INCO LIMITED

THE DEVELOPMENT OF A VEGETATIVE COVER

ON THE LEVACK TAILINGS AREA:

THE PRELIMINARY WORK, 1985

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Introduction

The Levack Tailings area was selected for the following reasons:-

1) The site has a "difficult" surface cover,- pyrrhotite,

2) The site has an acidic surface,

3) The site has a typical surface dam seepage area, pH drops after oxidation,

4) The site has a typical acidic pond ground water discharge (gravel pit),

5) Records of the ground water characteristics exist from the past and the ground water is affected by the tailings,

6) The site has an alkaline water body, representing a treatment system,

7) The site is easily accessible, and

8) The site has areas that will remain dry.

For these reasons the Levack tailings site was deemed ideal as an area for applied research. The main emphasis was to demonstrate that indigenous acid and alkaline tolerant vegetation could be introduced, established and promoted, since this is a primary requirement in the development and testing of the concepts of ecological engineering.

The Levack tailings area may be conveniently subdivided into several characteristic areas:-

1) the mine water retention pond - alkaline,

2) a moist alkaline area covering a large fan extends all the way to the shores of the mine water retention pond,

3) areas of hard pyrrhotite cover,

4) areas of loose pyrrhotite cover,

5) vegetated islands that were not covered with tailings, and

6) the pre-bog acid creek.

Water enters the tailings area naturally through incident precipitation and run-off from the surroundings. There are additional inputs from the mining operation which have produced the fan shaped, moist, alkaline area, (the input of mine slimes).

The areas of hard pyrrhotite provide an extremely unsuitable medium for vegetative growth. This area is acidic in reaction, has a high iron content, and a shallow hard pan, which poses a severe physical barrier to root penetration. Experimental areas were established in the pyrrhotite tailings in 1982 and 1983. Lime was applied at the rate of 20 tons/acre, after the surface had been broken up. Agricultural grass species were then planted. The results of these experiments were disappointing, and it became apparent that other techniques needed to be employed in order to ensure successful revegetation.

After consulting with Boojum Research Limited, the pyrrhotite tailings were disked up in the fall of 1984, but left unamended. In most areas the hard pan was disturbed.

Under the direction of Boojum Research a series of experiments was set up. These included the re-distribution of the mine water discharge stream, transplanting of cattails and mosses, a greenhouse study of moss moisture requirements, creating dams (and ponds) on the acid creek, and growing cattails hydroponically.

The re-distribution of the mine water discharge stream.

The mines discharge streams flow across the pyrrhotite area and accumulate in the mines retention pond. The mine slimes are alkaline in nature, and provide a more favourable medium for plant growth. The present discharge course is essentially wasted. Several methods of re-distributing the mine slimes discharge were tried in an effort to cover the unfavourable pyrrhotite with the more favourable medium of mine slimes.

These methods included:-

a) circular spraying,

b) linear spraying,

c) the perforated pipe system,

d) the flooded furrow system, and

e) the stream re-distribution system.

a) The circular spray consisted of a pump drawing water directly from the tailings line, and an impact spray head. To improve the system a portable pump was included to provide sufficient head, and was used periodically to apply water over a designated area via the spray head. The spray head was elevated above the surface of the tailings by approximately 1 m. It was recommended that 5 cm of water be applied at each watering.

b) The linear spray consisted of a gravity line taken from a tap in the tailings line, through a throttle valve, to distribute water via perforated pipes. The system was designed to supply water continuously.

c) The perforated pipe system is an over land flow system designed to supply a water continuously. The objective was to distribute water over a long distance and to attain a more even flow. A piece of derelict tailings pipe was cut, capped at both ends and holes were drilled in the side. The pipe was then laid, approximately level, for a distance of 50 feet. A flexible hose was attached to one end of the pipe, so that water overflowed through the holes, onto the tailings.

d) The flooded furrows system was designed for use on the disked areas of the pyrrhotite, in order to identify any benefits that might be gained from capillary action in this material. Several furrows were excavated in the disked area, to a depth of 6 to 12 inches. The furrows were cut across the slope of the tailings, (contour furrowing). These furrows were then flooded periodically by the application of water from a flexible hose located at one end of each furrow. Once all the furrows were full, the filling was stopped and the water allowed to sit, and either infiltrate or be taken up by capillary action into the surface nearby. Three furrows were excavated on 6 foot centres, over a distance of 25 feet. In measuring the effectiveness of this system, the length of time the water remained in the furrows was considered.

e) The stream re-distribution system was designed to provide moisture to a wide area by constructing a series of small dams on the stream emanating from the tailings pipeline. These dams were constructed by rolling wet pyrrhotite tailings inside a tube formed of polyethylene sheeting. The tubes were placed in the discharge channels on the surface of the tailings. Several were placed in such a way that the channel was forced to change direction and thereby wetting a larger surface area.

Evaluation of the systems.

a) This system was the easiest to install and control, however problems were encountered with the lines silting up. Periodic cleaning of the lines was required to maintain an adequate head of water for the impact sprayer. The circular spray is a variation of a system widely used in agricultural irrigation. It is a simple system which irrigates a large area with a minimum of equipment. The entire system is portable.

b) The linear spray system was also easy to construct, and was flexible enough to be moved into other areas where water was required. Again regular cleaning was necessary to remove built up sediments in the line. The 1/4 inch holes recommended in the design specifications were found to be too small and enlarged to

3/8 of an inch. The water streams from the linear spray system quickly formed channels in the surface, and therefore did not irrigate as large an area as was hoped.

c) The perforated pipe proved to be less than satisfactory. The pipe section had to be modified in the field, and levelling of the pipe section proved to be difficult due to it's unwieldy nature. The pipe became clogged with tailings fines, requiring excessive maintenance. This system was deemed unsuitable and eliminated from any further considerations.

d) The flooded furrow system proved to be difficult to construct, due to the shallow hard pan. When the furrows were filled, the water quickly infiltrated the tailings, with no migration by capillary action into the surface between the furrows. This system was deemed unsuitable and eliminated from further considerations.

e) The installation and maintenance of small dams to re-distribute the flow over a wider area was easy. These dams reduced the tendancy of the main stream to erode large deep channels in the tailings surface. Their performance was not appreciably impaired by the settled fines upstream of the dams, since the dams were designed to re-direct the flow rather than create ponds of water on the surface.

Based on the above field evaluations three methods of water re-distribution merit further attention in the 1986 field season. These are the circular spray, the linear spray and the small dam methods.

Containment of area 6, the pre-bog acid creek.

The acid creek on the tailings was dammed in order to provide an acidic water supply with extreme chemical and physical characteristics, due to contact with the highly reactive pyrrhotite.

Water flowed down this creek to a pond. This pond contains several small cattail stands. The flow of water down the creek was severely restricted by the construction of three earthen dams. These dams also created small experimental ponds for studies on aquatic plant growth. The first dam was installed near the mine water pipe trestle at the head of the creek. The dam was approximately 3 feet in height. The second dam, midway along the creek, was 2 feet in height, and the third, just below a natural stand of cattails, stood 1 foot in height. These dams provided 3 ponds of various depths, for a series of experiments on introduced acidophillic biota, such as algae, aquatic mosses, and hydroponically grown cattails.

These physical amendments to the Levack tailings area were necessary in order to carry out the experimental work using cattails and mosses, (both indigenous to the tailings area).

The following is a mostly qualitative report based on observations made in the field, on the appearance and survival of the mosses and cattails transplanted into the experimental areas. The cattail experiments are presented first.

Cattails

The natural stands of cattails growing on the Levack site provided the opportunity to conduct elemental determinations on an acid and an alkaline population. One population was growing in the mine retention pond, and another was growing in the acid creek pond #3. A control sample was collected from a swampy area on Side Road 65, off Hwy 144 N. Leaves were collected from vegetative stalks, and from fruiting stalks. Leaf tips were collected from the acid and alkaline populations, also. The leaf collections were dried at room temperature, and then oven dried at 150°C for 30 - 60 minutes. They were then ground in a Wiley mill outfitted with a 20 mesh screen. The ground samples were stored in sealed, labelled, plastic bags. ICP analysis for 18 metals and phosphorus were conducted on the samples by the Central Process Technology Division of Inco Ltd. Water samples from the acid creek were also analysed at this time. The results of the element determinations are presented in tables 1 and 2.

There was little difference in the elemental levels of the vegetative and the fruit stalk leaves, for a given population. The leaf tips from the acid and alkaline populations were analysed because of the necrosis observed. The tips of the acid population were blackened, and frequently this blackening extended down the leaf margin. The tips of the alkaline population were brown. Both colours indicated leaf cell death, but the severity of the toxicity problem appeared, at least qualitatively, greater in the acid grown cattail leaves. These discoloured tips contained significantly higher levels of iron and sulphur.

Table 1. Concentrations of selected elements in cattail leaves collected from two sites on the Levack tailings, and a control site.

Element Content (mg/kg dry wt)	Cattail Category/ Leaf type: Control		Acid Population			Alkaline Population		
	Vegetative	Fruit Stalk	Veg.	fruit	tips	Veg.	Fruit	Tips
Aluminum	41.8	54.4	37.3	52.8	126.0	19.0	25.6	40.4
Boron	5.9	6.4	9.5	12.4	54.2	5.5	10.1	55.7
Calcium	10339.0	13165.0	9350.0	10669.0	7681.0	12506.0	14036.0	11928.0
Iron	80.5	70.5	632.0	575.0	3008.0	54.2	64.7	172.0
Magnesium	3871.0	3958.0	905.0	986.0	1155.0	377.0	190.0	646.0
Manganese	861.0	1726.0	941.0	1287.0	2026.0	729.0	762.0	2958.0
Phosphorus	1666.0	1618.0	1315.0	960.0	1230.0	1253.0	814.0	1570.0
Sulphur	1613.0	1309.0	3938.0	3065.0	5952.0	1649.0	1150.0	2039.0
Copper	7.8	1.9	16.8	2.9	9.6	3.6	2.9	9.1
Nickel	2.6	4.8	40.3	35.9	91.0	10.8	5.2	8.1
Zinc	11.1	13.0	8.4	7.6	15.9	8.7	10.5	18.5

Table 2. Comparison of the concentrations of selected elements in the acid creek, and the leaves of it's resident population of cattails.

Element	Acid Creek Water	Cattail Leaves*
Aluminum	20.0	23.3
Copper	0.6	4.7
Iron	1232.0	312.9
Magnesium	114.5	490.0
Manganese	8.2	577.2
Nickel	26.0	19.7
Phosphorus	0.1	589.6
Sulphate	5292.0	1814.5
Zinc	0.6	4.1

* - Elemental data averaged for vegetative and fruit stalk leaves.

The differences in the elemental contents of the alkaline and the acid populations is considered to be a direct effect of the pH of the growth medium. It is well documented that at different pH levels the solubility and availability of elements differs. It is particularly apparent from these results that iron and sulphur are highly soluble and readily available at the low pH's experienced in the acid creek. The high calcium levels in the alkaline population is attributable to the amendment of the mine slimes discharge with lime. The lime used is considered to be low in magnesium, since the magnesium levels are low in the alkaline population leaves.

When the elemental content of the acid population is compared to the elemental content of the acid creek (table 2), it is clear that these cattails are removing iron, sulphur and nickel from the water, and accumulating these elements in their aerial portions. This accumulating effect is referred to as "scrubbing". From an ecological point of view, it would appear that cattails have the potential to clean up acid creeks.

In an attempt to increase the potential "scrubbing" of the acid creek, cattails were transplanted and grown hydroponically in the acid creek pond #3. Cattails were dug up from the mine retention pond. The entire aerial portion was cut off leaving the root crown, roots and any rhizomes. It should be noted that cattails growing on the alkaline mine slimes may be transplanted into the acid creek where the pH was 2.5 - 3.5. Although the parent plant succombs to this drastic change, young shoots emerge from the root crowns or from the short rhizomes.

Eighteen cattail explants were placed about 0.3 m apart on a 6 m long polyethylene net (5 cm mesh size) and laced into place with polyethylene line. This array was then anchored into acid creek pond #3. Survival and new shoot production will be recorded and monitored in the growing season of 1986.

Another array similar to the one described, was anchored in an area of recently accumulated mine slimes behind a small dam built to redistribute the mines discharge waters. This will also be monitored for new shoot production in the spring of 1986.

The natural stands of cattails growing in the tailings area appeared healthy and vigorous, but did not appear to be expanding into new territory. One of the reasons for this lack of root migration may have been the physical barrier of compacted mine slimes. In order to test this hypothesis, trenches were excavated around the perimeter of existing plots. The material removed was broken up and used to back fill the trenches. Control plots were marked, but were not trenched. In the spring of 1986, the number of juvenile stems appearing around the perimeters of the experimental and control plots will be compared.

To test the suitability of other barren areas for growing cattails, 60 mature cattails were transplanted from established stands. These transplanted areas were monitored through the 1985 growing season, and monitoring will continue in 1986.

Of the original 60 transplanted, 59 survived the summer. An indication of how well they did was estimated on the basis of juvenile shoot development. All six transplant stands produced juvenile shoots, with an average of 14 young shoots for every 10 mature plants. This is a rather high production figure and may be the result of the physical disturbance to the mature cattail plant. Although this method is rather labour intensive, it is considered to be an effective way to increase the distribution of cattails on the Levack tailings site.

Cattails are seed producing plants. In the spring cattail seedlings were observed to be growing on the tailings area. These areas were observed to be dying off slowly as the summer progressed. In order to determine the conditions necessary for encouraging cattail seedling growth, two small plots were fertilised with Scott's grow vegetables (18:24:6 NPK) and Scott's grow flowers (18:12:4 NPK). Approximately 1 kg of each fertilizer was broadcast by hand. Two adjacent plots were left unfertilized.

The young shoots in the treated plots showed good growth (height ranging from 2.5 - 15 cms) and a good green colour, whereas the unfertilized seedlings in the control plots died off over the summer. In the spring of 1986 the fertilized plots will be monitored for winter survival and growth.

Two types of mulch were tested in the field, as protection for the indigenous populations. Various thicknesses and amounts of straw and cotton tailings were spread by hand over established stands. Survival and growth will be monitored in 1986.

Mosses

The effects of drainage on moss growth was investigated in the Inco Copper Cliff Greenhouse. The moss used was identified as Funaria hygrometrica - an alkaline species.

The greenhouse moss experiments were designed to test the effects of various drainage conditions on moss growth. Moss samples were collected from the Copper Cliff Tailings Disposal Site in late June 1985. Clumps of moss and associated substrate were dug up and placed in wooden flats (seven in total). One flat of alkaline moss from the mine slimes of the Levack tailings was also collected. In the Inco greenhouse the profile of the moss and substrate layers was described, and pH and conductivity measured. Three drainage treatments were set up for each of the samples. The three treatments were:-

1) normal drainage, producing moisture fluctuations

2) no drainage - constant saturation

3) on demand drainage - intermediate conditions between saturation and drought.

Each flat of moss was divided into 3 subsamples to be used for each of the drainage treatments. The normal drainage condition was set up by placing the moss in an unlined wooden tray, the moss and substrate were watered and any excess water allowed to drain out of the tray. Watering was carried out twice a week, providing conditions from very wet to very dry.

In the second treatment, drainage from the trays was prevented by a plastic liner. The moss and substrate were placed on top of this liner. Water was added until the moss and substrate were saturated and a layer of water was kept on the bottom to maintain the saturated condition.

The third treatment provided an intermediate moisture situation. Plastic flower pots (4" diameter) were lined with paper towel and half filled with perlite. The moss sample was placed on top of the perlite layer. Three replicate pots were set up for each of the moss collections and placed in a plastic lined, wooden tray. Water was added until it drained into the plastic liner. A layer of water (2 - 3 cm) was kept in the tray to provide water as required, thus keeping the mosses moist but preventing the fluctuations in moisture levels present in the other two treatments.

The experiment was set up in late June and continued until the end of October. Over the 12 week period from Aug 1 to Oct 24 the condition (colour, mat thickness and number of sporophytes) of each moss treeatment was described at weekly intervals and moss cuttings were collected for growth quantification.

The results of the drainage experiment showed that the method of drainage <u>per se</u> did not noticeably affect the growth of this moss. However maintenance of sufficient moisture had an effect on the amount of growth observed. When the normal drainage treatments were allowed to dry out the moss did not spread out, or form new layers. When all the treatments were kept moist the differences between the treatments was more appropriately attributable to the condition of the original sample.

Under field conditions, two mosses, <u>Funaria hygrometrica</u> and

Leptobryum pyriforme (an alkaline and an acidic moss, respectively), were tranplanted on to areas of mine slimes and pyrrhotite, respectively. Both mosses were observed to be growing in their preferred habitats, and there was some indication that each one was spreading. The re-directing of the mine slimes over the pyrrhotite had a devastating effect on the transplanted populations of *L. pyriforme*. This acidic species is assumed to be non-tolerant of alkaline conditions. A similar disaster was encountered when the sand plant lines were flushed. The alkaline moss *F. hygrometrica* was washed out.

Several methods were tried to encourage the spread of the moss populations that survived devastation. These included fertilizer treatments, adding a layer of sand to the pyrrhotite surface, and straw mulching.

Fertilizing with ammonium nitrate and urea killed the mosses, but the application of Nutrite fertilizer had a positve effect. By the end of the observation period, the Nutrite fertilized mosses were still green, but no mosses were evident in non fertilized plots. A light spread of Nutrite fertilizer was applied to all the moss transplant sites in the late fall of 1985. The benefits of this application will not be felt until the spring of 1986, at which time growth and development will be monitored.

Digging straw into the pyrrhotite and mine slimes did not promote moss expansion. This was probably due to disruption. However, a light superficial covering of straw was very beneficial. The mosses flourished under this cover. It is thought that the straw either aided in the maintenance of the moisture balance, or may have provided some nutrients, or may have provided some shade, (factors necessary for good moss growth).

In Conclusion

It would appear that indigenous and transplanted moss and cattail stands may be encouraged to grow and expand with minimal effort.

It appears necessary to break up the ground to encourage the production of young cattails from mature stands. This lessens the physical impact of compacted mine slimes, and may also provide a form of "shock" treatment.

Applications of fertilizer and mulch are beneficial to the growth and development of cattail seedlings. The encouragement of seedling development is a must if revegetation is to be successful.

Mature cattails appear to be effective "scrubbers" of certain elements from the acid creek.

Moss growth was encouraged by the applications of fertilizer and a straw mulch.

The re-distribution of the mine slimes by the circular spray, linear spray, and the physical barriers, aided in covering the "hostile" pyrrhotite surface with the more "favourable" slimes. Although there were flaws with these systems, it is anticipated that these will be ironed out in the 1986 season.

All of this work was carried out under the direction of Boojum Research Limited. The Ecological Engineering aspects of this research programme were undertaken by Boojum, and their findings are presented as an addendum to this report.

It should be noted at this time, that the creation of the first dam on the acid creek permitted entry into an otherwise inaccessible area of the tailings. In the Fall of 1985, a 5 acre plot was disked up, limed (20 tons/acre) and seeded with the typical Inco mix of grass species. This area will be monitored throughout the 1986 growing season.