A COMMERCIAL APPLICATION OF
VIROMINE™ TECHNOLOGY

CASE STUDY
TAILINGS TREATMENT AT KING RIVER DELTA, TASMANIA

"This is the first time ever in Tasmania that we've had this type of vegetation cover in a tailings environment.

We are now feeling it is possible to change this landscape with the application of ViroMine™ Technology, and we didn't believe that before".

Polluted water entering King River

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TOWARDS A CLEANER ENVIRONMENT

"Many attempts have tried and failed to treat the contaminated tailings in the King River. ViroMine™ Technology was extremely successful, indeed the only demonstrably successful treatment we implemented, in treating the high levels of acidity and the large amounts of leachable and airborne heavy metals in the tailings, and was the only solution that allowed for successful revegetation of the tailings beach. The application of ViroMine™ Technology exceeded our wildest dreams. We have proved the impossible is possible".

Andrew Laird
Project Coordinator
West Coast Council

The King River tailings delta

BACKGROUND

The King River in western Tasmania is considered to be the most polluted river in Australia; it has been described as a "masterpiece of pollution". The river flows from southwest and discharges into Macquarie Harbour, which is the home of Tasmania's salmon fisheries industry. A delta at the mouth of the river was formed by a century of direct dumping of tailings from the Mt. Lyell mine northeast of Queenstown and contaminated deltaic sediment is more than 100 m thick in some places. Furthermore, the discharge of acid mine drainage water from Mt. Lyell into the river and harbour is expected to continue for the next 600 years.

It is estimated that until 1994, when dumping stopped, 100 million tonnes of tailings and slag were dumped into the Queen and King rivers, forming large deposits on river beds and banks, and creating the tailings delta at the mouth of the King River. With so much hazardous waste deposited into the river during the 20th century, the King River is heavily polluted with many heavy metals and other elements that are harmful to the environment and human health. The contamination of the King River has affected biodiversity throughout the Catchment. Fish populations in the tributaries are restricted from migrating to Macquarie Harbour to spawn and Dr. Peter Davies (University of Tasmania) has recorded highly abnormal populations (age and size distributions) of Galaxias truttaceus and G. brevippinis (Spotted and Climbing Galaxias) and Anguilla australis (Short-finned eel) in the King River Catchment.

Aerial view of the King River flowing southwest into Macquarie Harbour (centre right to centre left) and the King River tailings delta (centre left). Pockets of oxidized tailings can be clearly seen along the banks of the river although most of the tailings accumulated around the river mouth.

"The tailings delta is a layer-cake of oxidised and un-oxidised deposits," according to Andrew Laird, the remediation project manager from the West Coast Council in Zeehan. "When the oxidised upper layers of the tailings are moved by wind and water, the un-oxidised tailings are exposed and again start leaching acid and heavy metals into Macquarie Harbour. The un-oxidised tailings are also blown into Strahan by the wind, with health implications, or form dunes, causing more die-back of plant life. Our goal was to find a revegetation method that would cap the delta and thus minimise the movement of tailings," he said.

The river delta, which is essentially a large artificially formed beach of toxic tailings, covers about 3.5 square kilometres across the mouth of the King River (see Figure 1). Major toxic contaminants in the tailings include: arsenic, chromium, copper, lead, mercury, nickel, selenium and zinc. With the help of Federal Government funding, a remediation project designed to independently assess several treatment methods was undertaken by local government and residents. The goals of the project were to determine the optimum method for binding heavy metals and providing the tailings with enough nutrients to support long-term grass and tree growth.

Aerial photograph (looking south) showing the tailings "beach" at the mouth of the King River; Macquarie Harbour is in the foreground.

The treatment methods tested included:

- **a.** lime and fertiliser addition;
- **b.** sand addition;
- **c.** soil addition; and
- **d.** ViroMine™ Technology.

After application of each treatment method plots were direct seeded, had locally sourced slash added or had both slash and direct seeding. ViroMine™ Technology was chosen because it had previously been used successfully to treat and revegetate mine waste rock and tailings at the Rossarden Mine in eastern Tasmania. Establishing vegetation cover was considered the primary goal of the project because a vegetation cap would minimise and control the dispersal of toxic dust during the summer months into the nearby community of Strahan. The prevailing wind in the delta is from the south and the effect of dust on the town to the north is a particular worry to local residents.

TREATMENT METHOD

A large section of the King River delta about one kilometre from the edge of the harbour was cordoned off and a series of 100m2 sections of the tailings beach were treated with "best available practices" using the treatment methods summarised above. All sections were treated and seeded with locally collected grass species and trees.

The ViroMine™ Technology solution included the following elements:

1. initial sample analysis and treatment strategy development;
2. the development of a specially blended Terra B™ reagent designed for the site (the reagent was blended in Strahan prior to application);
3. transport to the treatment site and application of the Terra B™ reagent, including spreading, mixing and planting;
4. on-site project management; and
5. post-treatment analysis.

Photograph of the King River delta tailings beach. Note that after 100 years, nothing grows on the tailings because acidity and mobile metal concentrations are too high to support plant growth.

The tailings were monitored by local council and community representatives for the next 12 months, but no further work was carried out at the site after the initial treatment. Although the project site was chosen to minimise the effect of seawater on the treatment areas, during the first year it was inundated by high-tides and surging seawater about ten times.

RESULTS

Initial analysis of the tailings included sampling at two levels in the tailings: an upper layer (the first 100mm) and a lower layer (at 300mm); the results from both layers were almost identical and have therefore been averaged in Table 1.

The Terra B™ reagent was spread and mixed into the tailings using an excavator.

The existing pH of tailings at both levels was 3.9 and when the potential acidity of the tailings was evaluated, based on the abundance of sulphide-sulphur and other potentially acid-generating materials, it was clear that the pH of the tailings could potentially drop to 2.9 or less over the long term.

For a treatment method to succeed in neutralising acidity in the tailings it would have to neutralise both the acidity that was present when the remediation work was carried out (called "Total Actual Acidity" or TAA) and prevent any new acidity (called "Total Potential Acidity" or TPA) developing in the tailings in the future. Preventing any new acidity being produced can be achieved either by preventing acid generating reactions (e.g. pyrite oxidation) from occurring, or by retaining enough acid neutralising capacity in the treated tailings to neutralise any acid that could be produced in the future. The Terra B™ reagent used in the trials was specifically designed to achieve both of these objectives at the same time as it trapped and bound the contaminant metals (Table 2) such that they were no longer leachable or bio-available.

TABLE 1: INITIAL REACTION PH AND ACIDITY OF THE TAILINGS

Analyte	Existing Reaction pH[1]	Titratable Actual Acidity (moles/kg)	Potential Reaction pH	Titratable Potential Acidity (moles/kg)
Composite Tailings	3.9	29	2.9	84

1. Reaction pH values are for one part of tailings mixed with 5 part: of distilled water.

Only leachable heavy metal concentrations are used to classify solids in Tasmania. Table 3 shows that the tailings were classified as "contaminated soil" due to the high leachability of arsenic (As), copper (Cu), mercury (Hg) and selenium (Se). Furthermore, several metals have high total concentrations in the tailings (Table 2) including: arsenic, copper, lead, manganese and zinc, and these could be dispersed with dust blown from exposed unvegetated tailings. Such metal contaminated dust constitutes a risk to both human health and exposed ecosystems; arsenic, copper, lead and zinc in the tailings provided the greatest risk.

TABLE 2: TOTAL METALS IN TAILINGS BEFORE TREATMENT (mg/Kg)

Analyte	Concentration in Composite Tailings (mg/kg)
Arsenic	17.1
Cadium	0.1
Chromium	9.5
Copper	440
Iron	5.2
Mercury	0.10
Manganese	168
Nickel	9.0
Lead	41
Selenium	4.6
Zinc	139

Selenium (Se) is often overlooked as a contaminant of concern because selenium deficiencies in pastoral lands are common, and many scientists and regulators do not consider its significance. However, the particularly high concentration of selenium in the King River tailings (Table 3) is considered important by the regulatory authorities because:

1. Selenium can accumulate up the food chain;
2. Exposure to high concentrations of Se can cause adverse health effects in humans;
3. Short-term oral exposure to high concentrations of Se may cause nausea, vomiting and diarrhea;
4. Chronic oral exposure to high concentrations of Se can produce a disease called selenosis, the major signs of which are hair loss, nail brittleness, and neurological abnormalities (e.g. numbness and other odd sensations in the extremities);
5. Brief exposures to high concentrations of selenium in air can result in respiratory tract irritation, bronchitis, difficulty breathing, and stomach pains;
6. Longer-term exposure to air-borne selenium can cause respiratory irritation, bronchial spasms, and coughing; and
7. Animal studies have shown that a high selenium intake can affect sperm production and the female reproductive cycle.

TABLE 3: LEACHABLE METAL CONCENTRATIONS IN TAILINGS BEFORE TREATMENT

Analyte	TCLP Levels for Untreated Composite Tailings (mg/L)	TCLP Limits for Classification as "Low Level Contaminated Soil" in Tasmania (mg/L)	TCLP Limits for Classification as "Contaminated Soil" in Tasmania (mg/L)
Arsenic	1.0	0.5	5.0
Cadium	<0.01	0.1	0.5
Chromium	0.25	0.5	5.0
Copper	1.6	1.0	10
Iron	10.0	NA	NA
Mercury	0.01	0.01	0.1
Manganese	0.03	25	250
Nickel	0.76	1.0	8.0
Lead	0.1	0.5	5.0
Selenium	1.0	0.1	1.0
Zinc	0.11	25	250

* As specified in the Tasmanian EPA, Tasmania, Information Bulletin No. 105.The "red" numbers denote the metals for which TCLP values are equal to or greater than the allowable limit for that classification.

As shown in Table 4, after treatment all metals were more securely bound in the tailings, particularly those highlighted in red in Table 3, and the contaminated tailings could be re-classified as "low level contaminated soil" (the lowest reclassification category possible below "contaminated soil"). As a result of the treatment, the leachable arsenic concentration decreased from 1.0mg/L to 0.001mg/L, the leachable copper concentration decreased from 1.6mg/L to 0.62mg/L, the leachable mercury concentration decreased from 0.01mg/L to 0.001mg/L, and the leachable selenium concentration decreased from 1.0mg/L to <0.001mg/L.

Photograph showing the 200m^2 untreated control area on the tailings; note the complete absence of vegetation after 12 months.

Table 4 also shows that after treatment with ViroMine™ Technology, the reaction pH of the tailings was near neutral, and both actual and potential acidity had been completely neutralised or eliminated.

TABLE 4: pH AND TCLP RESULTS FOR ALL METALS IN THE TAILINGS AFTER TREATMENT USING VIROMINE™ TECHNOLOGY (mg/L)

Analyte	Composite Tailings After Treatment with ViroMine™ Technology (mg/L)
pH	7.9
Titratable Actual Acidity	0
Tritratable Potential Acidity	0
Arsenic	0.001
Cadium	<0.001
Chromium	0.02
Copper	0.62
Iron	2.56
Mercury	0.001
Manganese	0.01
Nickel	0.03
Lead	0.006
Selenium	<0.001
Zinc	0.07

The research areas, which had been treated with other methods (lime and fertiliser addition, sand addition or soil addition), showed little or no sign of improvement. Figure 6 shows the control area and Figure 7 shows the lime-treated area 12 months after treatment. The control area did not support any grass or tree growth whereas the lime-treated area supported sporadic grass growth but was considered unlikely to support any long-term vegetative cover, and was classed a failure. Previous field trials elsewhere had shown that, due to the moderately high solubility of lime, treating tailings with lime results in a short-term pH adjustment and reasonable plant growth but a return to acidic conditions and the release of mobile metals usually occurs within about 18 months and any vegetation that has taken hold begins to die off.

Photohraph showing the condition of of the 100m2 lime and fertiliser treated plot 12 months after treatment; note pools of salt water that have accmulated on the treated area as a result of seawater inundation.

Images on the following page show the area treated with ViroMine™ Technology. Within six months of treatment the following genera had germinated and were thriving on the ViroMine™-treated areas: Leptospermum, Melaleuca, Acacia, Allocassuarina, Senecio and

Eucalyptus; many grass species had also germinated. Moreover, the ViroMine™ Technology treated areas more readily shed seawater following inundation and plant growth in these areas did not appear to be adversely affected by short-term seawater inundation. There was also germination and establishment of grass and tree species not included in the seed mix or represented as seed in the slash in areas treated with Terra B™ reagent. This clearly indicates the suitablity of Terra B™ for natural germination and establishement of the local flora.

Photograph showing the effect of mixing Terra B™ into the contaminated tailings 12 months after treatment; note that there is good grass and tree growth despite periodic seawater inundation.

Photograph showing the condition of the 100m2 lime and fertiliser treated plot 12 months after treatment; note pools of salt water that have accumulated on the treated area as a result of seawater inundation.

Close-up of the Terra B™ treated tailings 12 months after treatment; note the wide variety of grass species growing on the tailings.

Close-up of genus leptospermum (or tea tree) growing on the Terra B™ treated tailings.

As a consequence of the great success of the ViroMine™ Technology application at the King River delta, the project has been widely reported in the local media.

The article stated that as a result of the application of ViroMine™ Technology, "for the first time in nearly 100 years plants and trees are growing on the banks of the King River and on the tailings delta at the mouth of the river in Macquarie Harbour".

SUNDAY EXTRA

Hope for dirty delta

Industrial waste may help clean up Tasmania's pollution 'masterpiece', **Gill Vowles** reports.

"For the first time in 100 years we have a very real chance of improving this river system and there is a serious possibility of rehabilitating the tailings delta"

A published article in the Sunday Tasmanian on March 7th, 2007 titled "Hope for dirty delta".


Concerted effort to correct environmental

Barren hills turn green

Teamwork drives success

sins of the past to create prettier picture

Rescuing rivers

Polluted waters target of clean-up strategy

Call of the Wild West

INSIDE TOMORROW

AXEMAN

CONTACT DETAILS

The Advocate

Article published in the Sunday Advocate on February 12th, 2007 titled "Concerted effort to correct environmental sins of the past to create prettier picture".

CONCLUSION

The application of ViroMine™ Technology in the King River delta increased pH from 3.9 to 7.9. Although there are no pH limits for classification of contaminated soils in Tasmania, the limit set for safe disposal of solids is typically within the pH 6.0-9.0 range. By most general world standards, a soil with a reaction pH of 3.9 would be classified as a "hazardous material". Of note also is the finding that most native grasses will not propagate in a soil with a reaction pH of less than 5.5. With a healthy near-neutral soil pH of 7.9 after 12 months, grass and trees were in abundance in the treated tailings. Data from similar tailings treatments suggest that plant growth on tailings treated with ViroMine™ Technology will continue indefinitely.

The observed increase in pH indicates that the "actual" acidity of the tailings was completely neutralised and tests carried out on the treated tailings showed that the acid generating potential of the tailings was also eliminated. These findings indicate that the treatment should remain effective well into the future and that the potential decrease in the pH to 2.9 will not occur. Both actual and potential acidity were reduced to zero as a result of the treatment.

Treated tailings also showed a substantial decrease in leachable metals concentrations. For example, the leachable arsenic concentration was reduced by 99.9%; the leachable cadmium concentration by 90%; the leachable chromium concentration by 90%; the leachable nickel concentration by 95%; the leachable lead concentrationby 90%; and the leachable selenium concentration by 99.9%.

These results indicate that the application of Terra B™ had successfully converted the King River delta tailings, from a "contaminated" soil, as classified by the Department of Primary Industries, Water and Environment, Tasmania, to a "low level contaminated soil", the lowest available designation.

More importantly, "this is the first time ever in Tasmania that we've had this type of vegetation cover in a tailings environment. We are now feeling it is possible to change this landscape with the application of ViroMine™ Technology, and we didn't believe that before", said Mr Laird.

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