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Design of Solidified/Stabilized Sludge Landfills

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Abstract

Rehabilitation of highly moist, compressible, and heavy metal-containing wastewater treatment sludges for final disposal in a landfill setting requires consideration of several factors. These factors are directly related to the improvement of the physical and environmental performance of the treated sludge as it relates to the disposal environment. This paper will discuss the laboratory treatability studies and field control methodologies used to guide the placement and storage conditions for approximately 261,000 cubic yards (199,550 cubic meters) of solidified/stabilized F006 electroplating sludges within an engineered waste disposal facility.

Introduction

Although there are several available methods for altering the physical and chemical characteristics of wastewater treatment sludges to improve handling and promote environmentally safe disposal (Malone and Jones, 1979; Cullinane et al., 1986), the use of a binding agent such as lime kiln dust (LKD) or flyash to solidify and stabilize F006 sludges has recently been selected by the United States Environmental Protection Agency (U.S. EPA)

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to define the "Best Demonstrated Available Technology (BDAT)" (Federal Register, August 17, 1988, Vol. 53, No. 159) for achieving established treatment standards. Several factors were considered in selecting the BDAT standard to rehabilitate these sludges (Berlow and Keenan, 1988):

(1) Reduction of infiltration rate through the waste,
(2) Reduction of future potential leachate generation,
(3) Maximization of the structural strength and integrity of the waste,
(4) Minimization of leachable constituents of concern through chemical alteration, and
(5) Compliance with land ban of F006 sludges.

Although the terms solidification and stabilization are often used interchangeably, they actually refer to distinct physical and chemical alterations that occur during sludge treatment (Colussi and Muller, 1983; Malone and Larson, 1983). Solidification, or the creation of a solid mass of material with high structural integrity, results from the pozzolanic reaction among the flyash, LKD, and molecular water in the sludges. The pozzolanic activity and ensuing cementation of the waste resulting from the reaction between the silicic mineral content of the flyash and the lime contained in the LKD, generates a monolithic mass exhibiting lower moisture content, porosity, and hydraulic conductivity. This altered solid matrix structure limits the surface area of waste exposed to the environment, reduces infiltration by water and thus limits the production of leachate.

Chemical stabilization of the sludge is accomplished through the isolation and entrapment of hazardous constituents within an alkaline matrix environment (pH of 9 to 11) by conversion of the waste constituents to less soluble compounds (precipitates). This alteration is more resistant to chemical attack and aids in reducing the leachable quantities of chemical constituents of concern such as the heavy metal ions.

Waste Characterization

Wastewater treatment sludges from electroplating operations are defined by the U.S. EPA as a listed waste with the code of "F006". Electroplating is broadly defined as any operation which involves electroplating, anodizing, chemical conversion coating, electroless plating, immersion plating, chemical etching and milling, and printed circuit board manufacture (51 CFR 43350). The U.S. EPA presently estimates that approximately 4500 facilities generate about 5 million tons of F006

Untreated raw sludge moisture and percent solids varied depending on handling operations and atmospheric exposure time. Therefore, all laboratory studies were initiated after the waste was homogenized to yield a uniform moisture content. The mean initial moisture content for the laboratory program was 153.5 percent. This high moisture content resulted in a low strength, highly compressible waste, with a mean compressive strength of 648 lbs/sq. ft. (31.0 kPa), and a compression index of 1.1. Falling head hydraulic conductivity values on the raw sludge varied with the percent of oil and grease and solid content, but typically ranged from $1x10^{-4}$ to $5x10^{-5}$ cm/sec.

As shown in Table 2, a decrease in waste moisture content and an increase in compressive strength were observed as the amount of admixture increased. Hydraulic conductivity of the treated samples ranged from $2x10^{-6}$ cm/sec, a reduction of one to two orders of magnitude over the untreated raw sludge hydraulic conductivity.

TABLE 2. PHYSICAL CHARACTERISTICS OF TREATED SLUDGE[a]

Admixture Quantity,[b] percent	Unconfined Compressive Strength,[c] ksf	Moisture Content, percent
15	3.4	80.1
20	3.9	77.5
30	5.4	60.3
40	14.8	48.2

[a] average of 7 and 14 day values
[b] percent by wet weight
[c] 1 ksf = 47.88 kPa

During the laboratory studies, it became apparent that the physical or solidification characteristics were the constraining variables on the mix design. The chemical or stabilization BDAT treatment standards (Table 3) as measured by the U.S. EPA Toxicity Characteristic Leaching Procedure (TCLP) were generally met with the addition of 15 percent by weight of the admixture, and easily met with the 20 percent by weight mix. However, these lower mix ratios did not satisfy the required strength parameters necessary to provide a solid monolithic mass of the structural integrity capable of supporting a landfill cap without excessive settlement, slope instability, and constructability concerns.

The bench scale testing indicated that a mix ratio of approximately 70 percent sludge and 30 percent wastewater treatment sludge per year.

Table 1 summarizes the range in chemical characteristics of the electroplating sludge studied in this investigation prior to any solidification/ stabilization. Recovery and recycling efforts prior to disposal of the sludge result in the reclamation of excess amounts of tin and chrome. As Table 1 shows, the waste composition can vary widely, depending on plant operations.

TABLE 1. SELECTED CHARACTERISTICS OF F006 SLUDGE

Parameter	Total Constituent[a]		
	Mean	Minimum	Maximum
Arsenic	65.2	.095	317
Barium	45.1	.43	154
Cadmium	<.01	<.01	1.0
Chromium	6902	26	12,600
Lead	73	.51	301
Mercury	1.12	.019	7.1
Nickel	46.4	.82	115
Selenium	.13	<.001	.27
Silver	3.38	.02	6.5
pH (units)	5.1	6.2	6.9
Oil and Grease (%)	15.6	0.02	61.6
Solids (%)	53.0	39.9	89.6

[a]All values are mg/kg, except where noted.

Treatability Studies

Bench scale studies were undertaken to address solidification/stabilization strategies for the particular F006 electroplating sludge and disposal environment. The focus of the investigation was to determine appropriate admixture quantities for properly designing a waste disposal facility to accommodate the altered wastes. These laboratory studies included the assessment of changes in sludge moisture content, strength, compaction characteristics, permeability, and chemical leachability resulting from the addition of varying amounts of flyash and LKD.

For pH control, the portion of the more alkaline LKD was held constant at 20 percent by dry weight of the total admixture quantity. To determine the appropriate percentage of admixture necessary to stabilize the sludge, the testing was performed on sludge samples composed of 15, 20, 30, and 40 percent (by wet weight) admixture. Additionally, each design mix was subjected to testing at several curing times to determine the extent of aging on the observed physical and chemical properties.

yash/LKD would be required to meet both the physical nd chemical characteristic objectives of the project.

TABLE 3. BDAT TREATMENT STANDARD FOR F006[a]

Constituent	TCLP, mg/l
Cadmium	0.066
Chromium (total)	5.2
Lead	0.51
Nickel	0.32
Silver	0.072

[a]Federal Register, August 17, 1988, Vol. 53, No. 159, pg. 31153.

Field Control Methods

The observed laboratory behavior was used to guide field waste additive quantities, field mixing and placement procedures, fill height and slopes, and final cover design for the disposal facility. Solidification/ stabilization of the in-place wastes was performed utilizing the area method (Cullinane et al., 1986). Following this procedure, the wastes were excavated with bulldozers and a trackhoe, loaded in scrapers and spread in 8 to 16 in. (20.3 to 40.6 cm) loose lifts over previously compacted areas. The stabilization admixture (flyash/LKD) was mixed into the sludge with bulldozers, discs, and sheepsfoot rollers. Typical mixing times for a particular lift of waste ranged from three to four hours until a homogeneous mix was achieved. Finally, the mixture was compacted with a sheepsfoot roller/landfill compactor.

Within the initial phase of the field construction, approximately 189,000 cubic yards (144,500 cubic meters) of sludge were solidified/stabilized with about 72,000 cubic yards (55,050 cubic meters) of flyash/LKD. Field testing of the solidified/stabilized waste indicated an average moisture content of about 24 percent at the completion of mixing. A cone penetrometer was used to provide real time in situ strength testing.

Conclusions

A laboratory treatability study was performed on a F006 wastewater treatment sludge from an electroplating operation to determine the quantity of a flyash/lime kiln dust admixture necessary for adequate solidification/stabilization of the sludge. It was determined that the structural integrity necessary for support of the proposed landfill cover and sideslope stability controlled the quantity of admixture needed to meet the project objectives. In general, an increase in admixture quantity and sample curing time improved both the physical and chemical stability of the treated sludges.

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