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REPORT OF INVESTIGATIONS/1991

Dewatering of Waste Effluent From a Tile Manufacturing Plant

By Gwendolyn D. Hood and Annie G. Smelley

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ft	foot	μm	micrometer
gal	gallon	min	minute
gal/d	gallon per day	mL	milliliter
gal/min	gallon per minute	pct	percent
h	hour	rpm	revolution per minute
in	inch	s	second
lb	pound		

DEWATERING OF WASTE EFFLUENT FROM A TILE MANUFACTURING PLANT

By Gwendolyn D. Hood[1] and Annie G. Smelley[2]

ABSTRACT

The U.S. Bureau of Mines developed a dewatering technique for treating wastewater that was tested on waste slurry from a commercial tile company in Alabama. Raw wastewater samples were pretreated with 10 lb calcium chloride and 10 lb Wyoming bentonite per 1,000 gal of slurry. After pretreatment, polyethylene oxide (PEO) at dosages varying from 0.05 to 0.20 lb per 1,000 gal was mixed with the waste slurry, forming strong, tough flocs that were separated from the clarified water using a trommel. The flocculated slurry was dewatered to a consistency that could be handled for subsequent disposal in a landfill. The clarified water quality was equivalent to that of the company's present treatment system.

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INTRODUCTION

In the processing of ores for the recovery of minerals, and in the manufacture of many industrial products, wastewaters containing ultrafine particles which respond poorly to conventional physical separation techniques are often generated. In many cases, these ultrafine (<20 μm size) materials contain mineral values and useful products that represent major resource and financial losses. Current practices usually dispose of these fine-particle wastes by impoundment in settling ponds because present technology, in most cases, can recover neither the valuables nor the water associated with these wastes. The settling ponds not only cover large land areas that are difficult to reclaim but also present potential environmental hazards. The tremendous losses in resources—materials, water, and land—plus the negative environmental impact have created a need for alternative disposal methods (*1-3*)[3].

The U.S. Bureau of Mines has developed a dewatering technique for treating mineral waste slurries that allows for recycling of water and elimination of above ground storage. This technique consists of mixing the waste slurry with a flocculant, PEO, and dewatering the resulting agglomerated mass on a trommel or static screen. Previous Bureau research has shown that industrial wastes such as phosphatic clay, potash-clay waste, uranium mill tailings, coal-clay wastes, talc tailings, and placer mine effluents can be successfully dewatered using this technique. Research has included both laboratory and field testing (*1, 4-6*). Cooperative field tests by the Bureau and the minerals industry have been conducted at four phosphate mines in Florida, three coal mines, two in Alabama and one in Kentucky, and several placer mines in Alaska. Franklin Minerals Products, a mica grinding facility in Franklin, NC, is currently using the technique to dewater their particulate waste. This commercial application is in its 5th year of operation. Also several other companies, after receiving technical assistance from the Bureau, have undertaken testing of the method at their own facilities.

The Bureau made a study of its process as a possible solution to an industrial waste problem at a commercial tile producer in Alabama. The process waste effluent consists of water and finely suspended glaze particles ranging from 0.31 to 3.41 pct solids. In the current method of disposing of the plant waste effluent, approximately 20,000 gal/d are treated with lime or magnesium oxide in a thickener. The clarified water from the thickener flows through a pond system and, after several days, is discharged into the sewer at a water clarity around two Nephelometric Turbidity Units (NTU). The thickener sludge, which contains 20 to 30 pct solids, is impounded in a holding pond where it further consolidates up to 65 pct solids. This material is thixotropic and cannot be handled mechanically to facilitate ultimate disposal in a landfill.

Research was conducted by the Bureau to devise a method to clarify the effluent so that the water could be safely discharged into the environment and to consolidate the waste solids for disposal in a landfill. Two approaches were explored. First, the Bureau's dewatering technique was applied directly to the plant waste effluent as an alternative to the present thickener system. Second, the technique was applied to the thickener underflow sludge to create a thickened sludge with suitable mechanical properties for disposal in a landfill. Laboratory batch tests were conducted on both the waste effluent from the plant and the sludge from the thickener. On-site continuous tests were conducted on the plant effluent.

DESCRIPTION OF MATERIALS

Waste effluent and sludge samples used in this investigation were obtained from the commercial tile facility. Solids in the samples consist mostly of glaze comprising clay, feldspar, zinc oxide, frit, and silica. Samples of the thickener underflow were taken from the disposal pond, at 65 pct solids. To simulate thickener sludge, the samples were diluted to 20 pct solids.

Aqueous solutions or slurries of magnesium hydroxide, lime, alum, bentonite, tile clay, calcium chloride, and Catfloc-T, a cationic polyelectrolyte manufactured by Calgon Corp.,[4] Pittsburgh, PA, were used to pretreat the effluents prior to dewatering with a polymeric flocculant. Several high-molecular weight polymers such as PEO, Nalco 7110, Zetalyte 2A, Percol 333, Percol 351, and Percol 455 were evaluated as flocculants. (PEO is manufactured by Union Carbide Corp., New York, NY, Nalco is manufactured by Nalco Chemical Co., Oak Brook, IL, Zetalyte is manufactured by Combustion Engineering, Inc., King of Prussia, PA, Percol 333, 351, and 455 are manufactured by Allied Colloids, Inc., Suffolk, VA.)

[3]Italic numbers in parentheses refer to items in the list of references at the end of this report.

[4]Reference to specific products does not imply endorsement by the U.S. Bureau of Mines.

LABORATORY PROCEDURE AND RESULTS

Laboratory-scale tests were conducted by pretreating 100 mL of sludge or of waste effluent with specified quantities of additives followed by mechanically stirring the mixture in a beaker while an aqueous solution of flocculant was added dropwise from a buret. The mixture was stirred with a magnetic stirring bar until flocculation reached a point where the individual flocs consolidated and moved around in the beaker as one mass. The supernatant water was decanted until the flocculated mass could be handled. The flocculated mass was then "squeezed by hand" (*1, 3*) to release additional water. The volume of released water was measured, and the solids content of the flocculated material was determined. The buret was read to determine the amount of flocculant solution used and the dosage was calculated, expressed in pounds of polymeric flocculant per 1,000 gal of effluent. This laboratory scheme was devised to give an indication of the effectiveness of a specific flocculant in continuous trommel dewatering tests (*1-3*).

Preliminary laboratory batch tests were conducted on thickener sludge taken from the disposal pond. While initially containing 65 pct solids, the sludge sample was diluted to 20 pct solids prior to testing to simulate the thickener sludge and to allow the flocculant to structure the flocs into a stronger, tougher sludge. Batches of sludge were pretreated with various dosages of additives such as bentonite, tile clay (used in the tile manufacturing process), lime, and calcium chloride. These additives readily flocculate with high-molecular weight polymers and improve flocculation of the fine solids. Best results were obtained with PEO as the flocculant. The results of these tests are summarized in table 1. More effective flocculation of the sludge was obtained with the bentonite and tile clay additives. The sample pretreated with tile clay at 80 lb per 1,000 gal required the least amount of PEO, 0.40 lb per 1,000 gal, to dewater. The dewatered sludge was not thixotropic and suitable for landfill disposal, but the turbidity (NTU) of the clarified water was still high.

Laboratory tests were also conducted on plant waste effluent containing 0.49 pct solids. Various polymer flocculants were tested to determine their ability to dewater the effluent. The results of these tests, given in table 2, show that PEO, at a dosage of 0.09 lb per 1,000 gal, was most effective in dewatering the waste effluent because it required the smallest dosage and dewatered to a high-solids content. A 54-pct solids flocculated sludge was produced that was not thixotropic and could be handled mechanically. The immediate water clarity was 240 NTU. After settling for 24 h to simulate a pond system, the water clarity improved to 92 NTU.

Table 1.—Laboratory dewatering tests of lime-treated sludge from thickener

Test	Additive	Additive dosage, lb per 1,000 gal	PEO dosage, lb per 1,000 gal	Clarified water, NTU	Dewatered solids, pct
1 ..	NA	NA	0.44	1,128	62
2 ..	Bentonite ..	80	1.29	492	43
3 ..	Tile clay ...	80	.40	498	54
4 ..	Lime	20	3.09	**	**
5 ..	$CaCl_2$	20	1.73	**	**

NA Not available.
Asterisks denotes no separation.

Table 2.—Laboratory dewatering tests of waste effluent using various polymers

Test	Polymer	Polymer dosage, lb per 1,000 gal	Clarified water, NTU: Immediate	Clarified water, NTU: Next day	Dewatered solids, pct
1 ..	Nalco 7110 ..	0.30	420	15	41
2 ..	Zetalyte 2A ..	.25	2,400	1,125	45
3 ..	Percol 333 ..	.22	600	300	73
4 ..	Percol 351 ..	.22	1,400	180	64
5 ..	Percol 455 ..	.45	1,600	900	66
6 ..	PEO	.09	240	92	54

To improve the water clarity of this process, waste effluent samples were also pretreated with various additives prior to dewatering with PEO. Best results were obtained by pretreating the waste effluent with 5 to 10 lb per 1,000 gal of Wyoming bentonite and 5 to 10 lb per 1,000 gal of calcium chloride followed by flocculation with PEO. Test results, given in table 3, show that this scheme was effective over the sampling range. A sludge containing 47 to 58 pct solids was produced that could be handled mechanically, and the next day water clarity was improved to 4 to 20 NTU's.

Table 3.—Optimum laboratory dewatering conditions of various waste effluent samples

Initial solids, pct	Additive dosage, lb per 1,000 gal: $CaCl_2$	Additive dosage, lb per 1,000 gal: Bentonite	Additive dosage, lb per 1,000 gal: PEO	Clarified water, NTU: Immediate	Clarified water, NTU: Next day	Dewatered solids, pct
0.8 ..	10	10	0.09	30	4	47
2.1 ..	10	10	.09	80	6	51
3.1 ..	10	10	.29	510	9	54
2.1 ..	10	10	.19	44	8	58
2.3 ..	10	10	.16	60	8	53
2.1 ..	10	10	.15	120	20	56
2.3 ..	5	5	.08	38	7	50

CONTINUOUS TEST PROCEDURE AND RESULTS

Based upon the laboratory results, Monarch Tile Co., Florence, AL was interested in on-site continuous testing of this technique on the waste effluent. In these continuous dewatering tests, 2.4 gal/min of plant waste effluent were pumped from a holding tank through a mixing hose where the bentonite, calcium chloride, and PEO were added to the slurry. A 5-pct solids slurry of bentonite and water was added to the waste slurry as it flowed through the hose at a dosage of 10 lb per 1,000 gal. Next, a 5-pct solids slurry of calcium chloride and water was added to the waste slurry in the mixing hose at a dosage of 10 lb per 1,000 gal calcium chloride. Finally, a 0.05-pct solution of PEO and water was added to the waste slurry at a dosage of 0.09 lb PEO per 1,000 gal of waste slurry. Beyond the point of PEO addition, the mixing hose spanned an additional 60 ft to allow roughly 90 s for the additives to react with the effluent. The mixing hose discharged into a 5-gal conditioner-mixer where the floc size continued to grow, assisted by the mechanical action of the mixer stirring at 200 rpm. After about 60 s, the flocculated mixture flowed into an 8-in-diam rotating trommel screen for dewatering (*5, 7*). A schematic of this equipment is shown in figure 1. The flocculated solids were caught by the 20 mesh screen and began to tumble forming a roll of thickened solids. The clarified water flowed through the trommel screen. As the roll continued through the 36-in-long trommel screen, the flocs continued to release water, which flowed through the screen. Samples of the dewatered sludge discharged from the trommel were collected, weighed, dried, and re-weighed for percent solids determination. Samples of the underflow water from the trommel were also collected. The analysis of the water was limited to only a suspended solids determination because the company did not have the capability for NTU measurements. Continuous dewatering tests were conducted on the waste effluent at the plant site for 8-h intervals spanning a 3-week testing period. Samples from the trommel underflow water and flocculated discharge were collected at 1-h intervals and percent solids determinations were made.

Table 4 shows the dewatering results for a typical 8-h test where wastewater ranged from 0.33 to 3.41 pct solids. The resulting trommel underflow water ranged from 0.13 to 0.28 pct solids, which is comparable to the water quality from the thickener in the existing treatment system, which ranged from 0.09 to 0.24 pct solids. The trommel's flocculated discharge ranged from 31 to 58 pct solids, but unlike the material from the thickener, the trommel sludge could be handled mechanically for final disposal in a landfill.

Table 4.—On-site dewatering tests

Sampling time, h	Initial solids of waste effluent, pct	Solids in underflow, pct	Solids in trommel discharge, pct
1	0.74	0.20	50
2	.76	.16	41
3	.85	.18	50
4	.31	.16	48
5	.33	.15	31
6	3.41	.15	49
7	2.14	.13	48
8	1.25	.28	58

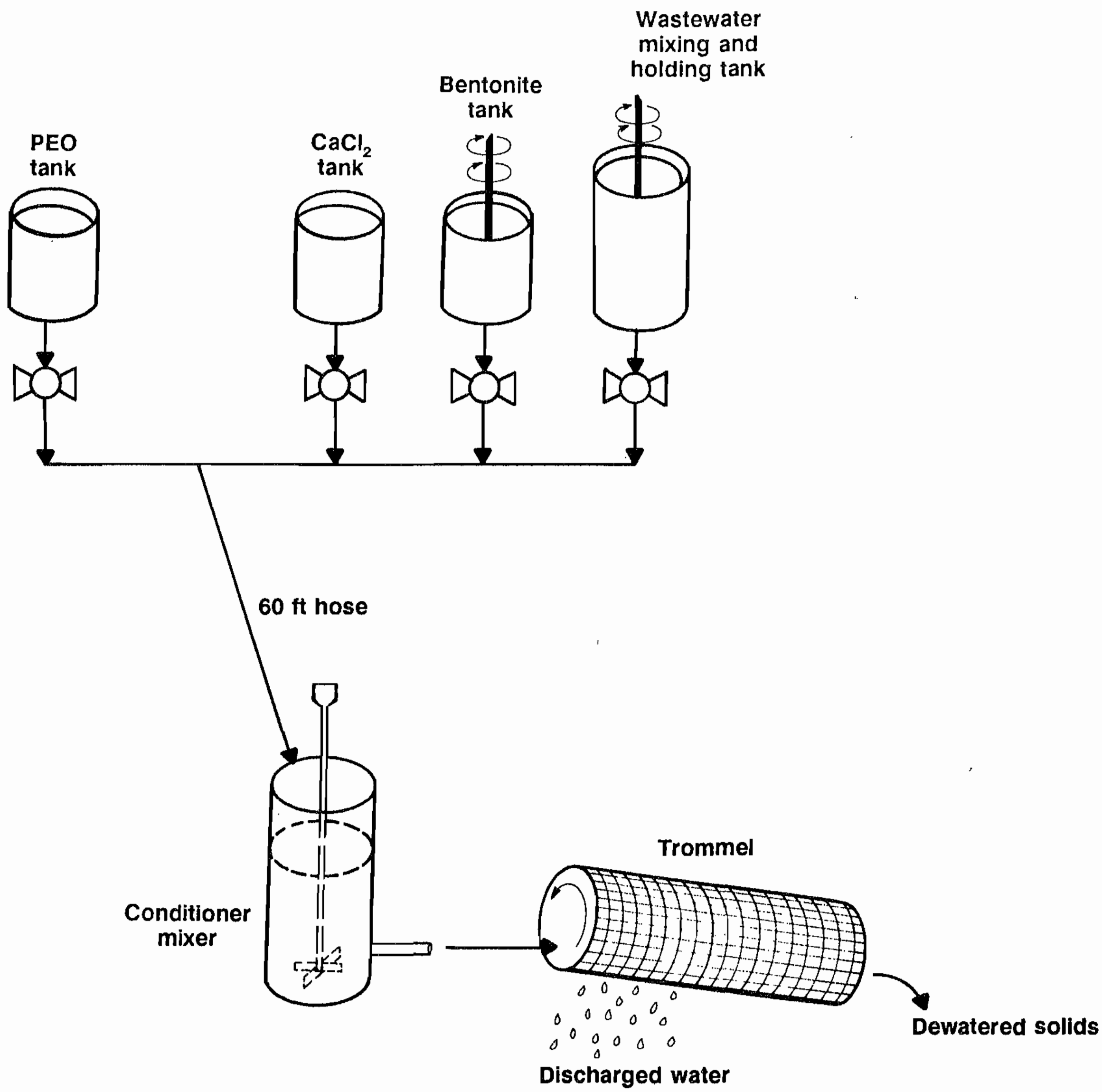

Figure 1.—Trommel dewatering apparatus.

SUMMARY AND CONCLUSIONS

Laboratory dewatering tests were conducted on lime-treated sludge from the thickener and waste effluent from the plant. Several polymer flocculants were tested to determine their ability to dewater the effluent. PEO was found to be most effective. Also, several additives such as tile clay, bentonite, and calcium chloride were effectively used to pretreat the thickened sludge and waste effluent followed by dewatering with PEO, which resulted in improved water clarity.

Test results showed that lime-treated sludge from the thickener pretreated with 80 lb per 1,000 gal of tile clay required a minimum PEO dosage of 0.40 lb per 1,000 gal. Plant waste effluent, containing 0.49 pct solids, pretreated with 10 lb per 1,000 gal of calcium chloride and 10 lb per 1,000 gal of bentonite was effectively dewatered using 0.09 lb per 1,000 gal of PEO.

Based upon results obtained from laboratory tests, continuous on-site dewatering tests using the Bureau-developed trommel dewatering technique were conducted on plant waste effluent pretreated with calcium chloride and bentonite. Waste effluent, ranging from 0.31 to 3.41 pct solids, pretreated with 10 lb per 1,000 gal each of calcium chloride and bentonite was successfully dewatered using 0.09 lb per 1,000 gal of PEO. The water quality was equivalent to the present thickener system, and the waste sludge was suitable for immediate disposal in a landfill.

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