASE STUDY: TAILINGS DAM REVEGETATION

TREATMENT METHODS

> *Remediation of tailings dams during tailings emplacement*

This is the preferred option for implementing ViroMine™ Technology using Terra B™ because it allows complete treatment of the tailings in the dam, offering a long term, one–off solution. Such on-going treatment can be achieved by adding the appropriate amount of Terra B™ as a slurry product to the tailings as they are pumped to the dam. Addition of Terra B™ in this way ensures that even if complete oxidation of all sulphide minerals in the tailings was to occur, acidity would never be generated because it would be neutralised *in situ* by the Terra B™ reagent.

> *Remediation of existing tailings dams*

Existing tailings dams, although harder to remediate, can also be effectively treated using ViroMine™ Technology and the Terra B™ reagents. Extensive laboratory, bench and field trials have demonstrated that utilising Terra B™ in acidic, metal contaminated tailings offers an economically viable and environmentally sound alternative to capping and acid neutralisation using lime or magnesium reagents. Terra B™ can be applied to existing tailings as a slurry, or as pelletised or powdered reagents.

Virotec's reagents can be applied in powder, pellet or slurry form.

In a world first Virotec undertook two trials to revegetate acidic tailings. The first trial mixed the layer of the Acid B™ reagent residue remaining after treating the water in the tailings dam with the tailings to allow the growth of pasture grass. The second trial added the Terra B™ reagent to the oxidised acidic tailings horizon at Mt Carrington to allow the growth of several vegetable species; root crops, grain crops and leaf crops were used to allow investigation of any possible metal uptake.

The vegetables were harvested at the completion of the study and tested for metal concentrations to complete assessment of the effectiveness of the treatment. Tailings chemistry was also investigated to determine whether all acidity had been neutralised and the soluble and exchangeable metals had been immobilised. Three Terra B™ application rates were tested against one control plot; each test or control plot was 10m x 10m. Terra B™ was combined with the tailings to a depth of 20 cm using a hand operated rotary hoe.

>>> CASE STUDY: TAILINGS DAM REVEGETATION

Figure 2. The germination of grass in the acid tailings after mixing the Acid B™ residues, remaining after water treatment, into the exposed tailings beach.

RESULTS

> ***Trial 1. Growth of pasture grass and reeds on exposed tailings.***

This first trial mixed the thin layer of the Acid B™ reagent that remained after treatment of the tailings dam water and a small amount of soluble with NPK fertiliser with the tailings using a rotary hoe. The results showed that the spent Acid B™ reagent had enough residual alkalinity to allow the growth of grass by neutralising acidity in the exposed tailings (Plate 2). The improvement in water quality also allowed the successional establishment of pioneer riparian wetland vegetation (Plate 3).

Figure 3. After the treatment and discharge of the tailings dam water, wetland plants have been able to colonise the exposed tailings beach. Before treatment using Acid B™ and Terra B™ no vegetation was able to colonise the exposed tailings or exposed dam walls.

> ***Trial 2. Growth of vegetable crops in acid tailings using Terra B™.***
> ***Tailings chemistry***

The tailings in the dam were initially tested using soil cores to determine pH, EC, total actual acidity or alkalinity and 0.01M $CaCl_2$ extractable trace element concentrations in the top 30 cm of the tailings profile. The data in figure 4 show that the tailings, to a depth of 50cm, had an average surface pH of 3.15 and had a high actual acidity (85mmol of acid/kg of tailings); the tailings pH increases sharply in oxidised tailings at a depth of 70 – 80 cm.

>>> CASE STUDY: TAILINGS DAM REVEGETATION

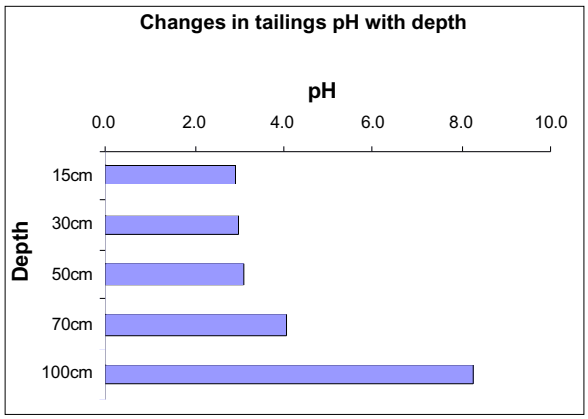


Figure 4. Changes in average water soluble pH in the tailings at Mt Carrington taken from 10 soil cores over a 400 m² area.

The tailings were also tested for pore water metal concentrations using the US EPA TCLP test (Table 1). These data show that the Terra B™ reagent reduced pore water metal concentrations substantially after only 2 months and data from other work indicates that these results should improve further over time.

	Before treatment with Terra B™	After treatment with Terra B™
pH Level	3.8	7.300
Cadmium (mg/L)	0.4	<0.001
Copper (mg/L)	6.8	0.150
Iron (mg/L)	18.7	3.200
Lead (mg/L)	4.2	0.026
Zinc (mg/L)	42.2	2.100

Table 1. pH and TCLP concentrations before, and 2 months after treatment with Terra B™.

>>> CASE STUDY: TAILINGS DAM REVEGETATION

> *Tailings vegetable growth*

The two vegetable crops used in this study were grown in tailings that were highly acidic and contained very high concentrations of heavy metals. Although revegetation had not been attempted in these tailings the fact that all seedlings died and all seeds failed to germinate in the control plot shows how unsuitable the untreated tailings were for plant growth.

The data from the analysis of Silverbeet leaf tissue and wheat grain collected after maturation of the plants show that Terra B™ can substantially reduce metal uptake in these species.

The vegetable garden grown on the tailings beach after treatment with Terra B™.

	Silverbeet grown in untreated tailings	Silverbeet grown in Terra B™ treated tailings	% Removal
Fe (mg/L)	776	390	50
Pb (mg/L)	42	0.86	98
Zn (mg/L)	501	149	70
Cu (mg/L)	28	29	-

	Wheat seed grown in untreated tailings	Wheat seed grown in Terra B™ treated tailings	% Removal
Fe (mg/L)	Wheat was unable to grow in the untreated tailings	541	-
Pb (mg/L)		3.2	-
Zn (mg/L)		176	-
Cu (mg/L)		41	-

Tables showing metal uptake by plants grown in untreated and treated tailings.

VIROTEC

>>> CASE STUDY: TAILINGS DAM REVEGETATION

CONCLUSION

The use of ViroMine™ technology has proven that tailings dam water can be treated *in situ* to a sufficient quality that it can be discharged to the environment and that exposed tailings can be treated simultaneously to allow sustainable habitat development with minimal on-going costs for managers or regulators.

Plant life flourishing near the banks of the treated tailings dam.

REFERENCES

Alloway, B. J. 1995. "The mobilisation of trace elements in soils", In: *Contaminated Soils 3rd International Conference on the Biogeochemistry of Trace Elements,* (Eds.) R. Prost, Paris, France. Instiut National De la Recherche Agronomique. May 15-19, Vol. 1 of 1.

Bengson, S. A. and Thompson, T. L. 1998. "Reclamation of acidic copper mine tailings using municipal biosolids", In: *Proceedings of the 25th Anniversary and 15th Annual National Meeting of the American Society for Surface Mining Reclamation "Mining Gateway to the Future",* (Eds.) W. Joseph, St Louis, Missouri. ASSMR. May 17-21, Vol. 1 of 1.

Brown, S. L., Henry, C. L., Compton, H., Chaney, R. L. and DeVolder, P. 2000. "Using municipal biosolids in combination with other residuals to restore a vegetative cover on heavy metal mine tailings", In: *Proceedings of the 17th Annual Meeting of the American Society for Surface Mining Reclamation, "A New Era of Land Reclamation",* (Eds.) S. G. Richardson, Tampa, Florida. ASSMR. June 11-15, Vol. 1 of 1.

Dollhopf, D. 1998. "pH control in acidic metalliferous mine waste for site revegetation", In: *Proceedings of the 25th Anniversary and 15th Annual National Meeting of the American Society for Surface Mining Reclamation "Mining Gateway to the Future",* (Eds.) W. Joseph, St Louis, Missouri. ASSMR. May 17-21, Vol. 1 of 1.

Kabata Pendias, A. and Pendias, H. 1992. "*Trace elements in soils and plants*", (Ed.). CRC Press. Boca Raton, U.S.

Miekle, T. W., Barta, L. and Barta, J. P. 1999. "Waste rock revegetation: Evaluation of nutrient and biological amendments", In: *Proceedings 16th Annual National Meeting of the American Society for Surface Mining Reclamation "Mining and Reclamation in the next Millennium",* (Eds.) D. M. Bland, Scottsdale, Arizona. ASSMR. August 13-19, Vol. 1 of 2.

VIROTEC