LOW COST DEWATERING OF WASTE SLURRIES

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ABSTRACT

The U.S. Bureau of Mines has developed a technique for dewatering mineral waste slurries which utilizes polymer and a static screen. A variety of waste slurries from placer gold mines and crushed stone operations have been successfully treated using the system. Depending on the waste, a number of polymers have been used successfully with polymer costs ranging from $0.05 to $0.15 per 1,000 gal treated. The dewatering is accomplished using screens made from either ordinary window screen or wedge wire. The screens used are 8 ft wide and 8 ft long. The capacity of the screens varies from 3 to 7 gpm/ft². The water produced is acceptable for recycling to the plant or for discharge to the environment. For example, a fine grain dolomite waste slurry produced from a crushed stone operation was dewatered from a nominal 2.5 pct solids to greater than 50 pct solids using $0.10 to $0.15 worth of polymer per 1,000 gal of slurry. The resulting wastewater had a turbidity of less than 50 NTU and could be discharged or recycled. The paper describes field tests conducted using the polymer-screen dewatering system.

INTRODUCTION

In the processing of minerals to produce concentrates and products, often times a dilute slurry is generated that must be disposed of in some manner. The use of impoundments for waste disposal is common throughout the minerals industry. With the promulgation of new environmental regulations, the cost associated with using and maintaining impoundments for waste disposal is increasing dramatically. The Bureau of Mines has been conducting research to develop low cost dewatering techniques ([1-2]). The most recent research activities include effluents from placer mines and slurries generated in the production of crushed stone.

In placer mining, gold bearing gravels are treated in a washing plant to remove boulders, small rocks, sand, and fines while trapping the gold particles. This is usually accomplished by placing the gravel into a trommel or on vibrating screens where the gravel is sized from 0.5 to 1 inch. The undersized material is washed into a sluice box while the small rocks, sand, and fines flow off the end of the sluice box into a sump, where a majority of the rocks and sand settle out. The water containing the fines and some sand flows from the sump and into a pond system at the mine site. The settleable material drops out as the water moves sequentially through the system of ponds, leaving the fine grain silts and clays in suspension. This is commonly referred to as the non-settleable fraction of the gravel being treated. With time, more fines will settle resulting in a solution containing ultrafine or colloidal particles that will remain suspended indefinitely. Contamination of surface waters is possible if this turbid water is discharged. The extent of this problem depends on the character of the gravel being treated. For some gravels, very little colloidal particles will be formed, whereas, for others a significant amount can be generated.

The crushed stone industry produces a variety of sized stone for sale. The stone is mined, crushed, and sized ([3]). During the sizing operation, especially for the smaller fractions, the stone is washed to remove undesirable fines. This results in a fine grained slurry which must be impounded. Oftentimes, due to the location of the mine near municipalities, the land available for use as impoundments is limited requiring the impoundments to be emptied and the material transported to a location where it can be disposed. This often entails the use of equipment such as draglines to remove the material and trucks for transport of the consolidated material to the disposal site. The fine material is often thixotropic and causes difficulty in removal and transport ([4]). Impoundment design and maintenance and sediment disposal are regulated under a number of environmental and zoning regulations. The fines generated during the processing oftentimes contain certain fairly pure materials that are saleable if they can

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be dried, i.e., waste fines from a magnesium/calcium carbonate quarry is often of high purity and can be sold as fine grain carbonate.

This paper describes a technique for dewatering fine grained slurries. The technique produces a consolidated material that can be handled by conventional equipment. The technique involves flocculation of the solids in a slurry with the proper polymer and dewatering on a static screen.

FLOCCULANT SCREENING

Prior to field testing, samples of the slurry are obtained from the mine site and laboratory experiments conducted. A large number of commercially available polymers are screened to determine the optimal polymer for the particular waste slurry. The technique used to test the polymer is described in detail elsewhere (4). The criteria used to determine the best polymer include dosage requirements, cost of polymer, clarity of discharge water produced, and the percent solids of the dewatered material. For the field testing described in this paper, high molecular weight polyethylene oxide (PEO) was the polymer chosen for the placer effluent tests, and a high molecular weight anionic polyacrylamide was used for the slurry from a crushed stone operation.

FIELD TESTING

The placer site evaluated is located in Livengood, AK, and the crushed stone operation is in Birmingham, AL. At the Alaska site, the unit was designed to handle up to 1,000 gpm of placer effluent. The flow sheet for the operation is shown in Figure 1. A 6-in pump with a capacity of 1,100 gpm was used to deliver the waste slurry to the unit. The PEO pumps with variable speed drive systems and with capacities of 45 and 20 gpm, respectively, were used to inject the PEO solution in-line by using 2-in-diam pipe. Placer effluent was delivered to the system by 6-in pipes of various lengths. A Kenics[1] static mixer (2-10 elements) was used, when needed, to increase the

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

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turbulence in the pipe. The flocculated slurry was emptied into a trough at the top of the screens and overflowed onto the screens. The water passed through the screen into a trough and was allowed to flow by gravity into the secondary pond. The dewatered solids rolled down the screen and discharged into a pit. The screen was comprised of two sections, the top section was set up at an angle of 47° and the bottom section at an angle of 38°. A common aluminum window screen, 16 by 18 mesh, was used as the screening device for the flocculated solids.
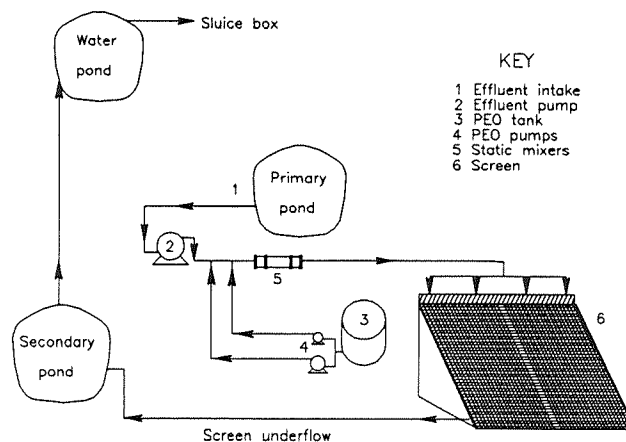

FIGURE 1.--Flow sheet for Alaska field test study.

For the crushed stone field test, a mobile unit was constructed and placed on a flat bed truck as shown in Figure 2. The equipment includes holding tanks for polymer solution, a mixing tank for preparing concentrated polymer solutions, a mixing tank for dilution of the polymer, and static dewatering screens 8- by 4-ft hinged together to form an 8- by 8-ft screen. The screens have horizontal openings that are 0.020 and 0.030 in wide, 2.75-in long. The screens can be replaced with other screens having horizontal openings of 0.010 or 0.040 in width. The waste slurry is pumped from the processing plant to the mixing trough above the screens. Polymer is added to this line. The polymer mixes with the waste and then enters the trough, and then overflows to the screen. The released water flows through the screen and is recycled back to the plant's water system. The solids roll off the bottom of the screen and are placed in a pit. Figure 3 shows the unit in operation at the crushed stone site.

RESULTS AND DISCUSSION

A variety of conditions were used at the Alaska field testing site. From previous research results it was known that obtaining the proper mixing of polymer and slurry was critical (5). To determine the best mixing conditions, a variety of different arrangements were tested. The PEO was injected into the feed line upstream of the dewatering screen. In-line mixing through 400 to 1,000 ft of pipe combined with a wide range of Kenics static mixers (2 to 10 elements) were tested. During initial testing on the primary pond, 600 ft of 6-in pipe and the 2-element static mixer produced best results. However, when the unit was transferred to the secondary pond, 600 ft of pipe alone produced good flocs. In both tests, treated water was recycled back to the secondary pond. The feed, which varied widely in solids content from 0.09 to 5.40 pct by weight and turbidity from 300 to 26,500 NTU, was dewatered using 0.01 pct PEO solution.
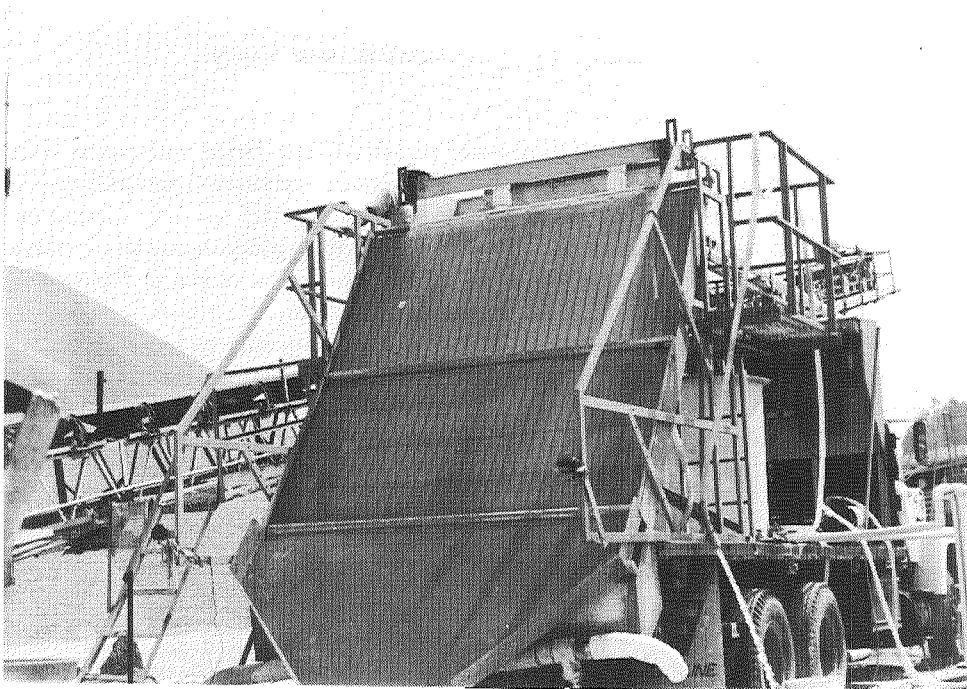

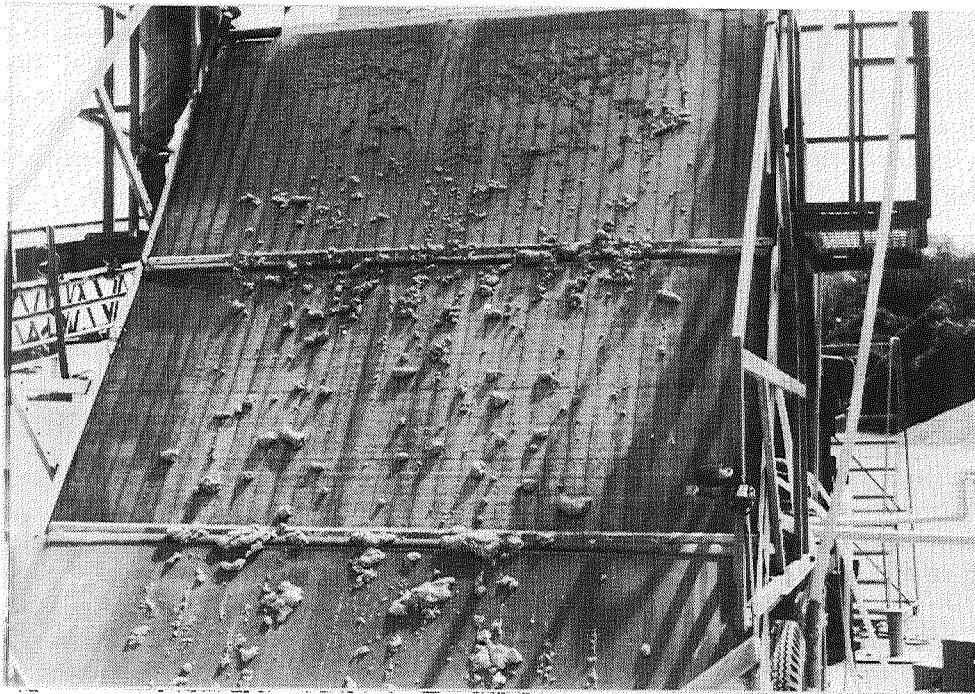FIGURE 2.--Mobile dewatering unit at stone quarry.

FIGURE 3.--Dewatering screen operating at stone quarry.

As shown in Table 1, the PEO dosage required to dewater placer effluent varied with initial solids and was calculated in pounds per 1,000 gallons of slurry treated. The PEO dosage increased from 0.02 to 0.19 lb/1,000 gal with an increase in initial solids. It was also found that the PEO dosage did not only depend on the initial percent solids but also depended on the Reynolds number (Re) which is directly proportional to the slurry flow rate. Therefore, Re is just a gauge of shear force requirement of a system. The results shown in Figure 4 indicate that when the Re increased from 50,000 to 130,000, the PEO dosage decreased from 0.15 to 0.04 lb/1,000 gal. Each point on Figure 4 represents an individual test and all the tests had a water quality of less than 50 NTU. Also, Table 1 shows that for higher initial solids in the 26,000 range the static mixer was a benefit, but at lower initial solids a static mixer was not needed. Finally, taking all the variables in consideration, it was found that a PEO dosage of 0.02-0.14 lb/1,000 gal was required to produce a dewatered product of 33 to 43 pct solids and screen underflow with turbidity of 20 to 50 NTU's, Table 1.

Table 1.--Results of the Alaska field dewatering test
on placer effluents using 0.01 pct PEO

| Mixer length, ft	Feed turbidity, NTU	Initial solids, pct	PEO dosage, lb/1,000 gal	Solids content, pct	Underflow, turbidity, NTU
600*	26,500	4.41	0.14	42.9	46
600	26,000	5.40	.19	40.5	45
600	14,000	2.42	.07	33.8	47
600	5,800	2.42	.06	42.2	33
600	5,400	.78	.05	42.5	31
600	5,200	.60	.03	20.1	40
600	2,000	.25	.02	35.6	32
600*	1,300	.52	.04	33.2	20
600	300	.09	.02	33.2	26
800*	15,000	2.68	.12	41.3	50
800	6,200	.68	.06	39.7	39

*Two element static mixer was used with pipe.
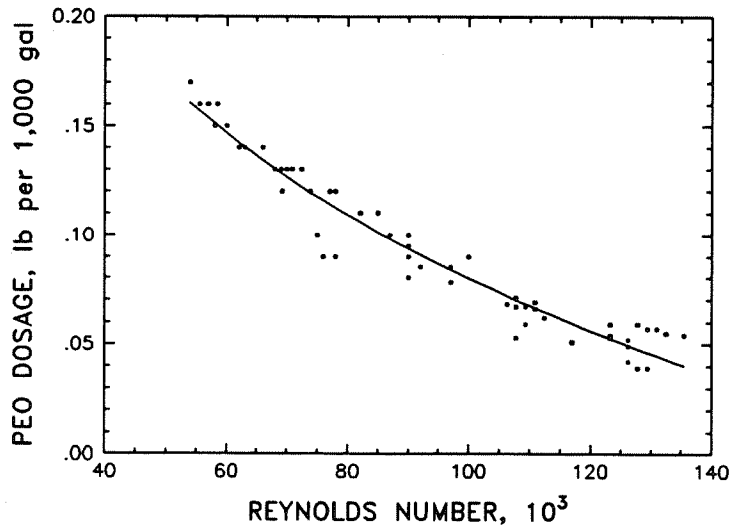
FIGURE 4.--Effect of Reynolds number on PEO dosage for the large field
test unit.

A cost estimate of the Bureau of Mines process for dewatering Alaskan placer effluent streams with PEO was determined and is reported in an open file report (6). The cost estimates are for dewatering plants processing 1,000 gpm of effluent slurry at three representative turbidity levels. Both the placer and dewatering plants operated on the same 1 shift-per-day, 6 days-per-week schedule for the 100-day Alaskan operating season. Estimated fixed

capital costs for these plants processing placer slurries with effluent turbidities of 1,000, 3,000, and 5,000 NTU are approximately $29,000, $31,000, and $34,000, respectively, on a fourth quarter 1986 basis (6). Operating costs are estimated to be $0.34, $0.37, and $0.40 per thousand gallons of effluent slurry including amortization, plan and chemical cost.

The field testing at the crushed stone operation was conducted using the mobile unit previously described. As part of the operation for the stone quarry, a sand screw is used to remove coarse particles from the waste slurry prior to impoundment. The feed for the unit was taken from the pipe going to the impoundment from the sand screw. A wide variety of parameters was investigated. Polymer concentration ranged from 0.02 to 0.10 pct, Reynolds number from 4,800 to 16,000, and retention time from 30 to 136 sec. It was determined that a polymer concentration of 0.04 pct gave the best results. It was also determined that the flow of solids down the screen using the polyacrylamide was quite different from the previous tests where PEO was used. The PEO flocs flowed easily off the screen whereas, the polyacrylamide flocs tended to abrade as they moved down the screen causing some blinding of the screen. The difference between the two polymers is that the PEO has inherent antifriction properties allowing the flocs to move down the screen without abrasion. To overcome this problem, it was determined that tapping the screen periodically reduced the blinding allowing the screen to function. In practice this can be accomplished with an automatic tapping device set on a timer. The major parameter that had to be optimized in the crushed stone slurry was the mixing requirement. For this system it was determined that a Re of 4,800 with a mixing retention time of 68 sec produced 50 pct solids at a polymer dosage of 0.30 lb/1,000 gal treated. The material continued to dewater after exiting the screen and reached solids contents as high as 70 pct in 24 to 48 h.

At the present time, the polymer used in the study on the slurry from the crushed stone operation costs approximately $0.50/lb when bought in bulk quantities. Therefore, the cost estimates for a crushed stone operation were estimated to be $0.15 to $0.25 per thousand gallons. The estimates are based on the operation where both a low cost anionic copolymer of acrylamide and a medium cost anionic polyacrylamide were used. Both polymers produced a dewatered product of 45-50 pct solids. The dewatered material has potential for use in a number of products, and any use would be a credit, this being the overall cost.

CONCLUSIONS

The field testing of two different waste slurries, one from a placer operation and the other from a crushed stone operation, has shown that the Bureau-developed polymer/static screen dewatering technique can be successfully used at low cost. To optimize the technique, the Re number and time of mixing in the feed pipe must be studied to obtain the optimum conditions.

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