United States
Environmental Protection
Agency

Industrial Environmental Research
Laboratory
Cincinnati OH 45268

Research and Development

EPA-600/S2-82-093 Mar. 1983

EPA

Project Summary

Leachability and Revegetation of Solid Waste from Mining

M. Lynn Apel

This research was conducted to assess the effectiveness of various disposal strategies in the abatement of pollution from mining solid waste. Column studies were undertaken to evaluate the quality and quantity of leachate generated by the disposal of a pyrite mine waste under various soil amelioration and layering configurations and to assess the vegetative uptake of potentially hazardous materials from the solid waste.

Columns containing the mine waste under 0.3 to 1.2 meters (1 to 4 feet) of cover soil were used to assess the capability of the cover material to reduce leachate volume, improve leachate quality, and enhance the growth of cover vegetation. Concurrently, columns containing neutralizing materials were used to determine if such materials aided in retarding acid formation and pollutant migration throughout the soil.

The results of this study illustrate that the quality of leachate resulting from the disposal of pyrite mine waste may be dramatically improved by incorporating lime, sewage sludge, and fertilizer into the upper strata of the mine waste; layering sewage sludge and fertilizer on top of the lime-treated mine waste; or by covering the mine waste with a relatively thick layer of cover soil.

The study was conducted by the Industrial Environmental Research Laboratory of the U.S. Environmental Protection Agency (U.S. EPA) in the greenhouse of the U.S. EPA Test and Evaluation Facility (T&E Facility) in Cincinnati, Ohio from August 1980 through January 1981. It should be noted that the results obtained from these column studies reflect the experimental conditions under which they were obtained and may or may not be indicative of what would occur at an actual mine site during the same period of time.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The vast amount of solid waste generated through the mining of mineral ores must be disposed of in an environmentally safe manner. It has been estimated that about 1.5 billion tonnes (1.7 billion tons) of mineral wastes are discarded annually in the United States and that total accumulated mineral solid wastes are approaching 23 billion tonnes (25 billion tons). Mineral waste piles currently cover over 800,000 hectares of land (approximately 2,000,000 acres) and represent over 30 percent of the total wastes produced in the United States.

Depending on the ore being mined and the processes used, mine wastes may contain potentially toxic substances including arsenic, cyanide, mercury, or heavy metals. These pollutants may be leached from waste piles and enter nearby groundwater systems or surface streams. In addition, lack of a vegetative cover on the waste piles can be conducive to severe wind and water erosion of the materials, resulting in wind and waterborne transport of potentially toxic materials inherent in the wastes.

Over the past several years the United States Government has shown an increasing interest in the proper disposal of solid wastes generated by the mining industry. Congress has passed several pieces of environmental legislation regulating the treatment and disposal of solid wastes representing a danger to public health or the environment. Of recent concern is the Resource Conservation and Recovery Act of 1976, (RCRA, PL 94-580) and its subsequent amendments. This act is implemented and enforced by the U.S. EPA and is intended to control the disposal of municipal and industrial solid wastes. The Surface Mining Control and Reclamation Act of 1977 (SMCRA, PL 95-87), which is implemented and enforced by the Department of Interior, is intended to control the environmental effects of surface coal mining operations and the surface effects of underground coal mining operations. The legislation regulating the disposal of uranium mill tailings is the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA, PL 95-604) which is also implemented by the U.S. EPA but enforced by the Nuclear Regulatory Commission. These pieces of legislation have contributed significantly to the development of solid waste disposal techniques that are practical and economically feasible.

This report presents the results of a series of pilot plant column studies performed to assess the effectiveness of various solid waste disposal strategies in controlling pollution from mine wastes. The strategies examined in this research project are currently being used or have the potential to be used in the disposal of pyritic mine wastes or other acidic solid wastes of similar character and composition. The objectives of these studies included: (1) determination of the physical and chemical quality of leachates generated from test columns containing an acidic mine waste under various soil amelioration and layering configurations; (2) determination of the quantity of leachate produced relative to water input based on rainfall statistics of the geographical location under study; and (3) assessment of the uptake of potentially hazardous materials by vegetation growing on the mine waste or cover soil.

For this study, a pyrite mine waste was chosen from the Contrary Creek watershed in Virginia. Contrary Creek is located in east central Virginia, approximately 65 kilometers (40.3 miles) northwest of Richmond and 120 kilometers (74.4 miles) southwest of Washington, DC. Contrary Creek is approximately 8 kilometers (5 miles) long and drains an 18 square kilometer area (7 square miles) which includes three abandoned pyrite (iron disulfide - FeS_2) mines and 17 hectares (42 acres) of pyritic tailings that have remained since mining ceased in the early 1920s.

Prior to state and federal involvement in the mid 1970s, this area was barren of vegetation and the creek was severely polluted. One of the reasons for federal involvement in the area was an attempt to demonstrate the utilization of sewage sludge to reclaim highly toxic mineral wastes. Today, most of the tailings piles have been regraded and vegetated, but areas still exist, particularly along the creek bed, where high acidity and erosion by the stream have prevented successful reclamation. Material from these areas was studied in the pilot plant experiment.

Three approaches were examined for treating the surface of a disposal area in order to mitigate the acid mine drainage resulting from disposal of this pyritic mine waste. The first approach included application of digested sewage sludge, agricultural limestone, and commercial fertilizer to treat the surface of a waste pile in order to neutralize the acidic waste and resulting drainage and develop a plant growth supporting medium. The second approach utilized a layer of cover soil placed over the mine waste to reduce water infiltration of the waste and to provide a growth medium. The third approach involved placement of a neutralizing layer between the mine waste and cover soil layer. In each case the treated surface was vegetated.

Materials and Methods

Column Design

The engineering design of this study included construction of seventeen 0.30-m (1-ft) diameter columns ranging in height from 2.1 m (7 ft) to 3.4 m (11 ft) (Figure 1). Each column consisted of a 0.6-m (2-ft) section of 0.3-m (1-ft) diameter, schedule 80, polyvinyl chloride (PVC) pipe secured to a concrete support platform. A lead support plate was placed between the PVC pipe and the platform. Attached to the upper end of the 0.6-m (2-ft) section of PVC pipe by means of a PVC/acrylic mounting flange was a piece of clear, cast acrylic tubing ranging in height from 1.4m (4.5ft) to 2.6m (8.5ft). An additional machined acrylic flange joint was used in the construction of columns greater than 1.5m (5ft) in height.

Located within the initial 0.6-m (2-ft) section of PVC pipe was an internal leachate collection system made from a 0.3-m (12-in) length of 5.3-cm (2-in) diameter PVC pipe perforated with 0.32-cm (1/8-in) holes and wrapped with a 200 mesh stainless steel screen. The function of this screen was to inhibit the discharge of fines from the ore or soil material with the leachate. A 5.1-cm (2-in) diameter, plain end, PVC cap sealed the top of the collection system and through a series of PVC linkages, a 0.3-cm (0.5-in) collection port allowed leachate to flow out of the column and into an external leachate holding system. The external system consisted of a test-tube air trap and an 18.9 liter (5 gallon) polyethylene collection vessel equipped with a spigot for draining leachate samples.

The internal leachate collection system was anchored in concrete within the 0.6-m (2-ft) section of PVC pipe. The top surface of the concrete was coated with an epoxy paint to prevent reaction with acidic leachates. At the base of the 5.1-cm (2-in) diameter PVC pipe, the concrete was sloped at an 80° angle relative to the pipe to enhance leachate collection.

Experimental Design

The climatological conditions maintained in the greenhouse during the project study period were based on five-year mean monthly precipitation, temperature, and humidity data for the Virginia study area as recorded by the National Oceanic and Atmospheric Administration (NOAA, 1974-1980). Climatic conditions representative of the Contrary Creek area during the months of May through October were simulated. Ten-year, 24-hour storm events were simulated during weeks 9, 18, 20, and 24 of the 24-week study period. Distilled water was applied to the columns weekly and greenhouse temperature and humidity control devices were set according to statistics derived from the NOAA data.

Approximately 3.2 tonnes (3.5 tons) of waste from a pyrite mine and 1.8 tonnes (2 tons) of topsoil (cover soil) were

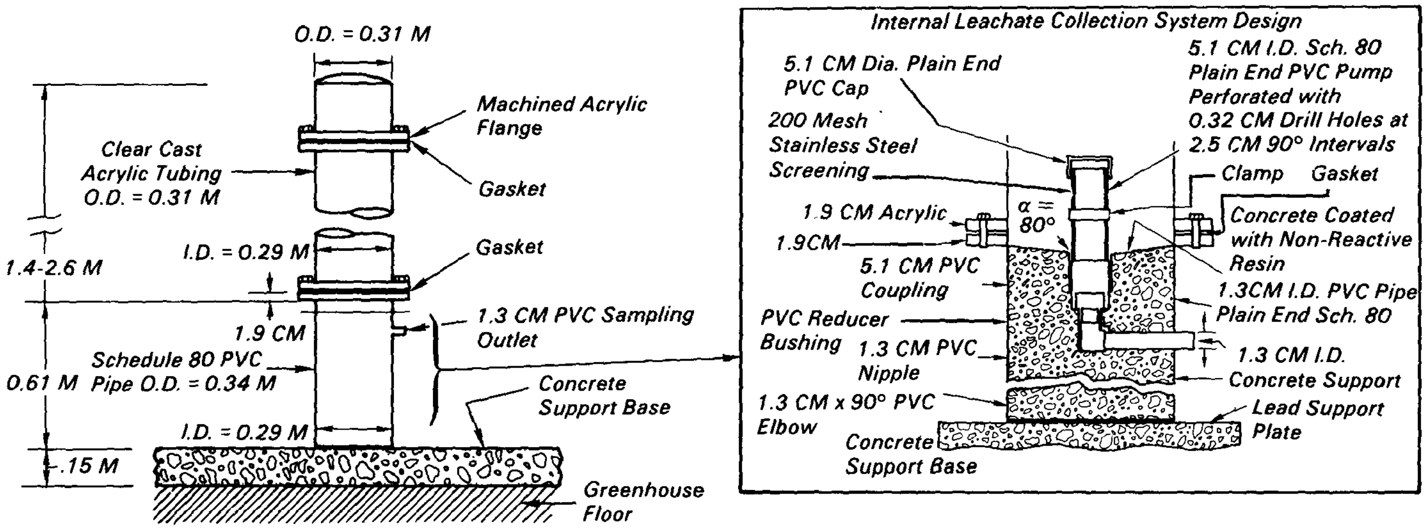

Figure 1. Column and collection system design.

To convert centimeters to inches multiply by 0.39370.
To convert meters to feet multiply by 3.28084.

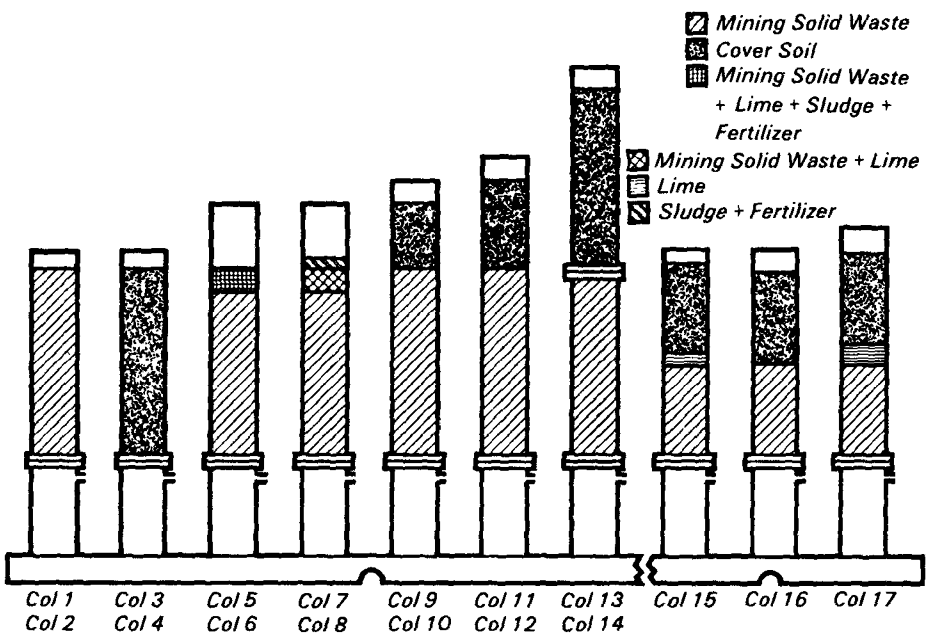

Figure 2. Contents of columns 1 through 17.

obtained from the Contrary Creek site. Soil tests and metal analyses were performed on representative samples of these materials. The resulting data showed that the mine waste contained approximately 200 mg/g iron, 4 mg/g lead, 10 mg/g copper, and 2 mg/g zinc. This compared to approximately 40 mg/g iron, 1 mg/g copper and less than 1 mg/g lead and zinc present in the cover soil material.

After being air-dried, the waste and soil were separately passed through a 1.3-cm (0.5-in) screen. The mine waste was then mixed and placed in the columns in 0.30-m (12-in) lifts. Each lift was graded, and a vibrator compactor was used to achieve a density of approximately 1600 kg/m^3 (100 lb/ft^3). The cover soil was placed in the columns in the same manner and compacted to a density of approximately 800 kg/m^3 (50 lb/ft^3). Amendments were then added to the columns according to the experimental design shown in Figure 2. The types and application rates of the amendments used in this study were similar to those used at the full-scale demonstration site at Contrary Creek and included agricultural limestone, 15-15-15 commercial chemical fertilizer, and anaerobically digested sewage sludge. Sludge used in the column studies was obtained from the Cincinnati Municipal Wastewater Treatment Facility. As a final step, the columns were then seeded and wrapped with brown paper to prevent light from penetrating into the subsoil.

Surface Treatment Techniques Studied

Overall, four surface treatment techniques for disposal of the pyrite mine waste were examined. These techniques were: (1) the incorporation of sewage sludge, agricultural limestone and 15-15-15 commercial fertilizer into the upper strata of the mine waste, (2) the layering of sewage sludge and fertilizer over the lime-treated waste, (3) the placement of a cover soil layer over the mine waste, and (4) the placement of a limestone layer positioned between the mine waste and cover soil.

Columns 1 and 2 contained 1.2m (4ft) of the pyrite mine waste only and served as controls. Columns 3 and 4 contained 1.2m (4ft) of the cover soil material only and also served as controls.

Columns 5 and 6 simulated the reclamation work done at the Contrary Creek Demonstration site. These columns contained sludge, lime and fertilizer incorporated into the top 0.15m (0.5 ft) of the 1.2-m (4-ft) column of pyrite mine waste. Columns 7 and 8 contained these same materials in a different configuration. A 1.2-m (4-ft) layer of the mine waste was placed in each column. Lime was incorporated into the top 0.15m (0.5ft) of the mine waste. Fertilizer and sludge were mixed and layered on top of the lime-treated mine waste.

Columns 9 through 14 addressed the effect of a layer of cover soil placed over the mine waste. Columns 9 and 10 contained 1.2m (4ft) of the mine waste under 0.46m (1.5ft) of cover soil. Similarly, columns 11 and 12 contained a 0.61-m (2-ft) layer of cover soil placed on top of 1.2m (4ft) of the mine waste while columns 13 and 14 contained 1.2m (4ft) of mine waste under 1.2m (4ft) of cover soil.

Columns 15 through 17 were used to examine the effects of placing a neutralizing layer between the cover soil and the mine waste. Column 15 contained 0.61m (2ft) of mine waste, on top of which was placed 1.6kg (3.5lb) of lime (approximately 2.5cm (1in) in height). A 0.61-m (2-ft) layer of cover soil was compacted over the lime. Column 17 was loaded in a similar manner and contained 3.2kg (7 lb) of lime (approximately 5.0cm [2in]) layered between a 0.61-m (2-ft) layer of cover soil and 0.61-m (2-ft) layer of mine waste. Column 16 contained 0.61m (2ft) of mine waste under 0.61m (2ft) of cover soil and served as a control unit. The contents of each column are shown schematically in Figure 2.

Methods Used for Data Analyses and Characterization

After the columns were loaded, simulation of the climatological conditions of the study area began in the greenhouse. Distilled water was added to the columns weekly to simulate average precipitation conditions. Approximately 24 hours after the water was added to the columns, leachate samples were collected from each column and analyzed for pertinent physical and chemical properties including acidity, pH, specific conductance, iron, copper, lead, and zinc. The resulting data were then converted to load data (i.e., concentration times flow) and these data were subjected to statistical analyses.

Vegetative growth was measured periodically during the project. At the end of the study period, samples of the vegetation were analyzed for metal uptake. Total concentrations of copper, iron, lead, and zinc in the plant materials were determined by Atomic Absorption Spectrophotometry. Mine waste and cover soil samples were also analyzed at the end of the study period to assess metal migration through the mine waste and cover soil material. As each column was disassembled, a sample from each approximately 0.31m (1ft) of material was obtained and total concentrations of the above mentioned metals were determined.

Results and Discussion

Leachate samples from each column were collected weekly and analyzed for pertinent physical and chemical properties. Quantities of leachate collected and leachate flow rates were measured and recorded. The temperature, pH, turbidity, specific conductance, and acidity of the lead concentrations in the acidity of the samples were also quantified. In addition, iron, copper, zinc and lead concentrations in the leachate were determined. The characteristics of the experimental columns were then compared to those of the control columns and the results of each treatment technique evaluated. Some of these results are shown in Figures 3 through 8 and Table 1.

Overall, metal migration through the mine waste and cover soil strata was minimal during the project study period. A small portion of the potentially leachable heavy metal content of the mine waste was actually leached during this study. Rough calculations performed using the data collected from the mine waste control columns (1 and 2) showed that approximately 1% of the copper, 10% of the iron, 0.02% of the lead, and 1.5% of the zinc were leached from the mine waste in these columns.

By the end of the study period, vegetation was observed on all columns except those containing the untreated mine waste. Overall, the rate of vegeta-

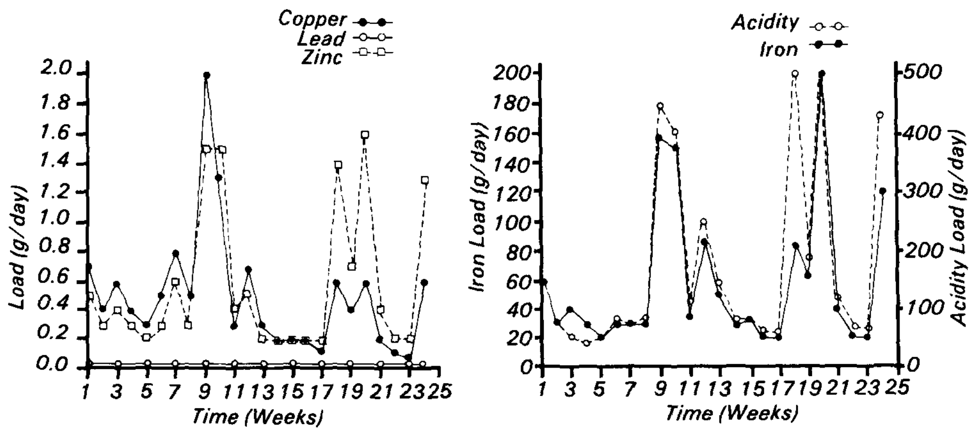

Figure 3. *Combined metal and acidity mean load data for columns 1 and 2 containing the untreated mine waste.*

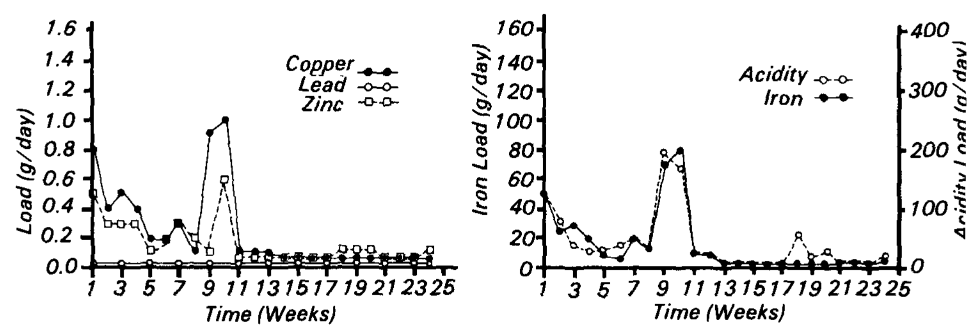

Figure 4. *Combined metal and acidity mean load data for columns 5 and 6 containing the lime/sludge/fertilizer layered over the lime-treated mine waste.*

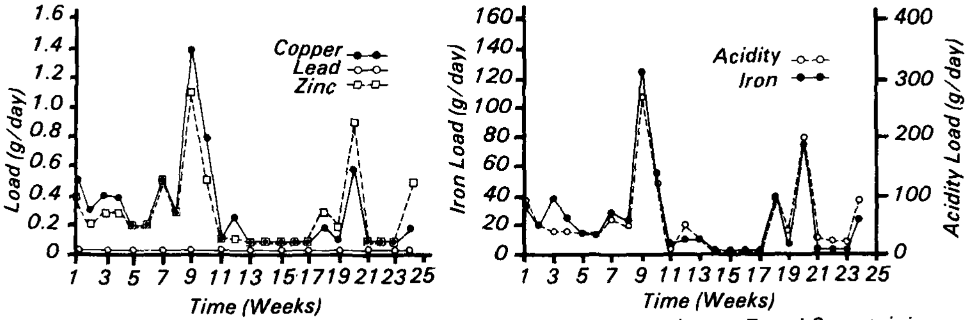

Figure 5. *Combined metal and acidity mean load data for columns 7 and 8 containing a sludge/fertilizer layer over the lime-treated mine waste.*

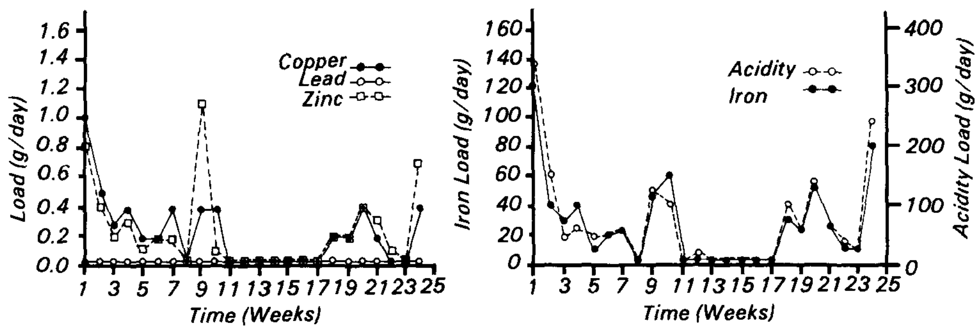

Figure 6. *Combined metal and acidity load data for columns 9 and 10 containing the mine waste under 0.46m (1.5 ft) of cover soil.*

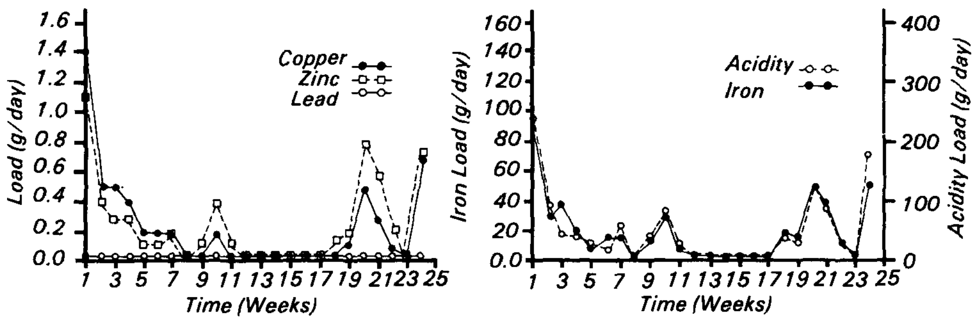

Figure 7. *Combined metal and acidity load data for columns 11 and 12 containing the mine waste under 0.61m (2 ft) of cover soil.*

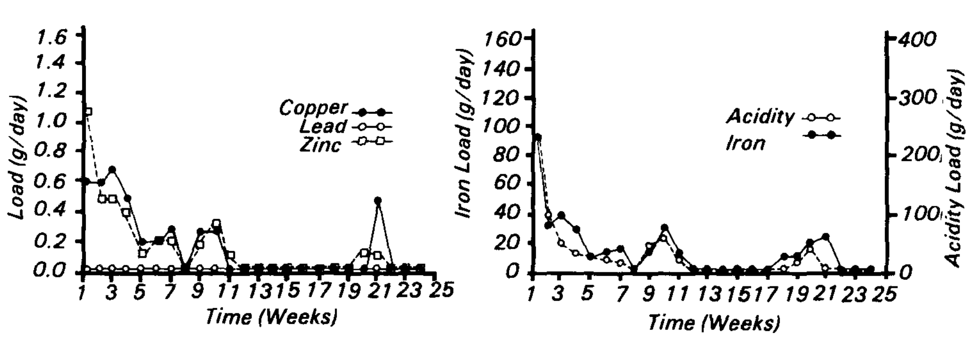

Figure 8. *Combined metal and acidity load data for columns 13 and 14 containing the mine waste under 1.2m (4 ft) of cover soil.*

tive growth was much slower on the sludge treated columns (5 through 8), since no cover soil had been applied and vegetation had to be established on the surface of the treated mine waste. However, growth on these columns indicated that even given the low application rate of digested wastewater sludge used, sufficient nutrients were supplied for vegetation establishment and growth.

Vegetative metal uptake data were recorded at the end of the study period. In general, it was noted that copper uptake concentrations were predominately higher when the amendments were incorporated into the upper portion of the mine waste (columns 5 and 6) than when layered over the lime-treated mine waste (columns 8 and 9). Iron uptake, however, was greater in the latter case, whereas lead and zinc uptake showed little differentiation with respect to either amelioration technique. Overall, the vegetation on columns containing the cover soil layered above the mine waste showed minimal metal uptake.

Conclusions and Recommendations

The results of this research indicate that the quality of leachate emanating from this pyrite mine waste may be notably improved by all of the treatment techniques studied in this experiment, i.e., incorporating lime, municipal sludge, and fertilizer into the upper strata of the mine waste; placing a mixture of sludge and fertilizer on top of the lime-treated mine waste; or covering the mine waste with a 0.6-m to 1.2-m (2-ft to 4-ft) layer of cover soil. Placement of a soil layer greater than 0.6m (2ft) over the mine waste, however, was found to be the best treatment technique. This technique not only improved leachate quality but also provided a soil stratum highly suitable for vegetation.

The utilization of municipal wastewater sludge in combination with limestone and fertilizer proved to be highly beneficial in establishing a vegetative cover over the mine waste. This pilot plant observation is in agreement with the results obtained at the Contrary Creek field demonstration site. Reclamation schemes including the use of sludge and other amendments, such as those studied here, are recommended for lands containing wastes which exhibit physical and chemical characteristics similar to the mine waste studied in this project.

These schemes not only provide a means of sludge disposal but also may have economic advantages depending on the extent and location of the waste material.

Both the layering and incorporation of sludge, lime and fertilizer into the upper portion of the pyrite waste resulted in an improvement in leachate quality comparable to that noted when the mine waste was covered with 1.2m (4ft) of cover soil. Incorporating the amendments, as opposed to layering the amendments, appeared to result in more significant decreases in leachate acidity and metal loads.

Placement of a lime layer between the mine waste and cover soil did not appear to enhance leachate quality during the study period; in fact, leachate quality tended to be worse than that from the control column. This was found to be correlated to a 15-20% decrease in flow rate for the experimental columns as compared to the control column.

As expected, vegetation was quickly established on the cover soil material placed above the mine waste, and no vegetation was established on the untreated mine waste control columns. Vegetative growth was much slower and about 75% less dense on columns containing the amendments layered and incorporated into the mine waste as compared to the columns containing a cover soil layer over the mine waste. Overall vegetative metal uptake by plants was minimal in all experimental columns.

It was noted that the adverse conditions of the mine waste (i.e., high acidity, low pH, high iron content) were greater deterrents to root penetration into the mine waste than lack of precipitation, as often expected. In addition, a thin layer of lime positioned between the cover soil and the mine waste materials was found to be highly conducive to root penetration into the mine waste layer.

Table 1. *Experimental Column Percent Load Decreases As Compared to the Untreated Mine Waste Control*

		Percent Decrease				
Columns	*Treatments*	*Mean Acidity Load*	*Mean Copper Load*	*Mean Iron Load*	*Mean Lead Load*	*Mean Zinc Load*
5 and 6	*Incorporated lime/sludge/ fertilizer into mine waste*	*77*	*58*	*67*	*53*	*67*
7 and 8	*Fertilizer/sludge layered over lime-treated waste*	*65*	*44*	*55*	*58*	*51*
9 and 10	*0.46-m (1.5-ft) cover soil*	*58*	*56*	*50*	*75*	*56*
11 and 12	*0.6-m (2-ft) cover soil*	*71*	*54*	*60*	*79*	*53*
13 and 14	*1.2-m (4-ft) cover soil*	*81*	*64*	*71*	*75*	*69*

*The EPA author **M. Lynn Apel** is with the Industrial Environmental Research Laboratory, Cincinnati, OH 45268.*

The complete report, entitled "Leachability and Revegetation of Solid Waste from Mining," (Order No. PB 83-136 010; Cost: $17.50, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

Industrial Environmental Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

☆U. S. GOVERNMENT PRINTING OFFICE: 1983/659-095/584

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

Postage and
Fees Paid
Environmental
Protection
Agency
EPA 335

Official Business
Penalty for Private Use $300

RETURN POSTAGE GUARANTEED

Third-Class
Bulk Rate

IERL0120766
LIBRARY REGION V
U.S. EPA
230 S DEARBORN ST
CHICAGO IL 60604