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Research and Development

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Project Summary

Feasibility of Using Chemical Liners for Landfilling Electroplating Sludges

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Various chemical liners were evaluated for use in a segregated monolandfill for the disposal of electroplating wastewater sludges. The tests were conducted in an unused portion of a secure landfill in South Carolina.

Seven cells were constructed, each 2.4 m (8 ft) square and 1.8 m (6 ft) deep. One cell was reserved as a control, and the other six were used as replicate test cells. Agricultural limestone, hydrous oxides of iron, and fly ash were each used to line two test cells. The control cell was lined with sand. All seven cells were then filled with sludges from the treatment of electroplating wastewaters.

Leachate was collected under a CO_2 environment from below the cells approximately once a month for 2½ years and analyzed to evaluate the capacity of the liners to retain heavy metals leached from the sludges. After the last leachate samples were collected in August 1982, each cell was core-sampled to assess the vertical distribution of selected metals in the sludge, the liner and the soils.

The concentrations of metals and soluble salts in the leachate varied widely during the first 12 to 15 months then leveled off. The leachate concentrations of the various metals did not appear to be related to levels found in the sludges. The volume of leachate collected indicated the permeabilities of the liners and did not correlate with rainfall.

The limestone and hydrous-oxides-of-iron appeared to retain more metals than did fly ash, but no significant metal leaching was observed in any of the test cells. The excavated sludges showed characteristics similar to the raw sludges originally deposited. Because only small amounts of metals were leached from the sludges, the overall relative performance of the liners cannot be judged from this study. Hydrous oxides of iron (derived from ferric sulfate) would probably be prohibitively expensive for this application, however.

More studies will be needed before chemical liners can be applied to the full-scale landfilling of metal-finishing sludges.

This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, Ohio, 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 metal-finishing industry generates a variety of wastewater streams containing acids, cyanides, hexavalent chromium, and other heavy metals. These wastewater streams are generally treated separately to remove these hazardous constituents or to convert them to less hazardous species. Continued emphasis on wastewater treatment and reduced effluent discharges are expected to increase the future quantities of wastewater treatment sludges.

Several relatively new hazardous waste management technologies (e.g., chemical fixation, encapsulation, and metal recovery) have been proposed for electroplating sludges, but none is sufficiently developed to be used on a wide scale. The prevalent disposal method has been to bury the sludge in a sanitary landfill or in a segregated, secure landfill.

As part of the regulatory effort under the Resource Conservation and Recovery Act of 1976 (RCRA), the U.S. Environmental Protection Agency (EPA) directed specific studies of technologies for the disposal and recovery of electroplating sludges in 1978. Since these sludges have a potential for future metals recovery, emphasis was placed on developing an environmentally acceptable, cost-effective disposal method to facilitate potential recovery. The approach was to test selected inexpensive yet promising chemical liners that could be used in a segregated monolandfill. The liner concept in the present study is not related to reduced permeability. Rather, the chemical liner serves as a filter for hazardous constituents, particularly heavy metals. These metals will be retained either in the metal sludge or in the liner so that they can be retrieved or recovered once the technology proves cost effective and environmentally sound.

This field study has two objectives:

1. To determine the effectiveness of using various inexpensive or waste materials to line disposal sites for metal hydroxide sludges, and;
2. To prepare a conceptual design (including cost estimates) of a full-scale disposal site using such liners.

Before the field study began, a literature review was conducted to gather data on chemical liners for leachate control.

Materials and Methods

Test Site

A test site was selected in the northwest quadrant of a secure landfill in South Carolina. The landfill is situated in an open-pit opal claystone mining operation. The area generally has a mild, humid climate, with normal Fahrenheit temperatures ranging from the low 90's in the summer to the 30's in the winter. Average annual precipitation is just under 119 cm (47 in.) and is fairly evenly distributed throughout the year. Average annual evapotranspiration ranges from 91 to 99 cm (36 to 39 in.).

Test Cells

Seven test cells were constructed, each 2.4 m (8 ft) square and 1.8 m (6 ft) deep (Figure 1). One cell was reserved as a control, and the other six were used as replicate test cells.

Agricultural limestone, hydrous oxides of iron, and fly ash were each used to line two test cells. The control cell was lined with sand. This chemical liner layer was 30 cm (11.75 in.) thick, a size selected to allow the liner to filter the leachate as it passed through and yet retain the heavy metals and other hazardous constituents.

Beneath the chemical liner layer were (1) a layer of bank sand to prevent migration of chemical liner particles through the gravel layer below and into the leachate collection device, (2) a layer of crushed gravel to support the chemical liner and facilitate the vertical flow of leachate toward the collection device, and (3) a 20-mil polyvinyl chloride (PVC) liner covering the cell's bottom and sides to contain any leachate that might pass through the chemical liner.

Above the chemical liner was a 76-cm (30-in.) layer of sludge and a 30-cm (14-in.) layer of cover soil to simulate actual landfill conditions.

Chemical Liner Materials

Agricultural Limestone

Agricultural limestone was purchased from a local distributor. Eighty-one percent of the limestone particles passed U.S. Sieve No. 8 (0.0937 in.). Crushed limestone is commonly used to neutralize acidic agricultural soil. As a test liner, it was expected to neutralize or retard the formation of acidic leachates that might mobilize cationic metal species. Limestone has been used in such applications at several sludge disposal sites, but little field research has been done to confirm its expected utility. Thus it was included as a test liner in this study.

Hydrous Iron Oxides

The hydrous oxides of iron were prepared by mixing an oven-dry, reagent-grade ferric sulfate with sand at 5 percent of the mixture, resulting in a mixture with a pH of 6.3 and total iron of 0.17 percent. Hydrous iron oxides were recommended for field trial as a sludge disposal liner because of their established role as scavengers of heavy metals in soils and water. They are also inexpensive and readily available. These factors combined to make iron oxides an attractive second test liner.

Fly Ash

Fly ash was obtained from the South Carolina Electric and Gas Company of Lexington, South Carolina. The pH was 6.8 and it contained 2.49 percent aluminum, 0.01 percent iron, 0.46 percent calcium, 100 ppm manganese, 270 ppm boron, 22.6 ppm arsenic, and 1.4 ppm selenium. Basic fly ash is a by-product of burning coal for energy and is thus widely available as a waste product. Fly ash contains lime and iron oxides (which retain trace metals) and tend to be basic (which favors attenuation of most heavy metals). Despite its potential as an attenuating liner, fly ash has not been extensively studied for this application and was, therefore, considered an ideal candidate for these field tests.

Sludges

All seven cells were filled with sludges from the treatment of electroplating wastewaters. Chemical characteristics of the two metal hydroxide sludges used appear in Table 1. Both sludges were alkaline (pH 8.8 to 9.1), but they differed as to metal concentrations, color and moisture content.

Leachate Collection and Analysis

Leachate was collected under a CO_2 environment from below the cells approximately once a month for 2½ years and analyzed to evaluate the capacity of the liners to retain heavy metals leached from the sludges. Each sample was analyzed for pH, electrical conductivity (EC), cyanide, boron, arsenic, selenium, mercury, chromium (III), chromium (VI), cadmium, nickel, copper, iron, manganese, lead, and zinc. The samples were also analyzed selectively for selenium, cyanide, boron and mercury.

Core Sampling

After the last leachate samples were collected in August 1982, each cell was core-sampled through the various layers in the cells to assess the vertical distribution of selected metals in the sludge, the liner and the soils.

Conclusions

The following conclusions can be drawn from the results of the field study:

1. The metal hydroxide sludges showed no significant leaching of

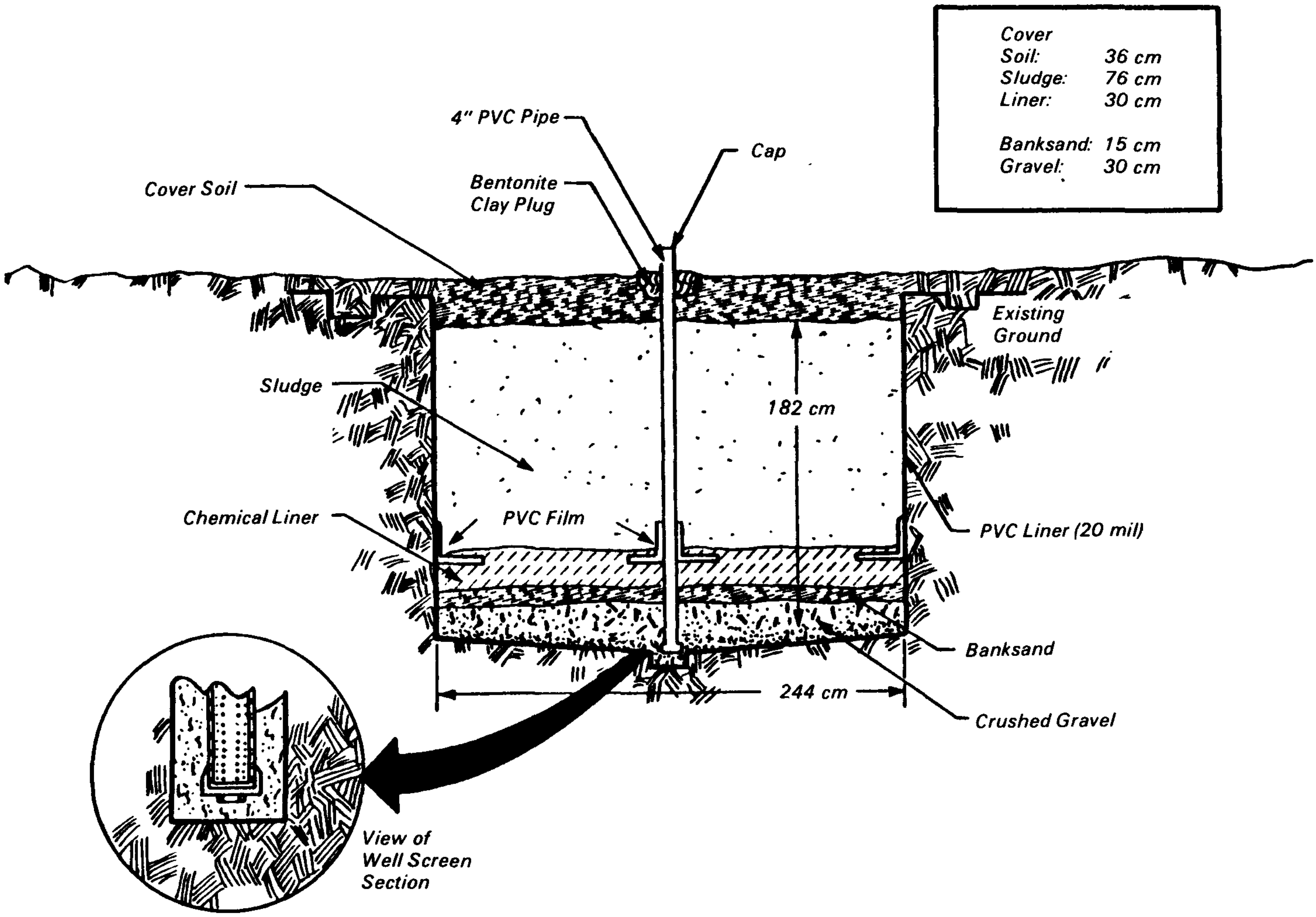

Figure 1. *Test cell design (not to scale).*

Table 1. *Chemical Characteristics of Electroplating Sludges Used*

Parameter	*Wolverine Brass[*]*	*Crescent Tool[†]*
pH (1:1)	*8.8*	*8.8 - 9.1*
	(%)[‡]	
Cr (Total)	*2.71*	*0.002*
Fe	*0.70*	*3.60*
Ni	*1.16*	*2.00*
Zn	*1.57*	*0.73*
Pb	*0.16*	—
Cu	*2.06*	*0.28*
B	*0.13*	—
	(mg/kg) #	
Mn	*56.0*	*650*
Hg	—	*1.0*
Cd	*23.0*	*6.5*
Se	*3.8*	—

[*]Analyzed by the Environmental Engineering Laboratory, University of South Carolina.
[†]Data obtained from Department of Health and Environmental Control, Columbia, South Carolina.
[‡]Oven-dry weight basis.

heavy metals. The excavated sludges exhibited characteristics similar to the raw sludges originally deposited.

2. The pH, soluble salts, and metal concentrations of leachate fluctuated in the first 12 to 15 months but leveled off thereafter. The concentrations of various heavy metals in the leachates were not related to their initial concentrations in the sludges.
3. The largest volume of leachate was collected from the limestone cells and the smallest volume from the fly ash cells. These volumes indicated the permeability of the chemical liners and were not directly correlated with the amounts of rainfall.

Table 2. *Metal Retention in the Three Chemical Liners*

Liner	*pH*	*Fe*	*Ni*	*Zn*	*Mn*	*Pb*	*Cd*	*Cu*	Cr^{+6}	Cr^{+3}	Hg
					mg/kg*						
Control	7.1	237	0.86	0.96	2.06	0.27	0.02	9.75	0.13	2.4	NA[†]
Limestone	7.9	248	17.2	8.15	97.8	18.1	2.01	12.8	0.17	3.7	0.36
Fly Ash	6.0 (6.8)[‡]	7,442 (6,212)	22.7 (17.4)	31.5 (25.8)	45.4 (100)	15.5 (21.2)	0.42	46.0 (36.3)	0.10	24.8 (8.46)	0.04
Iron Oxide	7.1	195	60.9	37.0	1.84	3.51	0.18	32.0	0.17	42.4	NA

*Concentrations are expressed on an oven-dry weight basis, and except for the control, they are averages of two replicate cells.
‡Concentrations in fly ash before placement in cells. Chromium value is total Cr.
†Not analyzed.

4. Limestone and hydrous oxides of iron appeared to have higher metal retention capacities (Table 2) than did fly ash. But because of the insignificant leaching of metals from the sludges and the resulting low metal concentrations measured in the chemical liners, the performance of these liners cannot be judged adequately in this study. In addition, the integrity and longevity of the three chemical liners cannot be determined from the laboratory data observations during cell excavation.
5. Large quantities of iron were released from the iron oxide cells, resulting in iron enrichment of leachate.
6. The costs of the chemical liners account for the cost differences in full-scale landfill operations using these liners. The cost of using hydrous oxides of iron (derived from ferric sulfate) as a chemical liner would be prohibitive.

Recommendations

Additional studies are recommended before chemical liners are applied to the full-scale landfilling of metal-finishing sludges. The studies may include the following:

— The arrangement and thickness of different materials in the cell with respect to maximum metal retention.

— The leachability of metals in electroplating sludges of lower pH than those used in this study.

— Protection for and stability of side slopes in landfill cells lined with chemical liners.

— Assessment of the permeabilities of various liner materials under placement (compaction) and chemical conditions.

The full report was submitted in fulfillment of Contract No. 68-01-5059 by SCS Engineers, Inc., under the sponsorship of the U.S. Environmental Protection Agency.

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The complete report, entitled "Feasibility of Using Chemical Liners for Landfilling Electroplating Sludges," (Order No. PB 85-117 091; Cost: $11.50, subject to change) will be available only from:
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