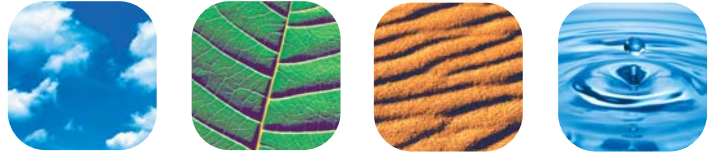


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THE APPLICATION OF VIROMINE™ TECHNOLOGY IN THE TREATMENT OF ACID ROCK DRAINAGE AND TAILINGS DAMS

VIROMINE™ TECHNOLOGY TECHNICAL DATA SHEET



>>> TREATMENT OF ARD & TAILINGS DAMS



The damage caused by Acid Rock Drainage can have a severe impact on humans, livestock, aquatic life and property.

A by-product of mining operations around the globe is mine waste rock, high in sulphur content and capable of generating significant quantities of acid.

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

This remarkable technology can be applied to economically treat Acid Rock Drainage (also referred to as Acid Mine Drainage or AMD), tailings dam water, 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™ Technology 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 Schuiling from the International Institute of Environmental Engineering in Delft, The Netherlands.

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.

ACID ROCK DRAINAGE

It has only been in the last 25 years that regulators have understood the devastating impact of Acid Rock Drainage (also referred to as Acid Mine Drainage or AMD). It is considered to be the principal threat posed by mining activity, past, present and in the future.

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Some examples of ARD. Mines can generate ARD for thousands of years.

Typical sources of Acid Rock Drainage at mine sites are underground workings where ground water percolates through a honeycomb of tunnels and shafts, piles of waste rock, mining overburden and exposed tailings. Mines may be a source of Acid Rock Drainage for thousands of years.

TAILINGS DAMS

It is estimated that some 13 billion tonnes of stone, 10 billion tonnes of sand and gravel, and 500 million tonnes of clay are used annually in the construction of tailings dams. Accordingly, there are tens of thousands of tailings dams worldwide containing billions of tonnes of mineral processing wastes.

Due to their vast quantities, liquid nature and very high content of toxic metal contaminants, their containment and control are an ongoing management concern at virtually all mine sites. The impact of seepage is a constant concern.

The most serious issue relates to the potential of tailings dams to fail or collapse, claiming lives and causing considerable environmental damage. The damage caused by these failures in terms of human casualties, destruction of property, disruption of communications, pollution of the environment and economic loss to the mining industry is enormous.



In this 25 ML tailings dam the total dissolved metal load equated to approximately 170 tonnes of dissolved metal.

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VIROMINE™ TECHNOLOGY APPLICATIONS

Virotec has developed a proven range of unique ViroMine™ Technology reagents to treat or prevent the devastating effects of ARD. These proprietary reagents are applied in a single-stage, 'in-situ' treatment capable of cleaning large volumes of tailings dam water and converting toxic dams into reservoirs of clean water which meet stringent environmental standards. The treated water can even be emptied into sensitive ecosystems or drinking water catchments.

- > Alka B™ Reagent designed to treat alkaline (pH >7) water contaminated with heavy metals.
- > Neutra B™ Reagent designed to treat mildly acidic (pH 6-7) water contaminated with heavy metals.
- > Acid™ Reagent designed to treat acidic (pH 4.5-6) water contaminated with heavy metals.
- > Acid B Extra™ Reagent designed to treat high acidic (pH <4.5) water contaminated with heavy metals.

When used to treat acid rock waters, ViroMine™ Technology reagents settle through 10 metres of water with-in 48 hours, extracting metals in the process. Unlike lime, the treatment does not leave behind a toxic sludge. Rather, it generates a thin, non-toxic, stable sediment – typically less than 5mm thick.

The application of these ViroMine™ Technology reagents can prevent the formation of acid rock drainage in the first place by stabilising exposed 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 immobilised metals cannot be translocated into adjoining non-polluted environments or taken up by plants.

ViroMine™ Technology replaces the conventional lime treatment and produces desirable, dense sediment that is easily recovered and dewatered. ViroMine™ Technology can be customised to suit any individual application.

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

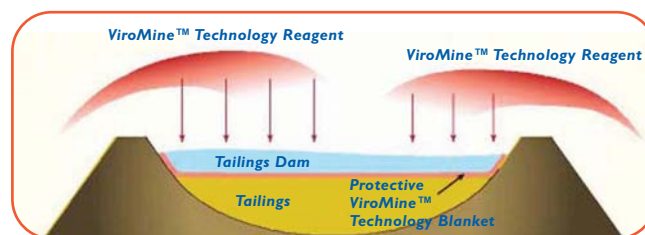


ViroMine™ Technology reagents are applied in powder, pellet or slurry form.

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ViroMine™ Technology reagents are applied to tailings dams in a single stage, in-situ treatment.



The sediment formed when ViroMine™ Technology settles and dries has potential re-use options. The sediment holds the bound metals sufficiently tightly that they can neither be taken up by the 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:

- > Reduction in sludge volumes generated.
- > Significant reduction in heavy metals in discharge water.
- > High pH buffering capacity.
- > Increased settling times resulting in improved water quality.

VIROMINE™ TECHNOLOGY APPLICATIONS

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

ViroMine™ Technology reagents have a high charge-to-mass ratio that increases their ability to strip metals ions from solution.

The heterogeneous mineral surfaces in ViroMine™ Technology reagents catalyse metal precipitation from solution at a pH lower than that achievable with conventional alkaline

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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 ViroMine™ Technology reagents 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 ViroMine™ Technology reagents to strip trace metals increases with time. Most metals bound by ViroMine™ Technology reagents are held as structural components of the mineral and therefore cannot be easily removed.

Most trace metals are initially trapped by adsorption. ViroMine™ Technology reagents are 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 recrystallisation.



Acid Rock Drainage before and after ViroMine™ Technology treatment.

ENVIRONMENT AND SAFETY

The use of ViroMine™ Technology to treat Acid Rock Drainage and tailings dam water 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 ViroMine™ Technology reagents are not hazardous or prescribed waste materials. Even after use in many applications, they can be usefully reused in other applications. Exhausted ViroMine™ Technology reagents can also be used in selected downstream applications depending on individual circumstances.

The leaching of used or spent ViroMine™ Technology reagents cannot result in the release of any trace elements at potentially environmentally hazardous concentrations.

ViroMine™ Technology reagents are classified as non-hazardous, inert or solid substances for transportation and are safe for unskilled workers to handle.

ViroMine™ Technology reagents consist of minerals that are not known to pose any environmental hazard.

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

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The contaminated tailings dam contained 1.6 billion litres.

CASE STUDY - AUSTRALIA

When a heavily contaminated tailings dam threatened to break its banks and spill toxic water into a large drinking water catchment in New South Wales, Australia, ViroMine™ Technology was used with outstanding success to treat and clean the polluted water.

The Problem

Following the closure of Mt Carrington Gold and Silver mine in northern New South Wales, Australia, in the early 1990's, a legacy of over 100 years of mining was left in the form of a severely contaminated tailings dam.

All Acid Rock Drainage seeping from the various contaminated sources around the site had been pumped into this tailings dam for storage. Until 1996, the evaporation rate matched inflows and the dam experienced a small but steady rise in metal concentrations.

In 1996, a major inflow of water almost filled the 35 acre dam. The situation deteriorated over time, and grave concerns regarding uncontrolled discharge across the spillway or breach of the dam wall were expressed by environment authorities.



Contaminated water in the tailings dam before treatment with ViroMine™ Technology.

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Table showing heavy metal and acidity levels before and after treatment (all values in ppm).

	Before ViroMine™ Technology Treatment	After ViroMine™ Technology Treatment	% of Metals removed
pH Level	3.56	8.27	-
Aluminium (Al)	60.7	0.03	99.95%
Arsenic (As)	0.0053	0.0028	47.17%
Cadmium (Cd)	1.73	0.00023	99.99%
Copper (Cu)	42.6	0.0037	99.99%
Iron (Fe)	7	0.034	99.51%
Lead (Pb)	0.07	0.00002	99.97%
Nickel (Ni)	0.17	0.016	99.59%
Silver (Ag)	0.0017	0.00001	99.41%
Zinc (Zn)	64.9	0.019	99.97%

The Virotec Solution

In 1999, Virotec undertook the treatment of the 1.6 billion litre tailings dam, using ViroMine™ Technology Acid B™ reagent, which was sprayed on to the surface of the dam. Following treatment, the dam water met stringent ANZECC standards for heavy metals and the protection of aquatic ecosystems. Approximately 350 million litres of water were subsequently released with safety into the local catchment.



First release of treated water using ViroMine™ Technology from tailings dam.



Fish in treated dam.

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The vast quantity of heap leach ore remaining on the heap leach pad.

CASE STUDY - 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.

The 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.

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.

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.”

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A Table showing 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	NA
Sodium (mg/L)	9,300	2,970	2,990	570	250
Sulfate (mg/L)	55,000	6,000	5,800	2,200	NA
Ag (µg/L)	150	<(1) est	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 est	3.7	<LLD (10)	<LLD (10)
Cd (µg/L)	630	0.41 est	0.4	<LLD (1)	<LLD (1)
Co (µg/L)	2,200	1.5 est	11	<LLD (10)	<LLD (10)
Cr (µg/L)	390	<(1) est	12	<LLD (10)	<LLD (10)
Cu (µg/L)	33,000	8.2 est	7.2	<LLD (10)	<LLD (10)
Fe (µg/L)	21,000,000	<LLD (25)	18	120	210
Hg (µg/L)	0.2 est	< 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 est	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)	NA
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.