THE APPLICATION OF VIROMINE™ TECHNOLOGY USING TERRA B™ REAGENT IN THE TREATMENT OF SULPHIDIC WASTE ROCK AND SOIL

VIROMINE™ TECHNOLOGY TECHNICAL DATA SHEET

VIROTEC

>>> VIROMINE™ TECHNOLOGY TECHNICAL DATA SHEET

INTRODUCTION

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.

Sulphide waste rock and exposed ore zones (which generate leachates to surface and ground water) contain heavy metals, including arsenic, cadmium, cobalt, copper, lead and zinc. Elevated nitrates and sulphates are also present in heap leach residues. Copper, cadmium, zinc and acidity are the major polluting risks to the habitats of local water catchments.

The magnitude of the problems associated with soil contamination is highlighted by 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^3 of highly contaminated soil, waste rock and tailings. Much of this contaminated material is a result of human activity undertaken between 1800-1945 and the conservatively estimated cost to remediate these sites is in excess of US$100 billion.

ViroMine™ Technology, provided by Virotec International Ltd, has the remarkable ability to neutralise acid and remove heavy metals from waste rock and soil across a wide range of applications.

This innovative technology can be applied to economically treat sulphidic mine tailings, acid sulphate soils and waste rock dumps to:

- Permanently neutralise acid.
- Trap trace metals and prevent leaching.
- Enhance nutrient retention capacity and promote vigorous plant growth.

ViroMine™ is a total and highly effective solution. Indeed, ViroMine™ Technology ***"may be the only acceptable and sustainable solution from an economic point of view to solve acid rock drainage and acid sulphate soils,"*** according to Professor Olaf Schuiling from the International Institute of Environmental Engineering in Delft, The Netherlands.

Professor Schuiling, International Institute of Environmental Engineering in Delft, The Netherlands.

VIROTEC

>>> VIROMINE™ TECHNOLOGY TECHNICAL DATA SHEET

The effectiveness of the technology was further confirmed in October, 2002, and again in June, 2004, through studies carried out by the US EPA.

ViroMine™ Technology ensures selection of the best application strategy. Management of the treatment process is based on Virotec's:

- Extensive research database.
- Practical experience with commercial scale applications
- Results of laboratory trials for each waste water to be treated.

VIROMINE™ TECHNOLOGY APPLICATIONS

Virotec has developed its Terra B™ reagent to remediate sulphidic waste rock and soil. The methods used to remediate contaminated soils allow *in situ* remediation and the reagent can be added to the soil profile using dry powdered, water soluble or slurried forms of the reagent depending on which form is most convenient and appropriate for each site.

The application of Terra B™ reagent can prevent the formation of acidic leachate in the first place by stab-ilising exposed sulphidic waste rock, mining overburden and tailings. In most cases treated soils and wastes can be used to create a rich substrate for plant growth safe in the knowledge that immob-ilised metals cannot be translocated into adjoining non-polluted environments or taken up by plants.

ViroMine™ Technology can be customised to suit any individual application. It can be easily added to existing treatment facilities and requires minimal capital works, depending on the application.

The remediated soil formed when using Terra B™ reagent has potential re-use options. The remediated soil holds the bound metals sufficiently tightly that they can neither be taken up by plants nor released in leachate. This property combined with the high organic content of the sludge has potential for use as a soil conditioner.

The major advantages of using ViroMine™ Technology can be summarised below:

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

VIROTEC

>>> VIROMINE™ TECHNOLOGY TECHNICAL DATA SHEET

Photos showing sulphidic, acid generating rock and in-situ soil remediation in progress.

CHEMISTRY OF VIROMINE™ TECHNOLOGY

ViroMine™ Technology works by forming strong ionic bonds with the various metal ions in the soil and effectively immobilises metals into an insoluble, non-reactive sediment.

Terra B™ reagent has a high charge-to-mass ratio that increases its ability to strip metals ions from the soil.

The heterogeneous mineral surfaces in Terra B™ reagent catalyse metal precipitation from solution at a pH lower than that achievable with conventional alkaline treatments such as lime, magnesium oxide and sodium hydroxide, by providing nucleating surfaces and acting as substrates for precipitation.

The primary mechanism of acid neutralization and metal uptake in Terra B™ reagent is the dissolution of readily soluble alkaline minerals which supply hydroxides, carbonate ions for the precipitation of insoluble metal hydroxides, carbonates and hydroxy carbonate compounds on the products surfaces.

The ability of Terra B™ reagent to strip trace metals increases with time. Most metals bound by Terra B™ reagent are held as structural components of the mineral and therefore cannot be easily removed.

Most trace metals are initially trapped by adsorption. Terra B™ reagent is dominated by particles with a high surface area-to-volume ratio and high change-to-mass ratio. During aging, elements are redistributed to become structural components of new minerals during recrystalisation.

ENVIRONMENT AND SAFETY

The use of ViroMine™ Technology to treat sulphidic mine tailings, acid sulphate soils and waste rock dumps is both environmentally sustainable and economically viable. ViroMine™ Technology reagents are environmentally safe and the exhausted material may be disposed as a non-leachable solid residue.

Used Terra B™ reagent is not a hazardous or prescribed waste material. Even after use in many applications, it can be usefully reused in other applications. Exhausted Terra B™ reagent can also be used in selected down-stream applications depending on individual circumstances. The leaching of used or spent Terra B™ reagent cannot result in the release of any trace elements at potentially environmentally hazardous concentrations. Terra B™ reagent is classified as a non-hazardous, inert

or solid substance for transportation and is safe for unskilled workers to handle. Terra B™ reagent consists of minerals that are not known to pose any environmental hazard.

Virotec International recommends checking with local environmental regulations before final disposal.

CASE STUDY: ACID WASTE ROCK REMEDIATION AT MT CARRINGTON, NSW, AUSTRALIA

"After two 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."

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.

Aerial of the Mt Carrington mine site.

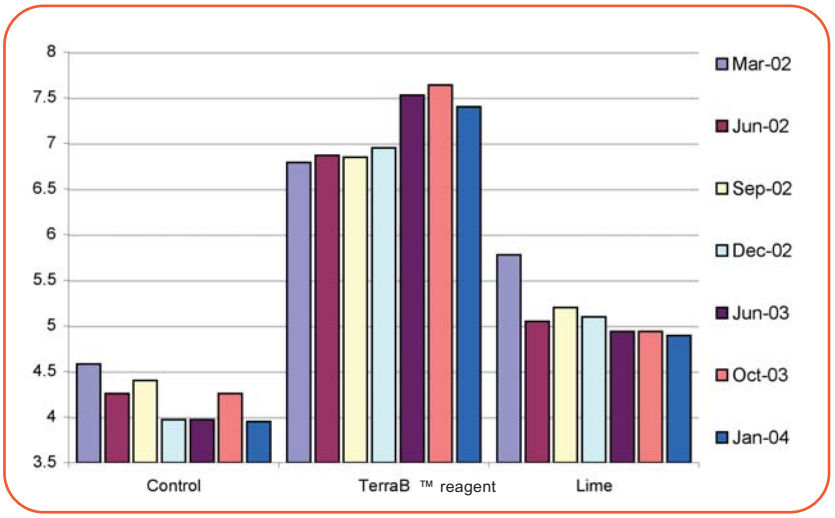
The remediation and revegetation that was undertaken on the acid waste rock dumps and haul road verges included clay capping and the addition of lime before planting. Most of these remediation attempts failed due to the presence of acid generating minerals such as pyrite and chalcopyrite, the high actual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

VIROTEC'S TOTAL SOLUTION

ViroMine™ Technology has proven to be highly effective in acid rock remediation at Mt Carrington. The results show that Terra B™ reagent is an effective *in situ* soil amendment that is suitable for the devel-opment 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.

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.

TABLE 1: ACID NEUTRALISATION IN A WASTE ROCK DUMP USING TERRA B™ REAGENT AND LIME.



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™ reagents no vegetation was able to colonise the exposed tailings or exposed dam walls."

PROBLEM

The Mt Carrington mine site 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. 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 ntechnology. 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, and in 2002 Virotec undertook trials using the Terra B™ reagent to revegetate the tailings.

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™ reagents no vegetation would grow in the exposed tailings or exposed dam walls.

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 neutralizing 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.

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

TABLE 2: PH AND TCLP CONCENTRATIONS BEFORE, AND TWO MONTHS AFTER, TREATMENT WITH TERRA B™ REAGENT.

	Before treatment with Terra B™ reagent	After treatment with Terra B™ reagent
pH Level	3.8	7.3
Cadmium (mg/L)	0.4	<0.001
Copper (mg/L)	6.8	0.15
Iron (mg/L)	18.7	3.2
Lead (mg/L)	4.2	0.026
Zinc (mg/L)	42.2	2.1

CASE STUDY: GILT EDGE, USA

Gilt Edge Mine in South Dakota was experiencing severe ARD resulting from mining operations. Recent tests conducted by the US EPA have demonstrated that ViroMine™ Technology was able to treat the water to a high standard without creating a toxic sludge.

PROBLEM

The Gilt Edge Mine is just five miles east of Lead at the headwaters of cold-water fisheries and municipal water supplies of the northern Black Hills. It is a 110 hectare open pit, cyanide heap leach gold mine, developed in highly sulphidic ore bodies. The mine consists of 570 megalitres of acidic, heavy-metal laden water in three open pits, as well as millions of cubic yards of acid-generating waste rock that need cleanup and long-term treatment.

The Gilt Edge Mine site where US EPA trials were carried out. The image shows the vast quantity of heap leach ore remaining on the heap leach pad.

Sulphide waste rock and exposed ore zones (which generate leachates to surface and ground water) contain heavy metals, including arsenic, cadmium, copper, lead and zinc. Elevated nitrates and sulphates are also present in heap leach residues. Copper, cadmium and zinc are the major polluting risks to the habitats of the receiving water catchment.

THE VIROTEC SOLUTION

"This is the first time that ViroMine™ Technology has been evaluated in the United States, however, it has been used to treat ARD at other sites throughout the world and met applicable water quality criteria," a consultant to the US EPA reported.

The data collected from the various trials the US EPA performed clearly demonstrated ViroMine™ Technology's capability of removing heavy metals from water and reducing leachate from waste rock dumps, and that this capability increases over time, even when no further treatment application occurs.

As Professor David McConchie of Southern Cross University has stated: ***"The new technology... is able to reduce the concentration of many environmentally hazardous trace metals by over one hundred thousand times."***

VIROTEC

TABLE 3: RESULTS FROM US EPA WASTE ROCK LEACHATE TRIALS (ALL VALUES IN PPB).

Analyte (Units)	Control 2003	Result 2001	Result 2002	Result 2003	Result 2004
pH	1.93	7.9	7.96	8.35	8.62
Acidity (mg/L as $CaCO_3$)	49,000	4	< 5	< 5	< 5
Alkalinity (mg/L as $CaCO_3$)	<LLD (5)	90	62	66	7
TDS (mg/L)	77,000	11,500	8,300	3,000	1,200
Sodium (mg/L)	9,300	2,970	2,990	570	250
Sulfate (mg/L)	55,000	6,000	5,800	2,200	840
Ag (µg/L)	150	<LLD (1)	1.1	<LLD (5)	<LLD (5)
Al (µg/L)	1,200,000	<LLD (50)	10	66	<LLD (50)
As (µg/L)	35,000	3.1	3.7	<LLD (10)	<LLD (10)
Cd (µg/L)	630	<LLD (1)	0.4	<LLD (1)	<LLD (1)
Co (µg/L)	2,200	1.5	11	<LLD (10)	<LLD (10)
Cr (µg/L)	390	<(1)	12	<LLD (10)	<LLD (10)
Cu (µg/L)	33,000	8.2	7.2	<LLD (10)	<LLD (10)
Fe (µg/L)	21,000,000	<LLD (25)	18	120	210
Hg (µg/L)	0.2	< 0.1	0.2	<LLD (0.2)	<LLD (0.2)
Mn (µg/L)	34,000	17	0.3	<LLD (10)	<LLD (10)
Ni (µg/L)	1,600	2.1	1.4	<LLD (10)	<LLD (10)
Pb (µg/L)	390	<2.2	2.9	<LLD (10)	<LLD (10)
Sb (µg/L)	500	<3.7	48	<LLD (10)	<LLD (10)
V (µg/L)	1,700	<0.9	1.0	<LLD (10)	<LLD (10)
Zn (µg/L)	29,000	42	21	<LLD (10)	<LLD (10)

Data for water leaching from sulfidic waste rock that had been treated using ViroMine™ Technology reagent in the Trench Trial at the Gilt Edge Mine site; the data span the four years since the treatment was carried out. The control data were obtained for leachate emanating from the same type of waste rock that had not been treated with ViroMine™ Technology reagent. < LLD indicates that the concentration is below the detection limit for the analytical procedure used (the detection limit is indicated in parentheses). NA indicates not analysed. Note: Data up to and including those for 2003 have been validated by CDM, but the data for 2004 have not yet been validated under the QC/QA procedures.