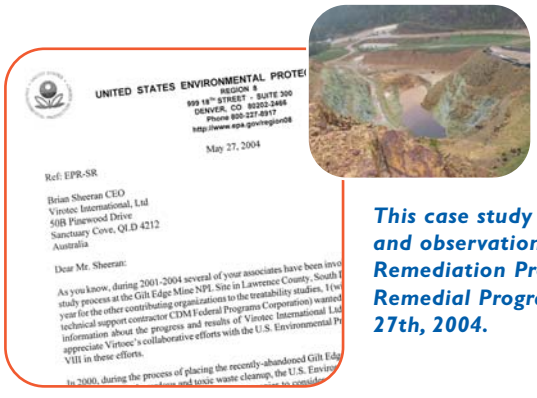
AN APPLICATION OF
VIROMINE™ TECHNOLOGY

CASE STUDY:
GILT EDGE MINE – USA

"I know of no other practical and economic technology in the world today that could achieve such conclusive and wide-ranging results..."



UNITED STATES ENVIRONMENTAL PROTE
REGION 8
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May 27, 2004

Ref: EPR-SR

Brian Sheeran CEO
Virotec International, Ltd
50B Pinewood Drive
Sanctuary Cove, QLD 4212
Australia

Dear Mr. Sheeran:

As you know, during 2001-2004 several of your associates have been invo
study process at the Gilt Edge Mine NPL Site in Lawrence County, South
year for the other contributing organizations to the treatability studies, I (w
technical support contractor CDM Federal Programs Corporation) wanted
information about the progress and results of Virotec International Ltd
appreciate Virtotec's collaborative efforts with the U.S. Environmental P
VIII in these efforts.

In 2000, during the process of placing the recently-abandoned Gilt Edg

This case study draws extensively from data and observations provided by Mr Ken Wangerud, Remediation Project Manager, Superfund Remedial Program, US EPA, Region VIII, on May 27th, 2004.

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INTRODUCTION

In 2000, during the process of placing the recently-abandoned Gilt Edge Mine site on the National Priorities List for hazardous and toxic waste cleanup, the United States Environmental Protection Agency – Region VIII (US EPA) invited several companies to demonstrate their technologies and cleanup processes.

The US EPA had been aware of some of the emerging technologies and invited several companies to participate in a Multi-Cell Treatability Study at the site in South Dakota. The study was designed to provide a side-by-side comparison of emerging waste rock stabilization technologies that were designed to prevent or suppress the production of acidic, metal-laden leachates.

The test program was originally planned to evaluate four waste rock stabilization technologies that were available for the treatment of Acid Rock Drainage (ARD). As the Multi-Cell Treatability Study was commencing in late 2000, the US EPA learned of a ViroMine™ Technology reagent developed by Virotec International and contacted Virotec to learn more about this product.

Open cut pits at Gilt Edge Minesite.

The US EPA was interested in the purported characteristics and potential applicability of the ViroMine™ Technology reagent to Gilt Edge Mine, and Virotec expressed a willingness to participate in some manner in the Treatability Study program.

Subsequently, Virotec made arrangements to ship a quantity of reagent to the site from Australia, and a ViroMine™ Technology test-cell was field-fitted and added to the original test program. An in-ground lined trench with generally similar characteristics to the cells used in the Multi-Cell Treatability Study was constructed and filled with ViroMine™ Technology-treated sulfidic waste rock (the Trench Trial). Except for replicate cells, the Trench Trial was designed to simulate as closely as possible the side-by-side comparison of all technologies.

In all cells, waste rock samples were analysed for acid-base accounting, net acid generating potential, and a large target analyte list (TAL) of elements. All leachate water samples were analysed for the TAL elements and other standard water quality parameters.

Additionally, in collaboration with the US EPA's technical support contractor CDM Federal Programs Corporation (CDMFP), Virotec proposed that three additional field trials be set up to test the ViroMine™ Technology reagent in other potential applications at the Gilt Edge Mine site.

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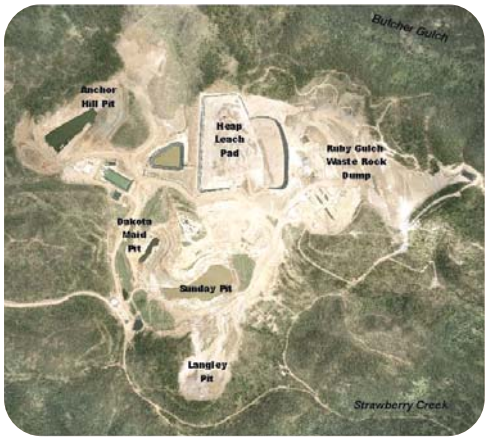

Aerial photograph of Mine Site.

The objective of the study was to provide a completely independent assessment of the ability of the various treatments to:

- Reduce the quantity of contaminated leachates generated by highly acidic sulfidic rock at the Gilt Edge Mine site, and
- Minimize the impact of these source materials on downstream aquatic ecosystems and other potentially impacted areas.

This case study outlines the contribution of Virotec's ViroMine™ Technology to the remediation efforts of the Gilt Edge Mine in South Dakota. Key factors governing the work include:

- All the trials followed US EPA protocols and no-one was allowed access to the site unless accompanied by US EPA representatives;
- The US EPA is evaluating cost-effective options for site remediation at the Gilt Edge Mine consistent with the evaluation criteria in the US EPA's National Contingency Plan;
- The US EPA states that ViroMine™ Technology may have several potential applications at the Gilt Edge Mine and possibly at other mine sites similarly affected by problems associated with acid rock drainage;
- The Trench Trial data (Table 1), from one single ViroMine™ Technology application to some of the worst waste rock encountered at the site, show that the ViroMine™ Technology Permeable Reactive Barrier (PRB) remains active more than three years after the original treatment was carried out, and leachates continue to meet or exceed established water quality criteria for the site;
- In 2003, an electron beam microprobe examination of a treated waste rock sample showed evidence of sulfide encapsulation.

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

BACKGROUND

The Gilt Edge Mine site is an open pit, cyanide heap leach gold mine, developed in both oxidised and highly sulfidic ore bodies. The Gilt Edge Mine was developed in sulfidic (acid-generating) rock at the headwaters of cold-water fisheries and local water supplies. When the operator went out of business, they left behind 150 million gallons of acidic, heavy metal-laden water in three open pits and millions of cubic yards of acid-generating waste rock that needed cleanup and long-term treatment.

Mining operations for gold, copper and tungsten had been conducted in this small mining district since 1876. About a century ago, a series of small mines began dumping metal-laden mill tailings into local catchments.

Sulfidic 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 concentrations of nitrates and sulphates are also present in heap leach residues. Copper, cadmium, zinc and acidity provide the major risks to habitats in the receiving water catchment.

PROBLEM

The Gilt Edge Mine was experiencing severe acid rock drainage (ARD) resulting from mining operations. There was a net positive water balance on the site and as such, evaporation alone could not manage the site's contaminated water problems. Leachate generated from the sulfidic waste rock dumps was contributing to off-site acid and heavy metal migration.

Of additional concern was the aesthetic appearance of the site. The site covers an area of about 110 hectares and there are about 12.0 million tonnes of overburden stored in waste rock dumps, a large quantity of heap leach 'tailings' stored with the overburden and about two million tonnes of heap leach ore remaining on the heap leach pad.

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TREATMENT METHODS

> ***Permeable Reactive Barrier Trench Trial***

The effectiveness of ViroMine™ Technology for treating waste rock was evaluated by using a lined trench containing about 20 cubic metres of sulfidic waste rock mixed with ViroMine™ Technology Acid B Extra™ reagent to a final concentration of ten percent (weight). The leachate was sampled monthly to determine water quality and ongoing sampling assessed the neutralizing and immobilization capacity of the Acid B Extra™ reagent.

Preparing the Permeable Reactive Barrier Trench.

Ongoing three-year results from the Trench Trial, wherein leachate pH was neutralised from 1.93 to 7.9, are shown overleaf in Table 1; other highlights include:

1. The concentration of the highly hazardous element ***arsenic (As) has been reduced from 35,000 to less than 4.0 parts per billion*** (well below the strict new U.S. drinking water standard of 10 parts per billion);
2. The ***extremely high concentrations of iron (21,000,000 parts per billion) and aluminium (1,200,000 parts per billion) were reduced to less than 50 parts per billion*** and have remained at very low concentrations ever since;
3. ***The concentrations of many other trace metals,*** including antimony (Sb), cadmium (Cd), cobalt (Co), copper, (Cu), chromium (Cr), lead (Pb), manganese (Mn), nickel (Ni), silver (Ag), vanadium (V) and zinc (Zn), ***were all reduced from potentially hazardous concentrations to concentrations that were near or below the analytical detection limits*** and well below discharge water quality standards;
4. The ***Total Dissolved Solids (TDS) concentration (i.e. salinity) was substantially reduced*** immediately after treatment and decreased further the longer the trial continued; and
5. The ***concentrations of many ions such as sodium and sulphate, which are difficult to remove, have continued to decrease substantially*** the longer the trial has continued.

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TABLE 1: 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	<(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	0.41	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.

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The data in Table 1 relate to water leaching from sulfidic waste rock that had been treated using the Acid B Extra™ reagent in the Permeable Reactive Barrier 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™ reagent. <LLD indicates that the concentration is below the detection limit for the analytical procedure used. The detection limit is indicated in parentheses.

> *Waste Rock Remediation (Drum Trial)*

A series of 200L drums were filled with a waste rock and Acid B Extra™ reagent mixture (10, 5, and 2 percent) to determine effective treatment at the lowest possible application rates. A pilot passive system for low-flow ARD was built using a 200L drum, gravel, sand, and Acid B Extra™ reagent and tested in batch mode.

Results from these Waste Rock Remediation trials, wherein leachate pH was neutralised from 1.92 to 7.21, are shown overleaf in Table 2; other highlights include:

1. The concentration of the highly hazardous element ***arsenic (As) has been reduced from 23,000 parts per billion to near or below the analytical detection limits*** and well below discharge water quality standards (i.e., below the strict new drinking water standard of parts per billion);
2. The ***extremely high concentrations of iron (19,000,000 parts per billion) and aluminium (1,400,000 parts per billion) were reduced to near or below the analytical detection limits*** and were at or below discharge water quality standards;
3. The ***concentrations of many other trace metals,*** including antimony (Sb), cadmium (Cd), cobalt (Co), chromium (Cr), lead (Pb), nickel (Ni), silver (Ag), and vanadium (V), ***were all reduced from potentially hazardous concentrations to concentrations that were near or below the analytical detection limits*** and well below discharge water quality standards;
4. ***The Total Dissolved Solids (TDS) concentration (i.e. salinity) was substantially reduced.***

Left: Waste Rock Drum Trials.

Growth trials within one of the drums containing a waste rock and Acid B™ reagent mixture.

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TABLE 2: VIROMINE™ TECHNOLOGY WASTE ROCK DRUM DATA

Analytes	Control 2003	Waste Rock 2001	Waste Rock 2002
pH	1.92	7.81	7.21
Acidity (mg/L as $CaCO_3$)	50,000	4	< LLD (5)
Alkalinity (mg/L as $CaCO_3$)	< LLD (5)	58	42
TDS (mg/L)	78,000	13,400	22,000
Sulfate (mg/L)	59,000	7,800	20,000
Ag (µg/L)	100	< LLD (1)	< LLD (5)
Al (µg/L)	1,400,000	< LLD (50)	< LLD (50)
As (µg/L)	23,000	9.2	< LLD (10)
Cd (µg/L)	1,100	< LLD (1)	< LLD (1)
Co (µg/L)	1,500	3.8	< LLD (10)
Cr (µg/L)	260	< LLD (1)	< LLD (10)
Cu (µg/L)	28,000	12.4	16
Fe (µg/L)	19,000,000	< LLD (25)	33
Mn (µg/L)	23,000	185	230
Ni (µg/L)	1,100	3.5	< LLD (10)
Pb (µg/L)	240	< LLD (2.2)	< LLD (10)
Sb (µg/L)	380	< LLD (3.7)	< LLD (10)
V (µg/L)	1,700	6.8	< LLD (10)
Zn (µg/L)	8,300	< LLD (25)	140

Examples of data for leachate accumulating in barrels containing sulfidic waste rock and various amounts of Acid B Extra™ reagent are shown in Table 2. These tests were used to determine the required Acid B Extra™ reagent addition rates. The results showed that an Acid B Extra™ reagent addition rate of 6-7 percent is optimal.

The control data were obtained for barrels that contained waste rock but no Acid B Extra™ reagent. The indicator, <LLD, is for when the concentration is below the detection limit for the analytical procedure used. The detection limit is indicated in parentheses.

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> *Pit Lake Treatment*

To simulate treatment of ponded ARD water (i.e. pit lakes), 17,000 litres were treated in a batch process using Acid B Extra™ reagent; the tank was sampled six, nine, and 42 days after the last addition.

Results from the "*in situ*" Pit Lake Treatment trials, wherein leachate pH was neutralised from 2.59 to 7.09, are shown below in Table 3; other highlights include:

1. The analysis of water showed ***a significant improvement after just 42 days;***
2. The concentrations of ***many trace metals,*** including aluminium (Al), chromium (Cr) and lead (Pb), ***were reduced from potentially hazardous concentrations to concentrations that were near or below the analytical detection limits*** and well below discharge water quality standards;
3. ***The Total Dissolved Solids (TDS) concentration (i.e. salinity) was reduced;*** and
4. ***The concentration of sulfate, which is difficult to remove, was decreased.***

TABLE 3: VIROMINE™ TECHNOLOGY PIT LAKE DATA

Analytes	Initial Pit Lake Data	Treatment Results
pH	2.59	7.09
Acidity (mg/L as $CaCO_3$)	1,890	< LLD (5)
Alkalinity (mg/L as $CaCO_3$)	LLD (5)	28
TDS (mg/L)	4,800	4,300
Sulfate (mg/L)	3,100	2,800
Al (µg/L)	101,000	< LLD (37.4)
Cd (µg/L)	214	15.3
Co (µg/L)	520	127
Cr (µg/L)	61.7	< LLD (0.55)
Cu (µg/L)	27,300	16
Fe (µg/L)	235,000	29.6
Mn (µg/L)	6,070	2,560
Ni (µg/L)	293	81.8
Pb (µg/L)	4.4	< LLD (1.3)
Zn (µg/L)	4,110	21.9

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One of the contaminated pit lakes – with flowing ARD visible to the right.

The treatment of Pit Lake water was simulated by direct addition of Acid B Extra™ reagent to a 5,000 gallon tank filled with water from one of the Pit Lakes on the site; the reagent was mixed with Pit Lake water to form a slurry and then slowly added to the tank to complete the treatment.

Analysis of a water sample taken 42 days after the final Acid B Extra™ reagent addition showed an excell-ent improvement in water quality. <LLD indicates that the concentration is below the detection limit for the analytical procedure used. The detection limit is indicated in parentheses.

Since the initial treatment was completed, additional trials have shown that the concentrations of many of the metals can be reduced still further by adding a little more of the ViroMine™ Technology reagent to raise the treated water pH from about 7.1 to about 7.8; this slight increase will have a particularly beneficial effect on the concentrations of manganese, nickel, cobalt and cadmium.

> *ViroFilter™ Passive Treatment*

Results from ViroFilter™ Passive Treatment trials, wherein leachate pH was neutralised from 4.47 to 8.38, are shown overleaf in Table 4; other highlights include:

1. The analysis of water showed that ***passive filter treatment could produce even better quality water than a direct addition "in situ" treatment;***
2. The ***concentrations of many trace metals,*** including aluminium (Al), cadmium (Cd), cobalt (Co), chromium (Cr), iron (Fe), lead (Pb), nickel (Ni), ***were reduced from potentially hazardous concentrations to concentrations that were near or below the analytical detection limits*** and well below discharge water quality standards; and

Conducting ViroFilter™ Passive Treatment trials at Gilt Edge Mine. The cells that gave the results overleaf were much larger – these small cells were subsequently used to help understand the limits of the method.

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TABLE 4: VIROFILTER™ PASSIVE TREATMENT DATA

Analytes	Initial Pit Lake Data	Treatment Results
pH	4.47	8.38
Acidity (mg/L as $CaCO_3$)	221	LLD (5)
Alkalinity (mg/L as $CaCO_3$)	LLD (5)	47
TDS (mg/L)	1,450	1,500
Sulfate (mg/L)	1,233	1,303
Al (µg/L)	22,418	< LLD (62)
Cd (µg/L)	121	< LLD (0.4)
Co (µg/L)	258.5	< LLD (1)
Cr (µg/L)	1.2	< LLD (0.5)
Cu (µg/L)	1,895	20.6
Fe (µg/L)	582	< LLD (21.1)
Mn (µg/L)	10,263	3.0
Ni (µg/L)	225	< LLD (2)
Pb (µg/L)	4.6	< LLD (2.6)
Zn (µg/L)	3,790	36.2

3. ***The high concentration of manganese (10,263 parts per billion) was reduced to less than .03 parts per billion.***

The use of ViroMine™ Technology in a passive treatment system was tested by passing acidic metal-contaminated leachate water through a drum containing 52.3 kg of Acid B™ reagent mixed with sufficient sand and gravel to maintain adequate hydraulic conductivity.

The passive treatment system produced excellent quality water and the data indicated that under the right circumstances the system could produce even better quality water than the treatment of acid rock drainage water by direct addition of Acid B™ reagent. <LLD indicates that the concentration is below the detection limit for the analytical procedure used. The detection limit is indicated in parentheses.

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CONCLUSION

Early in 2004, the US EPA reviewed the results obtained so far and, in consultation with Virotec, agreed that in view of the very promising performance of the ViroMine™ Technology reagents in the original trials, along with the EPA's need for quantitative data regarding metal-loading/sorption capacity, additional trials would be conducted with newer formulations of ViroMine™ Technology reagents at the Gilt Edge Mine site.

Results of these trials are intended to enable the US EPA to better determine how ViroMine™ Technology might be effectively used at the Gilt Edge Mine site and allow further evaluation and consideration of the applicability of ViroMine™ Technology in the final feasibility study for the site.

ViroMine™ Technology has proven to be applicable for the treatment of heavy metal and acidity problems associated with acid rock drainage from waste rock dumps and water accumulated in pit lakes. Acid rock drainage water and contaminated tailings dams can now be economically treated to strict environmental standards.

TESTIMONIALS

"EPA's findings to date indicate that ViroMine™ Technology reagents may have several potential applications at the Gilt Edge Mine and possibly at other mine sites similarly affected by problems associated with acid rock drainage.

In particular, the Trench Trial data (Table 1) showed that a single 10 percent mixture of ViroMine™ Technology reagent with the test waste-rock (some of the worst encountered at the Site) has produced high-quality leachate water, and the water quality has remained generally consistent over the three years since the treatment was applied.

At the other smaller field-trials, substantial improvements in water quality from the use of the ViroMine™ Technology reagent in the single-year Pit Lake Simulation (2001), a flow-through Passive Treatment Test, and several ViroMine™ Technology reagent waste rock mixtures in Barrel Trials (Tables 2 - 4) were also evident.

Periodic sampling and analyses appear to indicate that the ViroMine™ Technology reagent remain active in the Trench Trial waste-rock mixture more than three years after the original treatment was carried out, and leachates have continued to meet or exceed established water quality criteria for the Site."

MR. KEN WANGERUD
Remediation Project Manager
Superfund Remedial Program
US EPA Region VIII

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"This is the first time that ViroMine™ Technology has been evaluated in the United States, however, it has been used to treat ARD and AMD at other sites throughout the world and met applicable water quality criteria. The results collected to date indicate that ViroMine™ Technology may be a viable treatment option."

JAMES JONAS
CDM - Consultant for USA EPA

"I know of no other practical and economic technology in the world today that could achieve such conclusive and wide-ranging results. The new technology and application procedures are able to reduce the concentration of many environmentally hazardous trace metals by over one hundred thousand times."

PROFESSOR DAVID McCONCHIE
Southern Cross University

ARD before and after treatment with ViroMine™ Technology.

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