1-11658

Energy, Mines and Resources Canada | Energie, Mines et Ressources Canada

CANMET

Canada Centre for Mineral and Energy Technology | Centre canadien de la technologie des minéraux et de l'énergie

DEVELOPMENT OF WET BARRIERS ON PYRITIC URANIUM TAILINGS ELLIOT LAKE, ONTARIO: PHASE 1

N.K. DAVE, T.P. LIM, A.J. VIVYURKA, B. BIHARI AND D.A. KAY

ELLIOT LAKE LABORATORY

APRIL 1990

To be presented at Acid Mine Drainage Conference, Vancouver, 16/18 May, 1990, and published in the Proceedings.

MINING RESEARCH LABORATORY
DIVISION REPORT MRL 90-50 (OPJ)

Development of Wet Barriers on Pyritic Uranium Tailings Elliot Lake, Ontario: Phase 1

NAND K. DAVE, TJOE P. LIM
Elliot Lake Laboratory, CANMET, Energy, Mines and Resources Canada
Elliot Lake, Ontario, Canada

ALBERT J. VIVYURKA, BIMAN BIHARI AND DAVID A. KAY
Rio Algom Limited, Elliot Lake, Ontario, Canada

ABSTRACT

A joint research program between the Elliot Lake Laboratory, CANMET, and Rio Algom Limited, Elliot Lake, Ontario, has been established to investigate, as a close-out option, the feasibility of establishing a saturated hydrologic condition at the surface of pyritic tailings and developing appropriate wetland vegetation cover to control acid generation and release of contaminants.

During the first year of the program the work plan included: 1) a literature review on wetlands and their role in treating acid mine drainage; 2) field evaluations of pertinent wetland sites on tailings and control areas in Elliot Lake for their hydrogeochemical and biological characterization; 3) wetland vegetation transplantation, survival and propagation studies on tailings; and 4) column leaching lysimeter tests to determine oxidation, leaching and neutralization characteristics of various grain sized tailings and limestone mixtures under trickle and flood leaching conditions. This paper discusses results of the field and laboratory investigations.

INTRODUCTION

Under the Mine Environment Neutral Drainage (MEND) program, a joint research project entitled "Development of Wet Barriers on Pyritic Uranium Tailings" was initiated in 1989 between the Elliot Lake Laboratory, CANMET, Energy, Mines and Resources Canada, and Rio Algom Limited, Elliot Lake, Ontario. The objective of the program is to establish a saturated hydrologic condition at the surface of the pyritic uranium tailings and to develop an appropriate wetland vegetation cover to:

1) act as an oxygen barrier, and hence control acid generation;
2) stabilize the tailings surface; and
3) minimize surface and ground water contamination.

Background

It is well recognized that the generation of acid and subsequent mobilization of contaminants, from tailings containing sulphides of iron and other metals and trace elements is a major environmental problem. These tailings produce conditions similar to those experienced with Acid Mine Drainage (AMD), where the effluent has to be continuously collected and treated prior to discharge into natural water courses.

The long-term management strategy for decommissioning these tailings requires development of a technology whereby the tailings areas can be rehabilitated and eventually abandoned in an environmentally safe, predictable and cost-effective manner, in a walk-away situation requiring minimal human intervention.

To date, above grade inactive tailings impoundments are successfully rehabilitated with conventional revegetative land reclamation technology where the tailings surface and dam slopes are stabilized with agronomical or native terrestrial vegetation consisting of a mixture of several grasses and legumes. This type of reclamation has been very effective in controlling water and wind erosion and improving aesthetics. However, the expected benefits of vegetation in reducing the generation of acid from reactive tailings containing sulphides have not been realized (1).

Wet barriers, such as water and/or wetland cover on tailings, are believed to be effective in preventing acid generation by cutting off the oxygen supply to the tailings (2). The anoxic conditions so produced further support the growth of anaerobic heterotrophes such as sulphate reducers, which, with the breakdown of sulphates, produce hydrogen sulphide, thereby precipitating dissolved metals as sulphides (3).

Scope

Over a three-year period, both field and laboratory studies will be undertaken to investigate the hydrogeochemistry of pyritic uranium tailings using various types of wet barriers in order to evaluate the feasibility of such covers as a close-out option.

The project work plan will be as follows:

1. Undertake a Literature Review on the state-of-the-art use of wet barriers, both natural and constructed, for controlling acid mine drainage.

2. Carry out field evaluations of pertinent wetlands on existing tailings sites and their immediate vicinity in the Elliot Lake area.

3. Based on the above literature review and field evaluations, develop and implement small scale field tests to evaluate the suitability of local wetlands vegetation species for transplantation and growth on tailings, and determine suitable planting methodologies.

4. Carry out hydrological assessment of the field demonstration site to determine:

   a) water retention capability and storage capacity of the tailings material;

   b) level of water table and the seasonal fluctuations caused by varying rates of water inflow and outflow;

   c) water balance of the tailings area;

   d) optimize a flow control system to provide water flow into the area if necessary;

   e) assess storm control management.

5. Carry out a large scale field demonstration program of a flooded wetland site (65 ha).

6. Evaluate the presence or extent of the capillary fringe, its controlling factors and methods of enhancement to maintain wet barriers during dry or low water supply periods.

7. Carry out laboratory lysimeter tests to determine leaching rates of pyrite, calcium sulphate and radionuclides. Evaluate the effectiveness of adding limestone, or other natural materials, in varying concentrations and varying screen sizes, to neutralize the above normal acidity of the ground water.

8. To review various internal dyke or cell designs and test them for water retention capabilities, effects on mechanical stability, and capacity to minimize acid generation.

9. Install field instruments to investigate the hydrogeochemistry of the demonstration site and other pertinent field sites before and after the establishment of wet barriers.

10. To collect, assimilate and correlate all the data needed to verify, confirm and calibrate various models which would have been developed to predict the oxidation of pyrite and leaching of various metals and radionuclides.

11. Establish and evaluate the role of sulphate reducing bacteria in the conversion of sulphate radicals to sulphides in saturated tailings including their optimum growth and survival conditions.

12. Tests and demonstrations will take into account the control of acid generation, uptake of metals and radionuclides and the migration of contaminants from tailings to the wetlands environment.

For the year 1989 to 1990 the work plan consisted of the above elements 1 to 4 and 7.

STATUS

1. Literature Survey

A literature review pertaining to the construction, use and performance of wetlands in treating acid mine drainage was conducted. A report entitled "Wetlands and Their Role in Treating Acid Mine Drainage - A Literature Review", by N.K. Dave and T.P. Lim, Mining Research Laboratory, Division Report, MRL 89-107(LS), describes the relevant information as it relates to the use of wetlands in controlling acid generation and metal release from mining wastes.

2. Wetlands Field Survey

A survey of wetlands established (natural) on existing inactive tailings and their immediate vicinity in the Elliot Lake area and a control reference site was conducted to evaluate their physical, chemical and biological characteristics controlling growth, survival and propagation potential. The objective was to identify certain key parameters that are responsible for the adaptation of wetlands on the tailings environment. The parameters measured were: species composition and classification, vegetation density, physical and chemical compositions of the substrate, depth of root zone, water saturation and depth, and surface and porewater chemistry, etc.

The selected sites consisted of the following tailings and control areas. The tailings sites were: Nordic West Arm, Olive Lake Spanish American, below Panel Dam 'A', and the Stanleigh Waste Management area. The control site was located in a swamp area south of the Town of Elliot Lake (Figure 1).

At each site, 1 m x 1 m plots were randomly selected for characterization where vegetation species composition, density or number of plants, root zone depth and visual profiles, surface water depth and water saturation, pH, and electrical conductance were measured in the field. At each location substrate soil, pore and surface water samples were also taken for chemical analysis.

The survey showed that at most sites the wetland vegetation consisted predominantly of common cattails (Typha latifolia) with some sedges, canary reed grass and filamentous organic moss matting (1). The physico-chemical conditions varied depending upon the location with

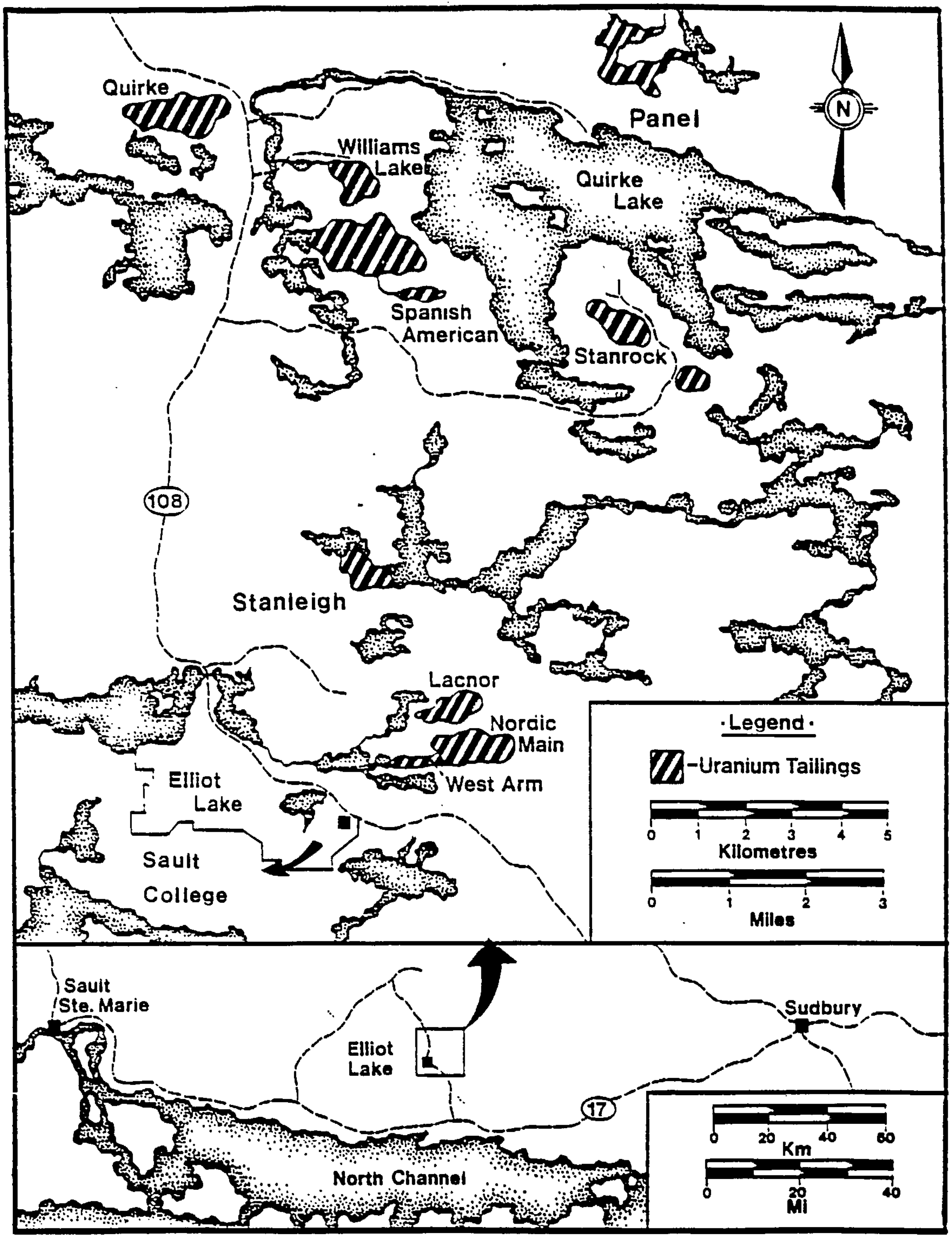

Fig. 1 - General area map of Elliot Lake tailings and wetlands.

pH ranging from 2.7 to 6.6, electrical conductance (Ec) 180 to 2300 μS, acidity 4 to 4000 mg/L $CaCO_3$, Mn 1 to 12 mg/L, Al 0.1 to 50 mg/L, Ca 15 to 550 mg/L, and Mg 4 to 400 mg/L, etc.

At most of the sites the roots extended down to a depth of 20 cm where anaerobic conditions prevailed, and were either completely underwater or water saturated. For tailings sites, the root zone consisted of mostly unoxidized tailings. The upper layer was sometimes oxidized which at some locations was completely covered with a thick layer of decaying organic matter or moss. At all locations there was a healthy vegetation growth where the water table was well above the root zone and not deeper than 30 cm. For deeper levels of water no vegetation encroachment was observed, and at locations where the water table receded to below the root zone for longer periods of time the plants had died (Spanish American site).

Because the wetlands were directly established on tailings, their influence on water quality was difficult to assess. At the Panel Dam 'A' site, however, a dramatic improvement in water quality was observed where the pH increased from 3 to 6.6 and electrical conductance decreased from 1100 to 300 μS. This site was the largest in size and supported a very healthy, dense and self-sustaining vegetation consisting of cattails and filamentous moss with an organic layer, 15 cm in height, on top of unoxidized tailings slimes. The water quality was observed to be improving with distance from the exposed tailings beach near the perimeter on the western side of the basin to completely submerged and ponded condition towards the centre and on the wastern side. This site should be further investigated in detail to establish if wetlands alone were responsible for such an improvement in water quality.

3. Wetlands Vegetation Field Test Plots

In order to assess various methods of establishing wetlands on tailings, their survival and propagation potential under a variety of hydrologic conditions, a series of field test plots were established. Because cattails were the most predominant wetlands species in the area, these tests were limited to various planting methods for cattails only.

A total of thirty test plots, 2 m x 2 m in size, were established during the month of June 1989 at two locations in the West Arm section of the Stanleigh Mine waste management area (Figures 1 and 2). At each location the following five planting and three hydrologic conditions were used:

Planting conditions:

1) Transplanting of individual cattail plants.
2) Planting of cattail seeds.
3) Planting of rhizome sections from cattail plants.
4) Planting of stem sections from cattail plants.
5) Transplanting of organic growth substrate with cattail plants from the control area.

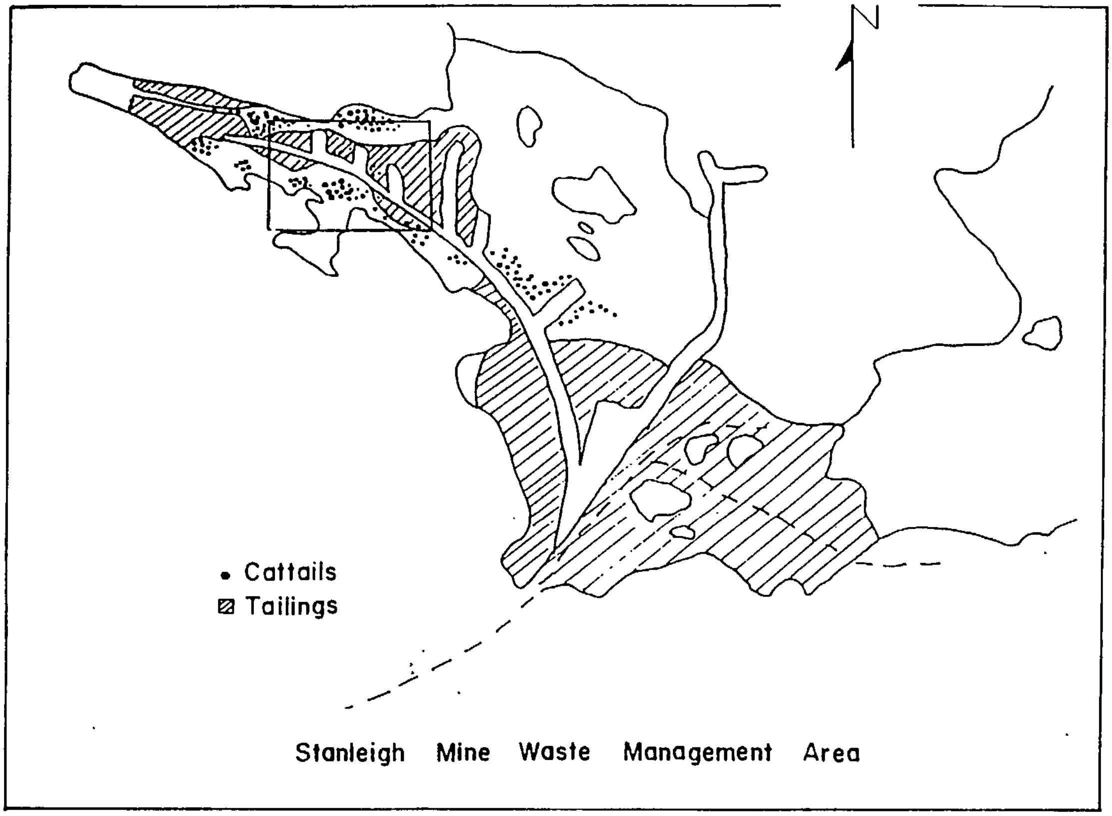

Fig. 2 - Stanleigh waste management and field test plot area.

Hydrologic conditions:

1) Water table 15 cm below the soil surface;
2) Water table at the soil surface; and
3) Water table 15 cm above the soil surface.

A set of fifteen plots were laid out in one beach area, and a duplicate set established at a second beach area. In all plots, the planting was done by hand with the aid of a spade or trowel in uniform rows 30 cm apart. Individual plants were removed from the immediate area and were planted 6 cm deep. Seeds planted at the site were harvested from the Nordic tailings West Arm area in September 1988 and were subjected to a freeze thaw cycle. Clusters of 10 to 20 seeds, wrapped in a kleenex tissue were planted at a depth of 5 to 6 cm. Rhizomes and stems also collected from plants in the area were planted vertically such that segments were just visible at the soil surface. Plants with the organic substrate 10 cm thick were dug up from the control area and were transplanted as such by removing a layer of tailings 8 to 10 cm deep in the plots. Other than the selection of the initial hydrologic conditions the plots were all subject to water table fluctuations.

The test plots were monitored on a weekly basis for their growth and hydrologic conditions. At the end of the first field season it was observed that for all water table fluctuations, plants in the individual and organic substrate transplanted plots survived and produced new plants. All other plots showed no activity or new growth (2).

4. Leaching and Neutralization Tests

1) Column lysimeter tests: Column lysimeter leaching tests are being conducted to determine pyrite oxidation, leaching characteristics and neutraliziang potentials of various grain sized tailings and limestone mixtures. Oxidation and leaching characteristics of coarse tailings under flooded conditions and crushed waste rock having different acid producing potential or sulphur content are also being investigated.

For these tests, two types of tailings were chosen. The first one consisted of fresh and homogenized total mill tailings from the Quirke mill circuit and contained approximately 50%, -200 mesh, fraction by weight. The second one consisted of fresh and predominantly coarse tailings (6%, -200 mesh) from the Quirke West Arm tailings pond. Crushed waste rock material, size -6.3 mm (0.25 in), was obtained from the Quirke tailings area dyke building material and was separated into three acid producing groups: high, medium and low (17.8, 10.7 and -13.8 kg/ton of sulphuric acid production, respectively).

In total 30 columns were filled with tailings and crushed waste rock for these tests. The columns, 122 cm in height, were made from 15.2 cm diameter PVC pipe, the bottom of which contained 7.6 cm thick layers of gravel and sand for support and filter purposes (Figure 3). All columns contained approximately 14.3 kg of tailings, or tailings limestone mixture, or waste rock which filled them to a height of 30 cm. Columns 1 to 15 consisted of five sets, all in triplicates. Set 1 contained only total mill tailings and was used as a control. The other four sets contained total mill tailings mixed with 7.5% (by weight) limestone of grain sizes -6.3 mm (-4 mesh), -2.4 mm (-8 mesh), -0.84 mm (-20 mesh) and wet ground limestone, respectively. Columns 16 to 21 consisted of three sets, all in duplicates and contained coarse tailings as control in the first set, with the other two sets containing coarse tailings mixed with 7.5% (by weight), limestone of 6.3 mm (-4 mesh), and wet ground, respectively.

Columns 22 to 24 contained only coarse tailings with no limestone for calcium sulphate and radionuclides leaching under flooded conditions.

Columns 25 to 30 consisted of three sets in duplicates, and contained crushed waste rock classified as low, medium and high acid producing potential, respectively.

Initially, all the columns were inoculated with 100 mL of underground leaching solution from the Quirke Mine and were allowed to rest for a few days. For all the columns, except columns 22 to 24, the leaching scheme consisted of a daily addition of 100 mL of fresh water, collected from Gravel Pit Lake near Quirke Mine, for five days a week with two days rest, for a period of two weeks. The composite effluent sample was analyzed on a weekly basis for pH, Ec, Eh, acidity, and alkalinity, and for dissolved Fe, Ca, Mg, Al, Mn, U,

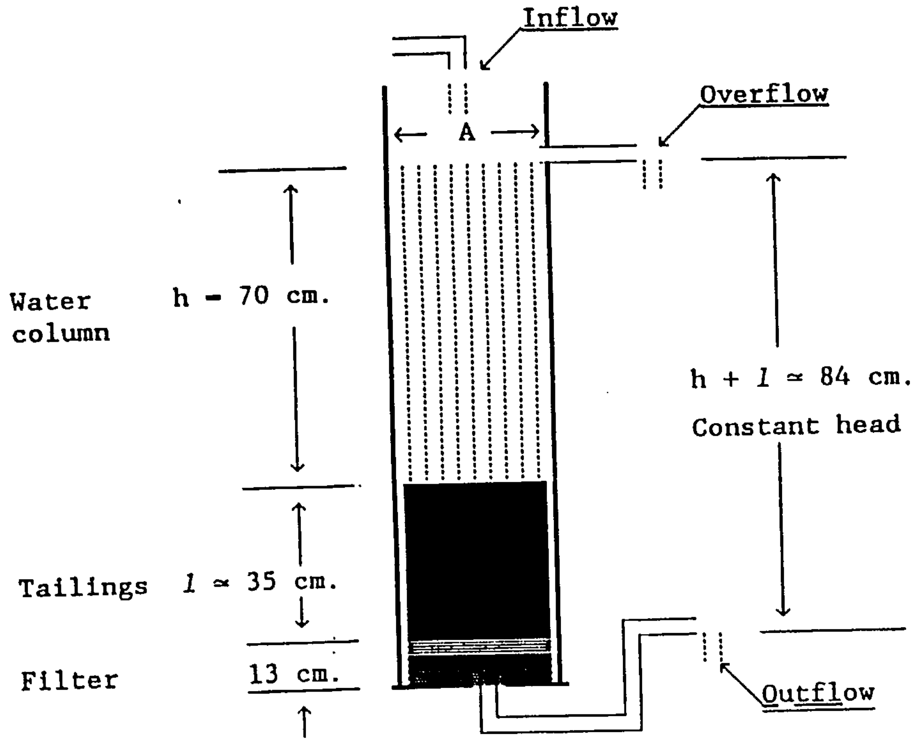

Fig. 3 - Leaching column layout.

Th, Ra-226 and sulphate on a bi-weekly basis. The water table for these columns was adjusted near the bottom of the tailings sand/gravel bed interface which represented field conditions of the water table 30 cm below the tailings surface.

Columns 22 to 24 were filled with distilled water to a height of 70 cm above the tailings and were leached under flooded conditions. Distilled water was continuously added from the top with a flow rate of approximately 1 litre per day. These columns represented leaching of soluble gypsum and radionuclides under anaerobic conditions.

The results to date for these columns are shown typically in Figures 4 to 9. In general, no evidence of significant oxidation was observed after approximately 300 days of leaching for all tailings and waste rock samples. With the present water table configuration and leaching scheme, these columns appeared to be in a state of moisture saturation which is slowing down the oxidation process. A clear column filled with a mixture of total mill tailings, 7.5% (by weight) crushed limestone of -2.4 mm (-8 mesh) size, confirmed these results that for total mill tailings the water saturation was high under these conditions. The leaching tests are still being continued.

2) Air agitated leaching tests: Batch leaching tests were also set up to further investigate the oxidation and leaching characteristics of total mill tailings and the various tailings and limestone mixtures with a shallow water cover, approximately 10 cm in height and the water layer was continuously agitated with air.

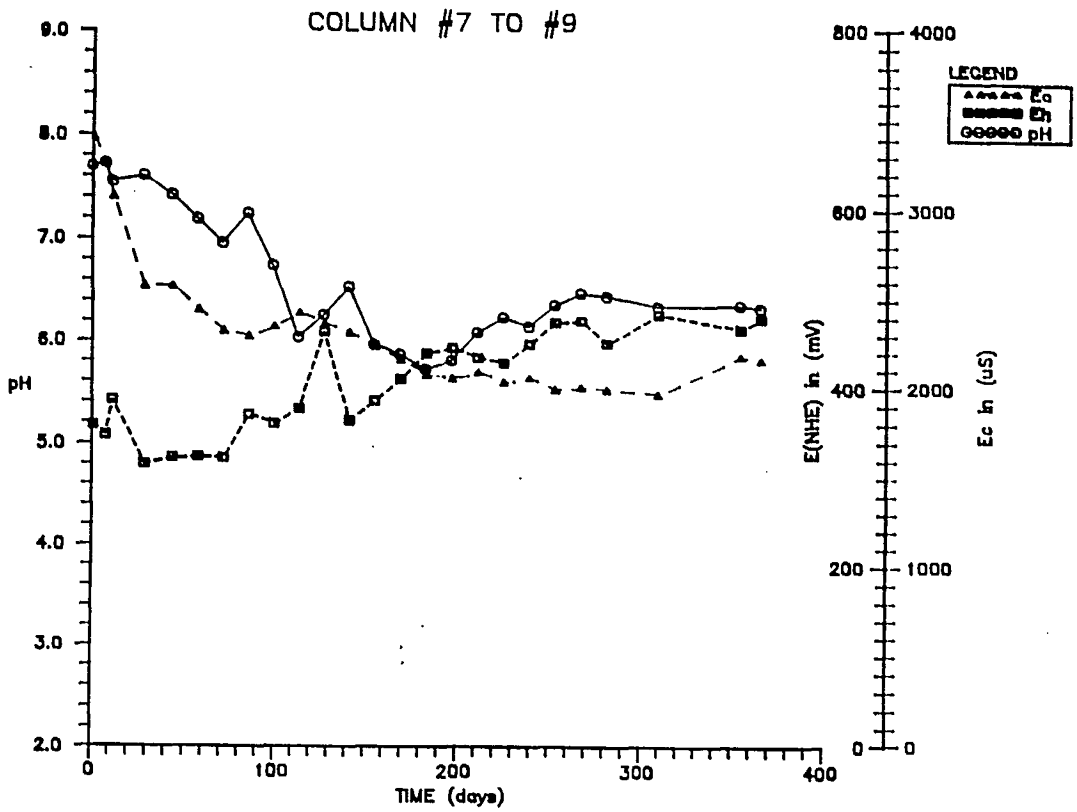

Fig. 4 - Leaching characteristics of total homogenized tailings with -8 mesh lime, pH, Eh, Ec profiles.

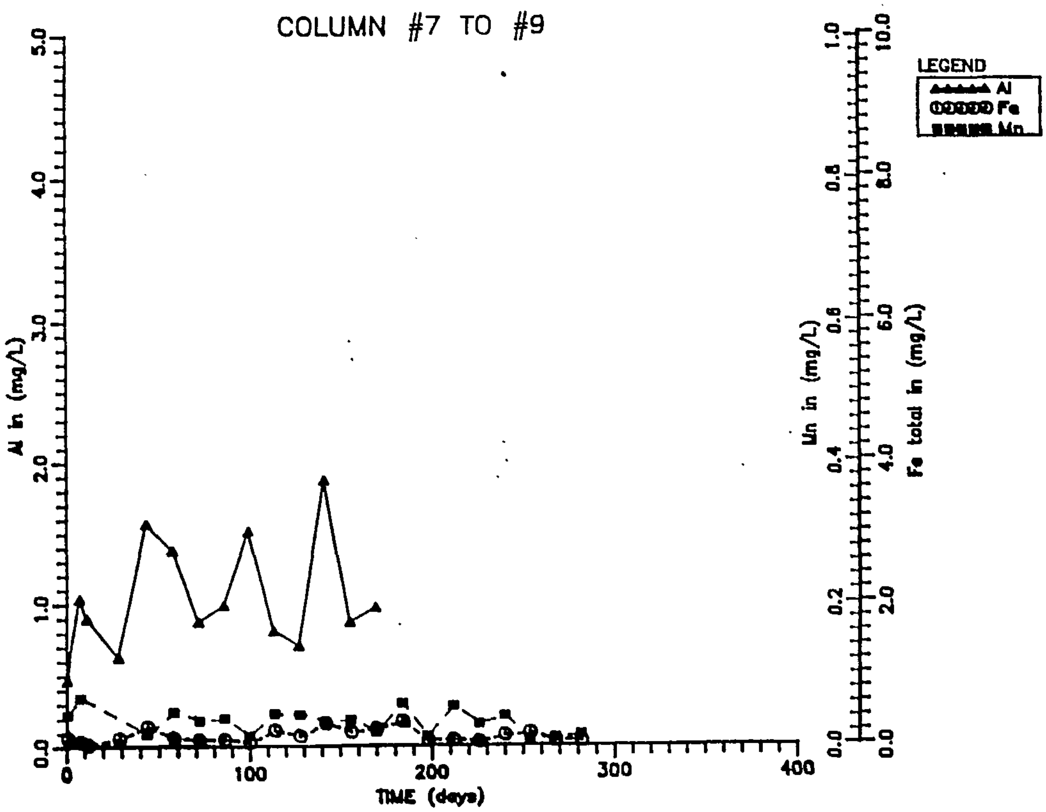

Fig. 5 - Leaching characteristics of total homogenized tailings with -8 mesh lime, Al, Fe, Mn profiles.

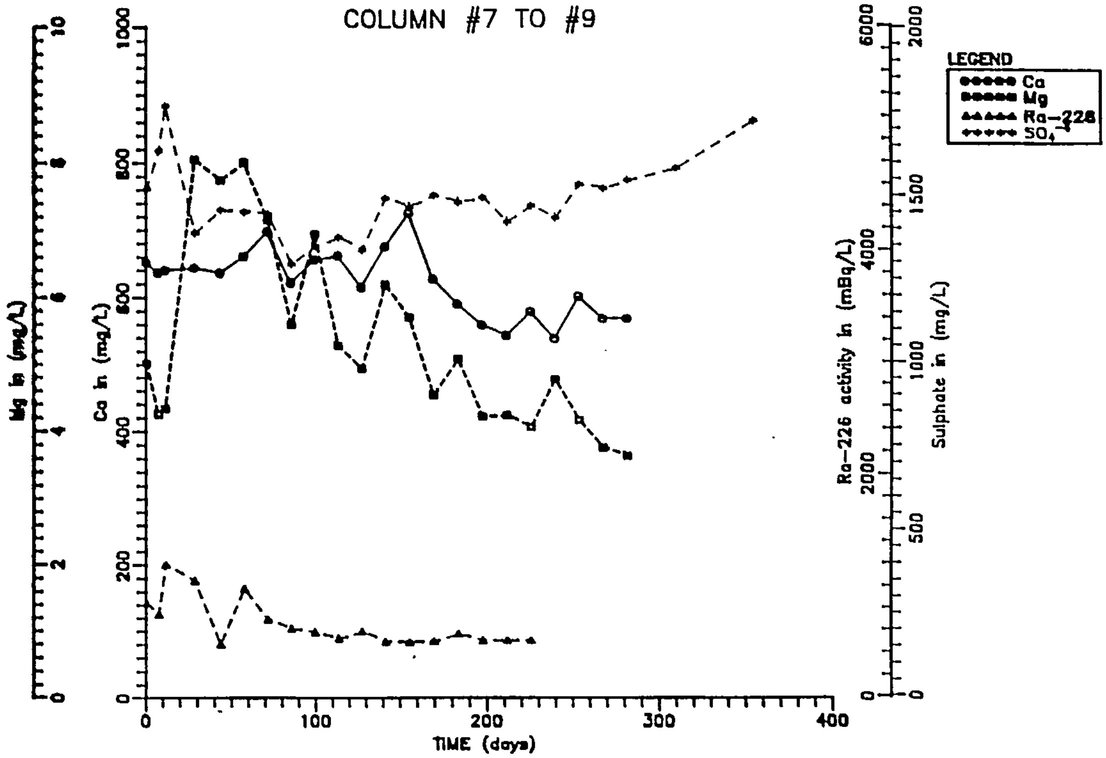

Fig. 6 - Leaching characteristics of total homogenized tailings with Ca, Mg, Ra-226 and SO_4^{-2} profiles.

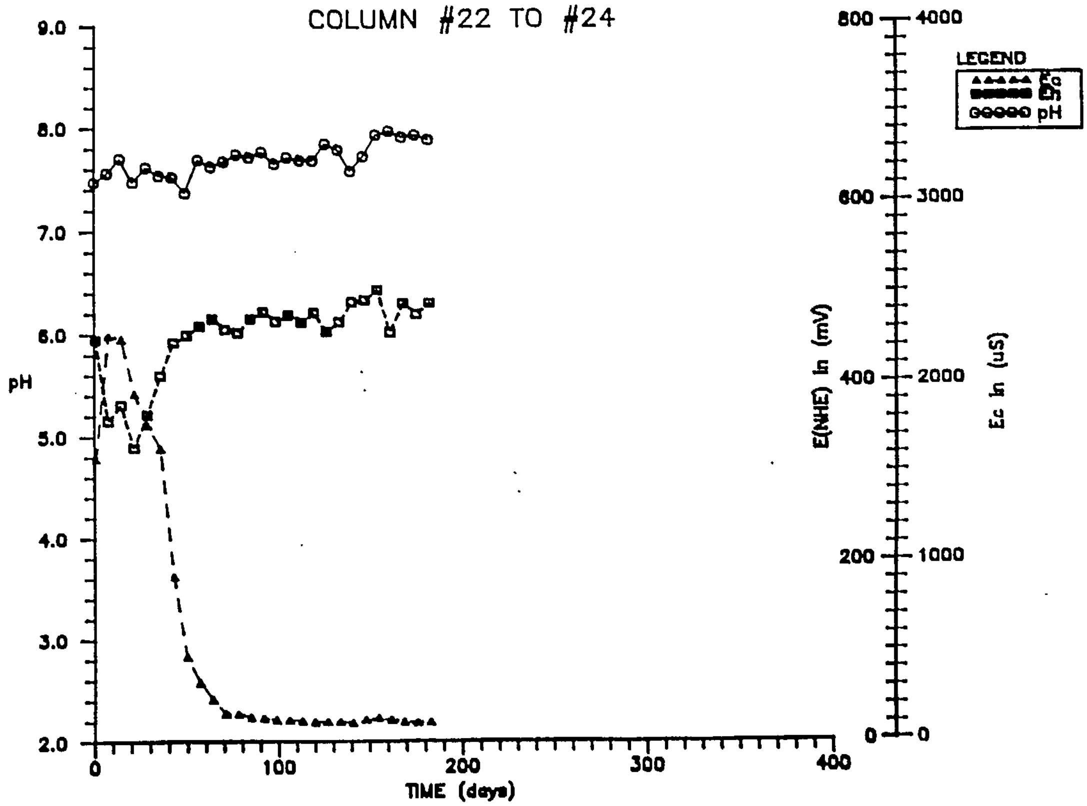

Fig. 7 - Leaching characteristics of flooded coarse tailings with pH, Eh, Ec profiles.

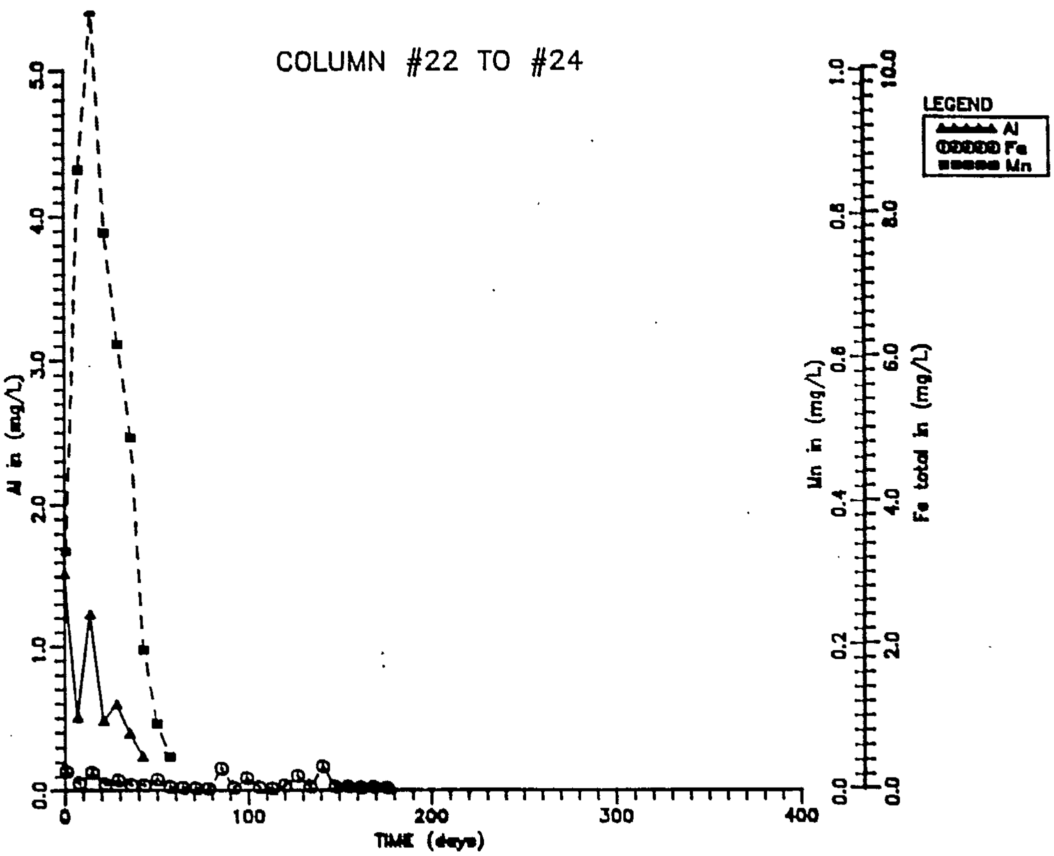

Fig. 8 - Leaching characteristics of flooded coarse tailings with Al, Fe, Mn profiles.

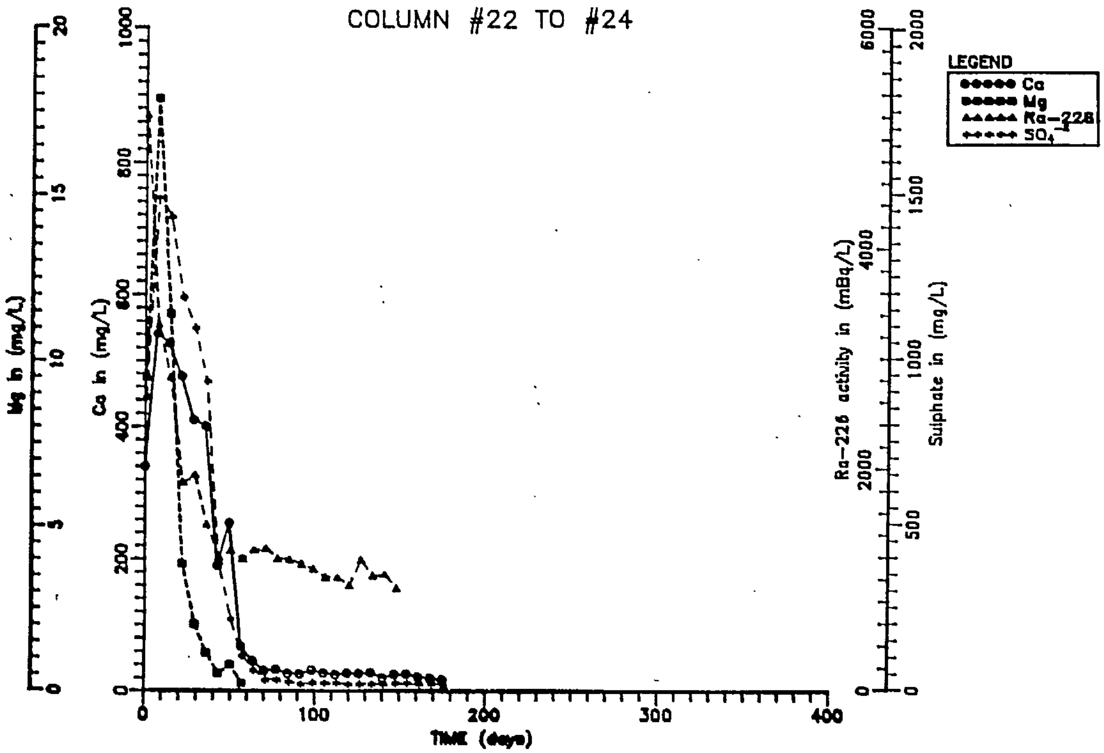

Fig. 9 - Leaching characteristics of flooded coarse tailings with Ca, Mg, Ra-226, SO_4^{-2} profiles.

Results of these tests are shown in Figures 10 and 11, which also showed no evidence of oxidation after 155 days.

3) Limestone neutralization tests: In order to assess the neutralization potential of tailings mixed with limestone of different grain sizes, batch acid neutralization tests were conducted on total mill tailings, and tailings with coarse grained -6.3 mm (-4 mesh), and wet ground limestone. For each test 500 gm of homogenized tailings and/or tailings limestone mixture was placed in a plastic jar to which 75 mL, equivalent to its pore volume of pH 2.0 sulphuric acid was added at a time, and mixed slowly. The solution was kept in contact for approximately 0.5 hours, and the pH of the solution was measured at intervals of 5 and 30 minutes after the acid addition. The solution was then decanted from the tailings and discarded. This procedure was repeated with new batches of pore volume equivalent solutions until an end pH of 4.8 was reached. Figures 12 to 14 show the typical neutralization curves for various samples.

The measured neutralizing capacities for tailings, tailings with -6.3 mm (-4 mesh) limestone and tailings with wet ground limestone were, respectively, 0.8, 1.0 and 8.5 g $CaCO_3$ equivalent. These values are to be compared with the total stoichiometric neutralizing capacity of 37.5 g $CaCO_3$ equivalent for the limed tailings. It is clear from these results that wet ground powdered limestone had at least 8.5 times more neutralizing capacity than that of the coarse fraction which was only slightly higher than the tailings without limestone.

PHASE 2: STUDY PLAN

The following program schedule is planned for the Phase 2 investigation:

1. Determine the kinetics of the acid neutralization process for various size limestone.

2. Determine the acid generation and limestone neutralization characteristics in a worst case scenario, and evaluate the role of sulphate reducing bacteria and capillary fringe.

3. Assess and evaluate the Panel Dam 'A' wetlands performance in treating AMD.

4. Assess the wetland field transplantation test plots at the Stanleigh Mine waste management site.

5. Design, construct and implement a field test plot program for tailings with shallow and deep water, wetland and municipal compost covers.

6. Prepare the Quirke Mine West Arm tailings area for a large scale demonstration plot.

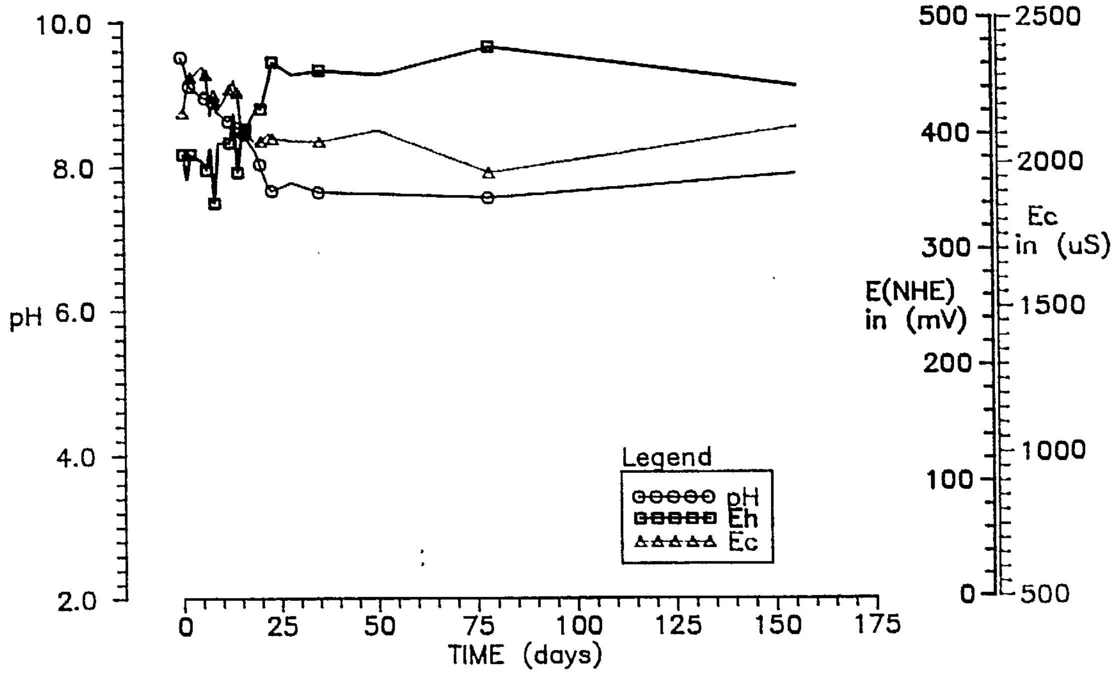

Fig. 10 - Oxidation profiles of undisturbed control tailings with pH, Eh, and Ec profiles.

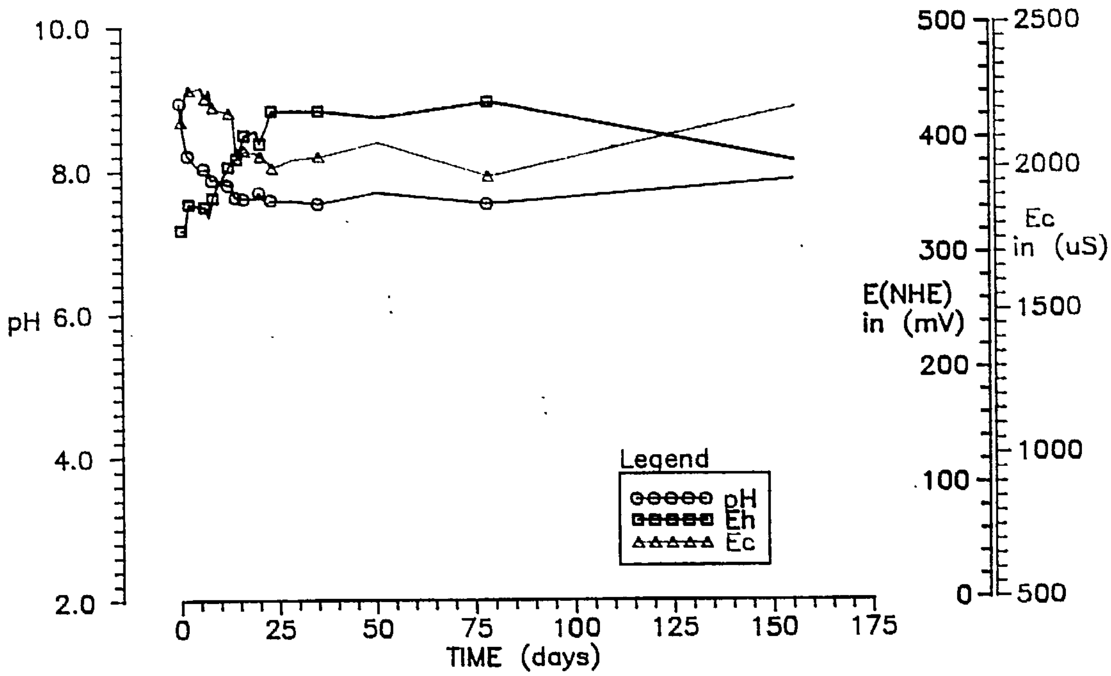

Fig. 11 - Oxidation profiles of air agitated tailings with ground lime, pH, Eh, and Ec profiles.

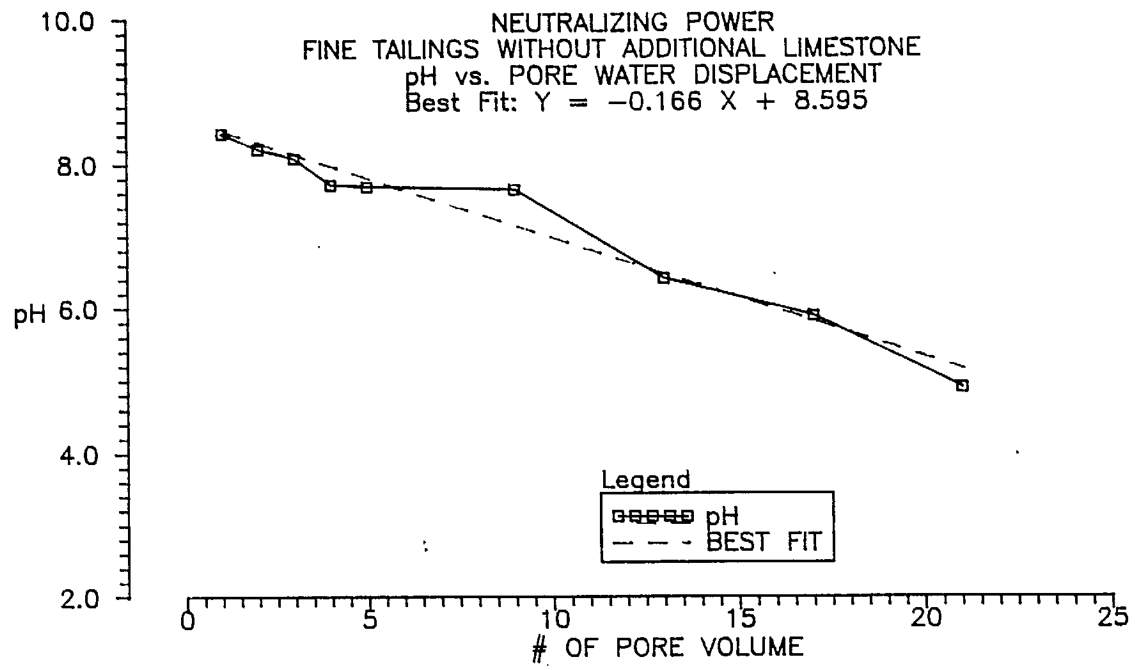

Fig. 12 - Neutralizing power of total homogenized tailings, pH versus leaching pore volume.

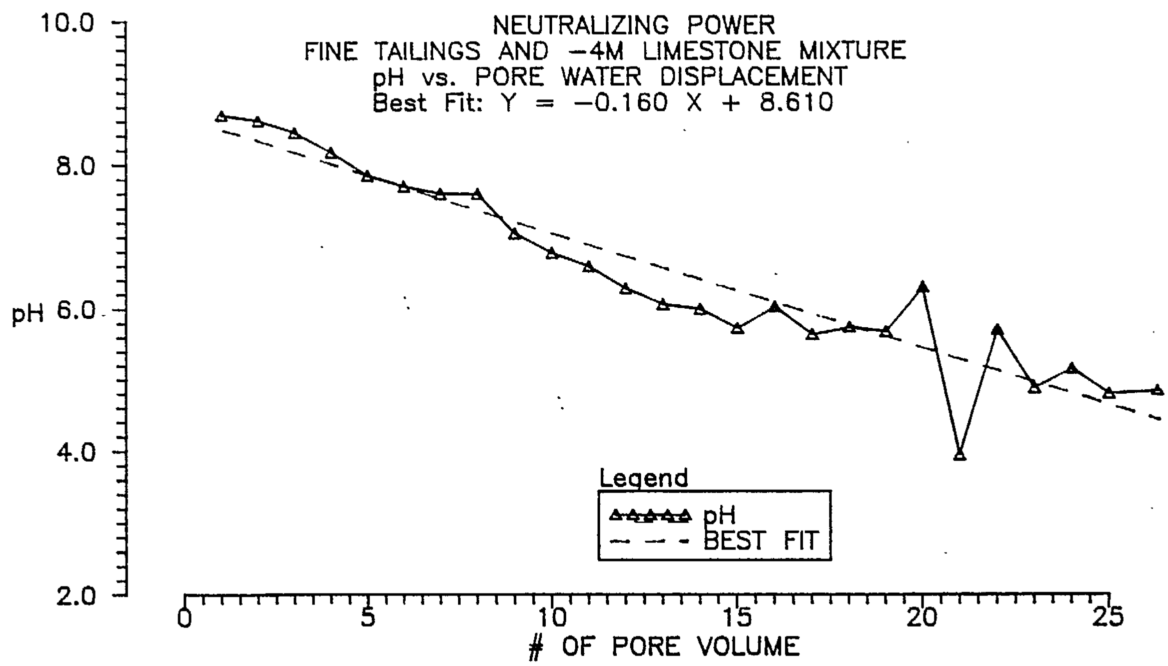

Fig. 13 - Neutralizing power of total homogenized tailings, with-4 m lime, pH versus leaching pore volume.

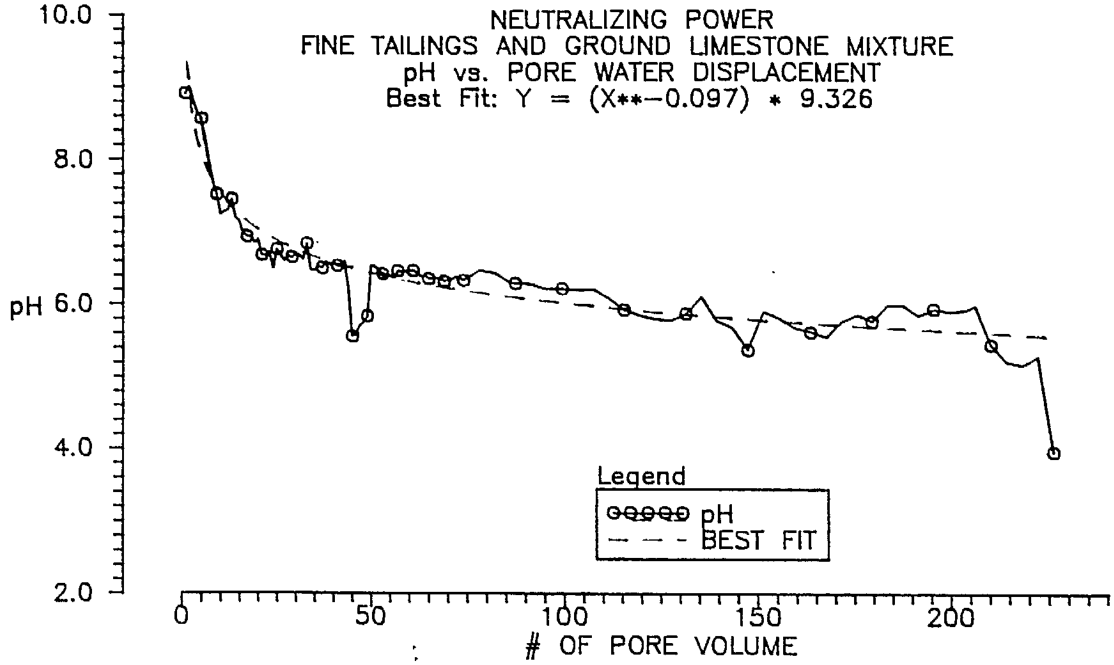

Fig. 14 - Neutralizing power of total homogenized tailings with ground limestone, pH versus leaching pore volume.

REFERENCES

1. Veldhuizen, H., Blowes, D.W. and Siwik, R.S., "The effectiveness of vegetation in controlling acid generation in base metal tailings"; Proc. Seminar/Workshop on Acid Mine Drainage, Halifax, Nova Scotia, Supply and Services Canada, pp. 507-536, 1987.

2. Nicholson, R.V., Gillham, R.W., Cherry, J.A. and Reardon, E.J., "Reduction of acid generation in mine tailings through the use of moisture retaining cover layers as oxygen barrier"; Can. Geotech. J., vol. 26, p. 108, 1988.

3. Hedin, R.S., "Treatment of acid coal mine drainage with constructed wetlands"; In: Wetlands Ecology, Productivity and Values: Emphasis on Pennsylvania, Pennsylvania Academy of Sciences, (in press) 1989.

4. Hedin, R.S., Pammack, R. and Hyman, D., "The potential importance of sulphate reduction processes in wetlands constructed to treat mine drainage"; U.S. Bureau of Mines Report, (in press) 1989.

5. Kay, D.A., "Wetlands field survey"; Internal Report, Rio Algom Ltd., 1990.

6. Kay, D.A., "Typha latifolia test plots, Stanleigh waste management area"; Internal Report, Rio Algom Ltd., 1990.