

MIGRATION OF ACID SUBSTANCES IN SULLIVAN TAILINGS
A COLUMN STUDY

Paper presented

by:

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INTRODUCTION

Reclamation of the tailings pond at the Sullivan Mine, at Kimberley, British Columbia, involves some unique problems. Although the pond is still active, procedures are being developed for the ultimate reclamation of the pond. Attempts at establishing vegetation directly on the tailings pond have met with little success because of the high acid production potential and the high salt content of the soil. This is because the reduced pyritic tailings are weathered in an oxidizing environment which converts sulfides to sulfates.

Several procedures for reclamation have been considered. One procedure involved covering the tailings with overburden or soil to some depth and the establishment of vegetative cover on this material. The question raised is: Will the acid produced by the oxidizing tailings slowly rise through the overburden and, with time, contaminate the overburden with acids, soluble salts and heavy metals to make the overburden ultimately ineffective? To test this, a laboratory study was initiated in cooperation with Cominco Ltd. at the Department of Soil Science, University of British Columbia.

The objectives of the study were:

- (1) To test whether an overburden that is applied directly onto the surface of the Sullivan Mine iron tailings would become severely contaminated with time, contamination occurring as a function of the potential upward migration of acids and toxic materials from the tailings, and
- (2) To test whether a barrier, in this case a layer of gravel, would provide "insulation" to the overburden from the iron tailings, thus inhibiting potential contamination.

METHODS AND MATERIALS

The oxidized iron tailings used in the study were collected from the surface of the iron tailings pond at Sullivan Mine. The tailings were taken to the laboratory, dried, and crushed for uniform packing in plexi-glass columns. The chemical composition of the reduced tailings (unoxidized) is given in Table 1. Some chemical and physical properties for the unoxidized and oxidized tailings are given in Table 2.

Overburden (glacial till) was removed from a ditch north of the iron tailings pond. The overburden was felt to be representative of the type of material that would be used if overburden were to be placed over the tailings. Routine chemical and physical analyses were conducted on the tailings material and overburden.

The study was designed as a nine-month project which consisted of two treatments. Nine plexi-glass columns, 190 centimetres in height, with an inside diameter of approximately 15 centimetres were constructed for each treatment. Treatment 1 consisted of 45 centimetres of overburden placed directly onto the surface of a 30 centimetre deep layer of iron tailings (Figure 1). Treatment 2 consisted of 45 centimetres of overburden separated from a 30 centimetre deep layer of tailings by a 5 centimetre layer of coarse gravel. The gravel layer had two functions in this study:

- (1) To provide a hydrologic barrier between the tailings and the overburden from the tailings. The upward movement of acids and toxic materials was considered to be a function of capillary rise through a uniform pore continuum. The gravel would break this continuum and therefore effectively act as a barrier under unsaturated water flow conditions, and

TABLE 1

Chemical composition of Unoxidized Iron Tailings^a

Mineral	%	Chemical Formula
Pyrrhotite	85	Fe ₇ S ₈
Pyrite	5	FeS ₂
Sphalerite	1	Zn S
Galena	1	Pb S
Quartz	5	SiO ₂

^aFrom Gardiner and Stathers (3).

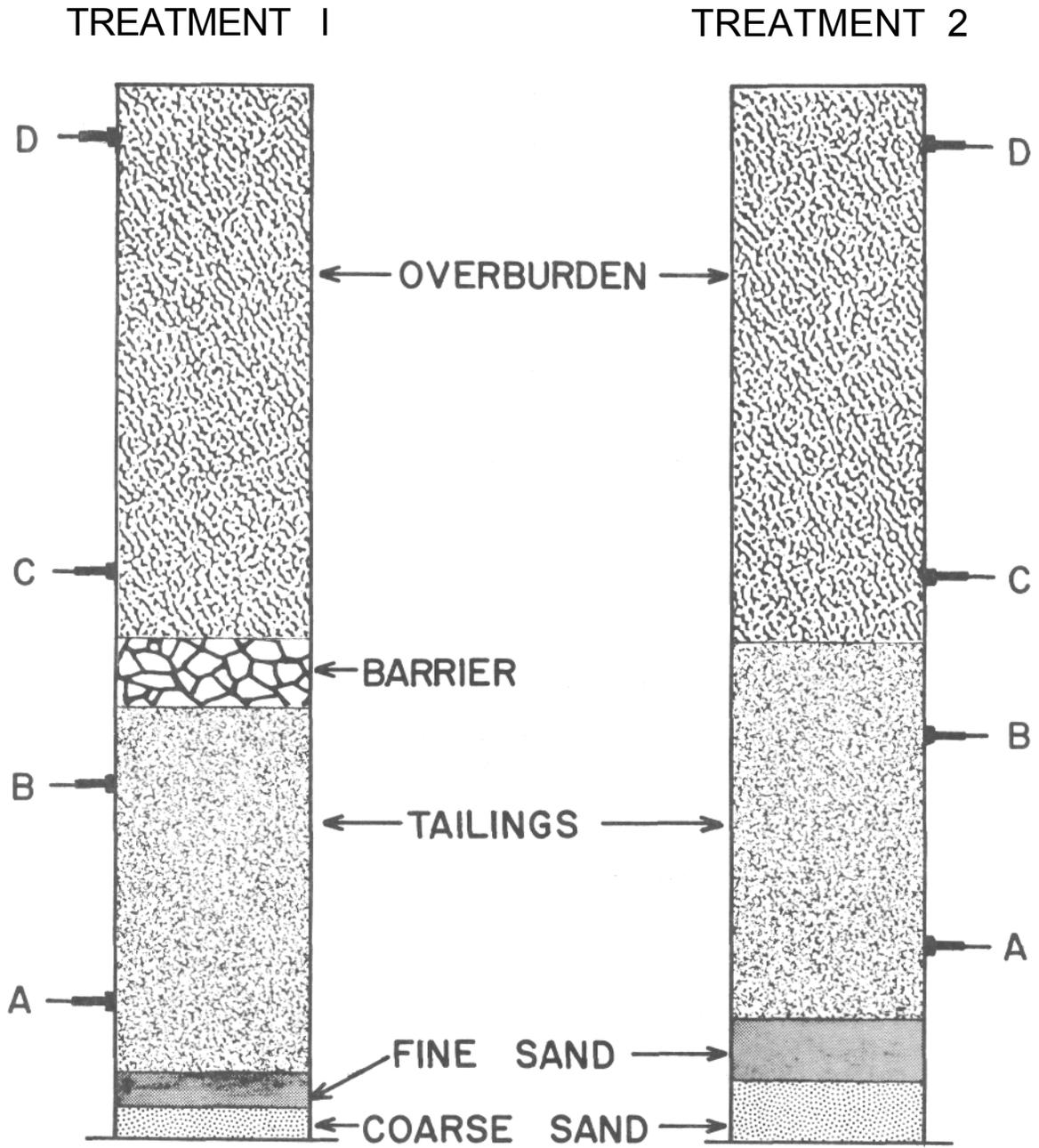
TABLE 2

Physical and Chemical Properties of Iron Tailings^b

Property	Unoxidized Iron Tailings	Oxidized Iron Tailings
Total S(%)	34	7.3
CEC (Milli equivalents/ 100 grams)	1.1	5.1
pH	6.0	2.2
EC (mmhos/centimetre)	2.6	18.0
Colour (Munsell)	5Y3/1	10YR5/6

^bModified from Gardiner and Stathers (3).

FIGURE 1
COLUMN DESIGN



- (2) To provide a means of reclaiming the waste rock dump. The mining process at Sullivan Mine produces waste rock. This could be used as a source of coarse material for the hydrologic barrier.

In order for upward migration to occur, water must move up through the columns by capillary rise. Thus, each column is equipped with a water table located at a height halfway up in the tailings material. Four sampling portals are specifically located to include sampling areas below and above the water table in the tailings material, at levels A and B, respectively; and, a sampling area in the overburden fairly proximate to the tailings overburden boundary at level C. A fourth portal is located near the top of the columns in the overburden, at level D (Figure 1). Solutions were extracted each month from each sampling portal for chemical analyses.

The upward movement of acids and toxic materials was promoted by accelerating evaporation at the surface of the columns. This accelerated evaporation was imposed by placing the columns in a wooden growth chamber constructed in the laboratory. The wooden structure is approximately 1.8 metres x 2.1 metres and is roughly 2.5 metres in height. It was equipped with a heater, insulation and a thermostat. The temperature was maintained at approximately 32 C. Arid conditions were mandatory for the success of this project. In an environment of room temperature and pressure the rate of reaction would be minimal.

The experimental approach of evaporation processes as opposed to leaching processes is justified by considering the climatic zone in which the mine site is located. Kimberley has been described as in the 'dry belt' of British Columbia. It receives approximately 378 millimetres of precipitation annually of which roughly 229 millimetres are allocated to rainfall. The climatic data for Kimberley is given in Table 3. With summer temperatures reaching a maximum of 32 C and a relatively long (181 day) growing season, evaporation is considered to be the dominant process as opposed to leaching.

TABLE 3

Climatic Data for the Kimberley Area^c

Precipitation (mm)

Mean annual	377.6
Mean annual rainfall	228.8
Maximum rainfall	51.8 (June)
Mean annual snowfall	154.5
Maximum snowfall	42.4 (December)

Temperatures (°C)

Maximum	32 (August)
Minimum	-21.1 (March)

Growing Season (days) 181

Frost free 95

^cFrom Canada Dept. of Transport (1) and (2).

Chemical Analyses

Standard pH measurements were carried out on the solutions to monitor changes in acidity. Electrical conductivity is important as it indicates soluble salt content. Iron, aluminum, zinc, and copper were analysed by atomic absorption spectrophotometry as these elements were in relatively high concentrations in the iron tailings and were considered toxic to vegetation when in large amounts. Data is presented for the solutions extracted from the overburden at levels C and D. The experiment has been in operation for six months.

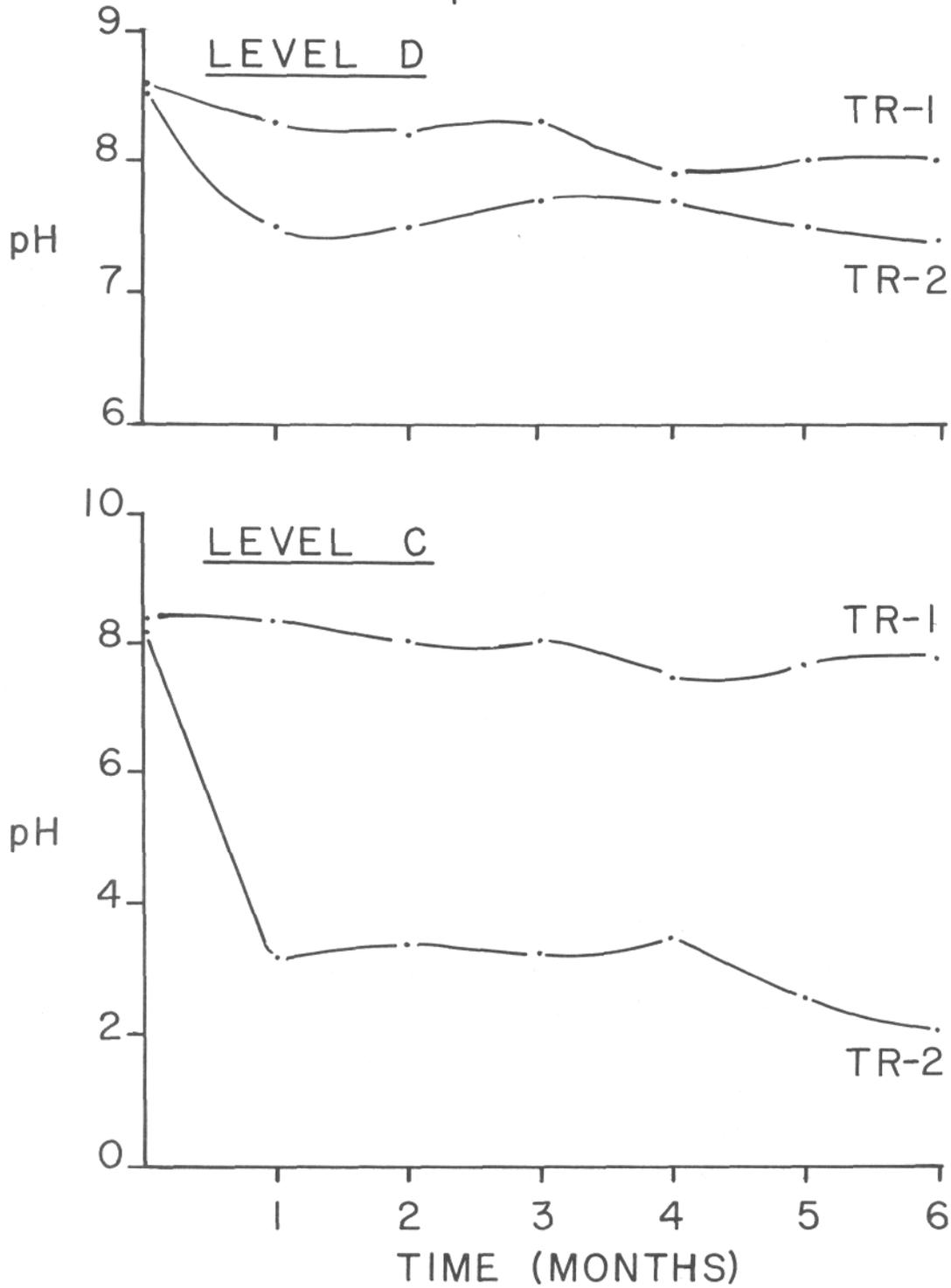
RESULTS AND DISCUSSION

Preliminary analyses indicated that the gravel barrier was effective in preventing the upward movement of salts, acids, and other toxic materials into the overburden from the tailings material. The overburden material placed in direct contact with the tailings became contaminated by these substances. The extent of the chemical changes occurring in Treatment 2 in comparison to Treatment 1 can be effectively discussed if each type of analysis is considered separately.

Analysis of pH

As noted previously the most intense reactions were predicted to occur at level C in the columns. The barrier in Treatment 1 was effective in preventing acid movement (Figure 2). Changes in pH did not occur in this treatment during the experimental period. However changes in pH occurred in Treatment 2. The pH dropped from an initial basic reaction to a very acid condition at level C. The absence of a barrier resulted in a pore continuum between the tailings and overburden providing a direct path into the overburden. Indications that acids moved up to the D level in the columns became apparent as measurements decreased 1 pH unit during the sampling period. The reaction was much more extreme at level C, as movement to the sampling portal at level C took place over a distance of 7 centimetres (from the tailings-overburden

FIGURE 2
pH vs TIME



TR = TREATMENT

boundary). The optional pH range for vegetation success is roughly pH 6.5-7.0. The levels of acidity persisting at level C in Treatment 2 would pose serious problems to the growth and maintenance of vegetation.

Variation in pH measurements in the overburden at time "0", between the two treatments, was the result of rapid migration of some acid substances immediately after the columns had been packed.

Soluble Salts

Electrical conductivity measurements reflecting soluble salts are plotted in Figure 3. Treatment 1 proved to be a successful means of preventing the movement of salts. Measurements of soluble salts fall below those levels considered deleterious to vegetation-set at 4 millimhos per centimetre or lower. Unsuitably high concentrations of salts moved into the overburden at level C in Treatment 2. The short distance of 7 centimetres from the tailings boundary resulted in "rapid" contamination of the overburden at this level. Such high salt levels persisted in the overburden, illustrating the potential source of salts from the tailings.

The salts in Treatment 2 migrated in a linear manner due to the greater distance (roughly 40 centimetres) before reaching the sampling portal at level D. High salt contents appeared to be "long-term". Future analysis will verify this.

Elemental Analysis

Elemental analysis was carried out in the solutions extracted from the overburden at level C, which indicated that the acids and salts moving into the overburden in Treatment 2 were accompanied by concentrations of iron, aluminum, zinc, and copper (Figures 4 and 5). Therefore, elements did not migrate into the overburden in Treatment 1. The barrier resulted in effectively insulating the overburden from the tailings

FIGURE 3
ELECTRICAL CONDUCTIVITY vs TIME

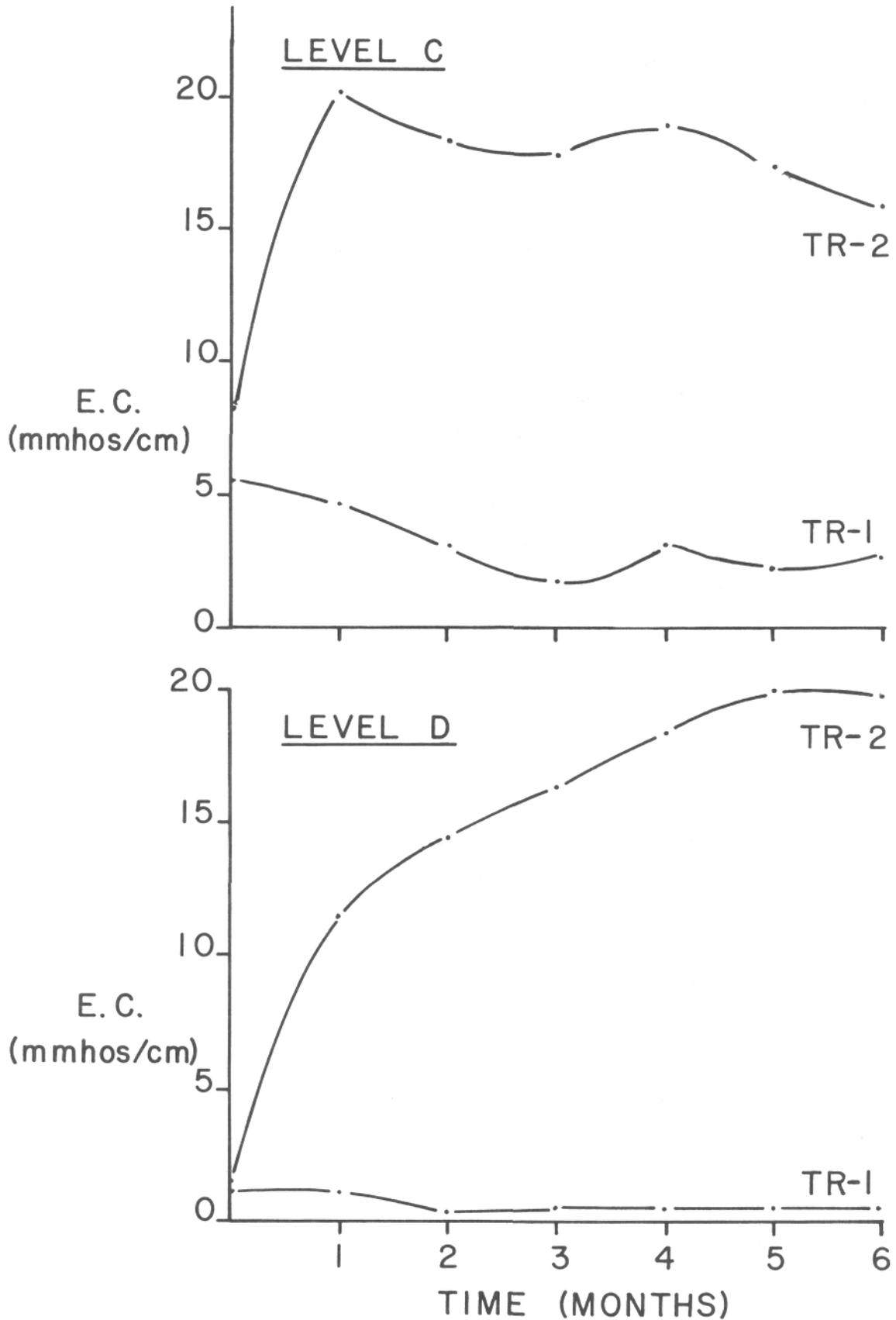
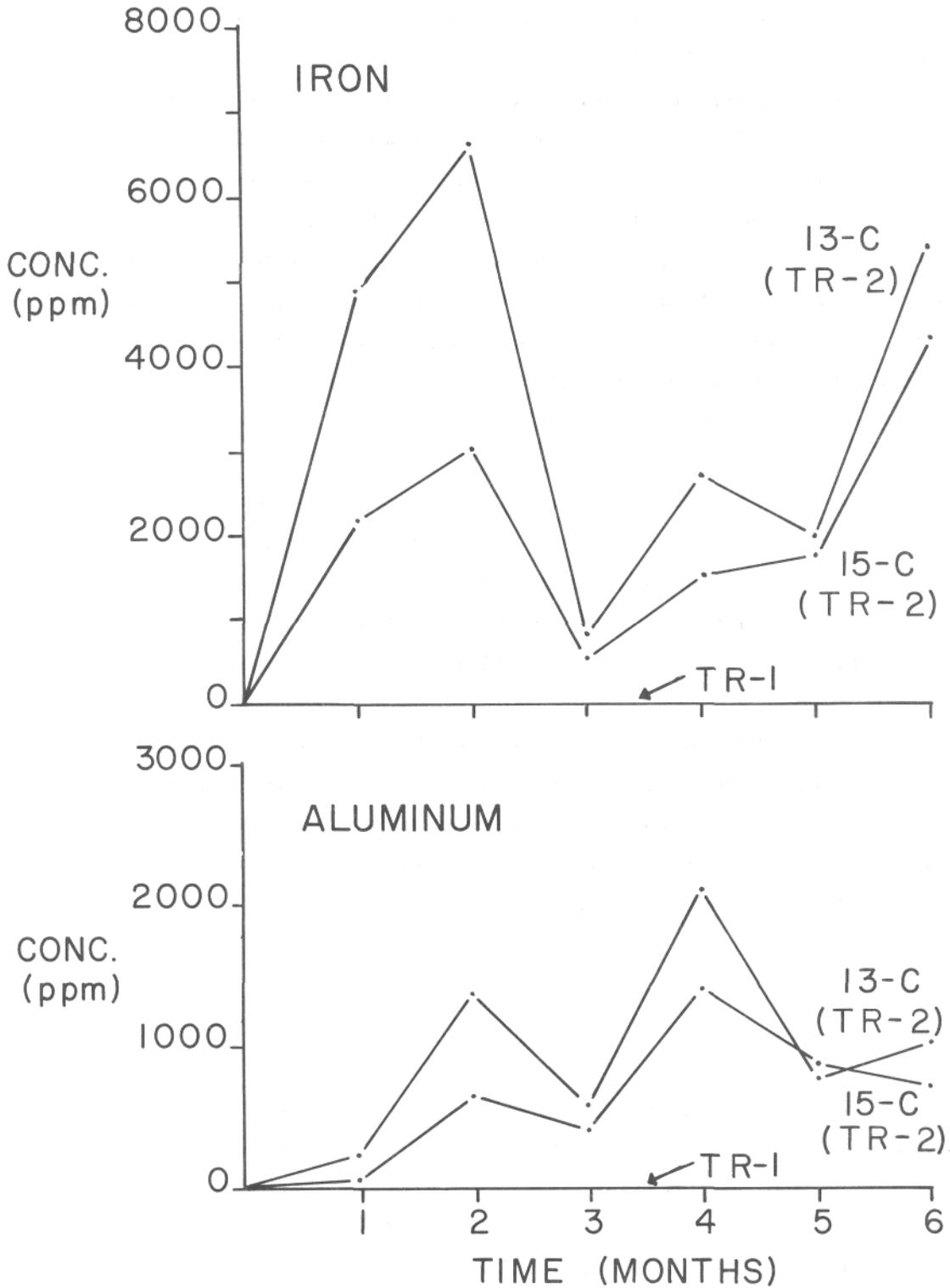


FIGURE 4
ELEMENTAL CONCENTRATION vs TIME



material. However, Treatment 2 was not effective as a reclamation procedure, as the overburden was contaminated. Relatively high concentrations of iron migrated upwards (Figure 4). This was attributed to the formation of soluble iron salts in the tailings when oxidation of the iron pyrite occurred. Data from two columns, arbitrarily numbered 13 and 15, indicated differential movement. This may give an indication of the kinds of variation that may occur in a field situation. The concentrations of iron, aluminum and zinc, rise and fall through the sampling period. This was attributed to precipitation and dissolution of precipitates under extreme acid conditions. Total analysis carried out on the overburden will verify this, or provide an alternate explanation for this pattern. As noted, this data is plotted from solutions extracted from the columns.

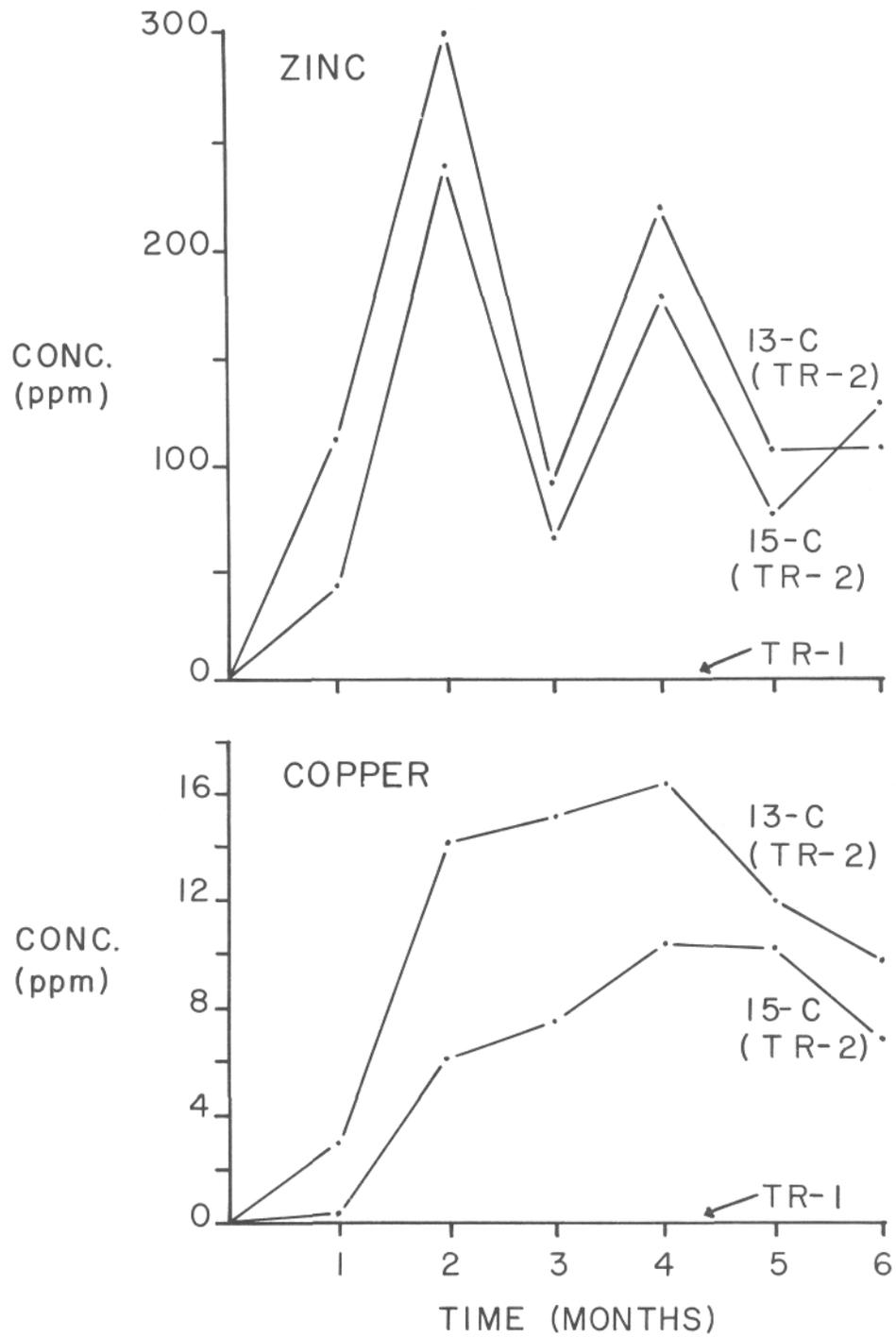
Aluminum and zinc concentrations were also relatively high. These high concentrations are predictable if a source is available, as these metals are soluble under acid conditions. On completion of the experiment, total analysis on the overburden will indicate whether the concentrations of these elements will be at a level toxic to vegetation.

Copper concentrations did not follow the same peak-depression pattern as the other three metals, iron, aluminum, and zinc. Explanation for this change in pattern may be attributed to the comparatively low concentrations of this element in the tailings. Higher concentrations may be required for precipitation.

CONCLUSIONS

The results of this study indicated that the overburden in Treatment 2 was contaminated by the migration of acids, soluble salts, iron, aluminum, zinc and copper. The barrier in Treatment 1 was effective because the pH remained high and the electrical conductivity remained low. Detectable iron, aluminum, zinc, and copper did not migrate up into the overburden. This data indicates the progress of the experiment to date. As was formerly noted, this data was plotted from analysis of solutions extracted from the overburden material. It is predicted that total analysis on the

FIGURE 5
ELEMENTAL CONCENTRATION vs TIME



overburden will confirm that the reclamation of Sullivan Mine iron tailings may be successful if a barrier is placed between the tailings material and the overburden. It is also predicted that overburden if placed directly onto the tailings pond may become contaminated in time.

ACKNOWLEDGMENT

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