

## DEWATERING OF RED MUD

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### Abstract

A solid-liquid separation technique devised by the Bureau of Mines, U.S. Department of the Interior, was applied to red mud, the caustic-containing residue generated when alumina is extracted from bauxite by the Bayer process. Red mud obtained from Jamaican bauxite was dewatered in laboratory batch tests and small-scale continuous tests to develop an inexpensive method of washing the mud and recovering the valuable sodium aluminate and caustic. A number of high-molecular-weight polymers were evaluated, and a high-anionic powder polymer used in combination with a high anionic, emulsion-type polymer proved to be most effective. In small-scale continuous tests using a baffled tube mixer to aid floc formation and a rotating trommel to dewater the solids, slurries with an initial concentration of 10 pct solids were dewatered to 27 pct solids using 0.20 kg of polymer per ton of dry solids. After the trommel treatment, the flocculated red mud was placed in a column fitted with a screen to allow released water to drain; after 15 days, the solids content increased over 40 pct.

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## Introduction

In the United States, alumina is extracted from bauxite via the Bayer process (1). In this process, foreign or domestic bauxite is treated with a highly concentrated sodium hydroxide solution to dissolve the aluminum oxide. Most of the aluminum oxide is dissolved, but quartz, iron oxides, and titanium oxides do not dissolve, and remain as a solid residue known as red mud (1). The red mud is washed by countercurrent decantation to recover the dissolved caustic. This wash process requires several thickeners. The waste mud is then pumped from the processing plant as a slurry containing about 20 pct solids and is impounded in mud ponds. Here, the mud is allowed to settle, and the caustic-containing water is recycled back to the plant for reuse. Approximately 10 million tons of mud wastes are generated annually in the United States (2).

From the standpoint of the effluent control, impoundment is not an ideal solution to the red mud disposal problem. Mud ponds require a large amount of land because the solids generally settle very slowly. Also, the dams of a mud pond must be maintained, and there is always the risk of a dam failure and spill of the caustic-containing mud into nearby streams. Moreover, the caustic content of the red mud represents a potential source of valuable material, which, if efficiently recovered, could reduce the overall cost of the process.

The Bureau of Mines has devised a novel solid-liquid separation technique for fine-particle slurries that allows for disposal of the solid wastes, reuse of water, and reclamation of mined land (3). The technique consists of flocculating the slurry with a polymer and dewatering the resulting agglomerate on a rotating screen.

## Description of Red Mud Sample

A sample of red mud was collected from the underflow of the last thickener at Kaiser Aluminum's Baton Rouge facility, which processes Jamaican bauxite. The slurry containing the dissolved alumina is treated with flocculants in a series of thickeners to aid in separating the product from the insoluble residue. The sample used in this study contained 0.26 g of insoluble solids per milliliter of slurry. The slurry also contained soluble salts, e.g., sodium aluminate. Evaporating the slurry to dryness indicates that the slurry contained 23.4 pct solids, including both soluble and insoluble constituents.

Qualitative X-ray diffraction analysis of the sample indicated that hematite,  $Fe_2O_3$ , is the major constituent. Table I (2) shows the complete results of the X-ray analysis.

Table I. Qualitative X-Ray Diffraction of Red Mud Sample

Mineral	Relative amount
Hematite.....	Major.
Goethite.....	Minor.
Gibbsite.....	Minor.
Boehmite.....	Trace.
Anatase.....	Trace.
Calcite.....	Trace-minor.
Perovskite.....	Trace-minor.

## Laboratory Batch Dewatering Tests

A standard procedure has been devised by the Bureau to investigate the effect of polymers on the flocculation of mineral wastes (4). The procedure consists of stirring a given amount of slurry vigorously with a magnetic stirrer and adding the polymer dropwise until the solids agglomerate and rotate as a coherent mass. However, the procedure had to be modified slightly for the red mud to account for the tendency of its flocs to break up when agitated. Gentle hand stirring was required.

### Test Procedure

The 23.4-pct-solids slurry was diluted to 10 pct solids to simulate the effect of repulping the slurry to obtain maximum recovery of the caustics. A 100-mL aliquot of the 10-pct-solids slurry was placed into a 250-mL beaker and an aqueous solution of flocculant was added dropwise from a buret. The slurry was stirred very slowly with a stir rod during addition of the polymer. Generally, upon addition of the polymer, there was immediate visual evidence of flocculation, but polymer was added until the flocs agglomerated and released water freely. After reaching the end point of the titration, the supernatant water was decanted until the agglomerated mass could be rolled around in the beaker. The flocculation dewatering sequence is shown in figure 1. The buret was read to determine the amount of polymer used for calculation of the dosage in kilograms per ton of dry solids, by the formula,

$$\text{Dosage, kg/ton} = \frac{\text{vol polymer, mL} \times \text{conc polymer, g/mL} \times 1,000 \text{ kg/ton}}{\text{vol red mud, mL} \times \text{conc red mud, wt pct} \times \frac{0.26 \text{ g/mL}}{23.4 \text{ wt pct}}} \quad (1)$$

### Screening of Polymers for Flocculation

Previous research indicates that polymers effective in dewatering red mud are characterized by medium- or high-anionic contents and molecular weights greater than 1 million (2). The polymers were prepared as 0.10-pct solutions in deionized water.

Of all polymers tested, Hercofloc 1021, a high anionic, 10-million molecular weight polyacrylamide powder was most effective in dewatering red mud. Red mud containing 10 pct solids was dewatered to 30.8 pct solids with 0.30-kg/ton Hercofloc 1021. The floc system, however, was very fragile and broke apart when agitated, indicating that it would not withstand mechanical handling on standard dewatering equipment. Also, the high cost of Hercofloc 1021, quoted March 27, 1985, at \$4.50/kg for quantities of 12,000 kg and over, make the technique economically prohibitive.

One method for improving the stability of the flocculated system and making it economically feasible would be to find an inexpensive polymer that produces tighter flocs to replace a portion of the Hercofloc 1021. This approach is generally referred to as synergistic flocculation (5).

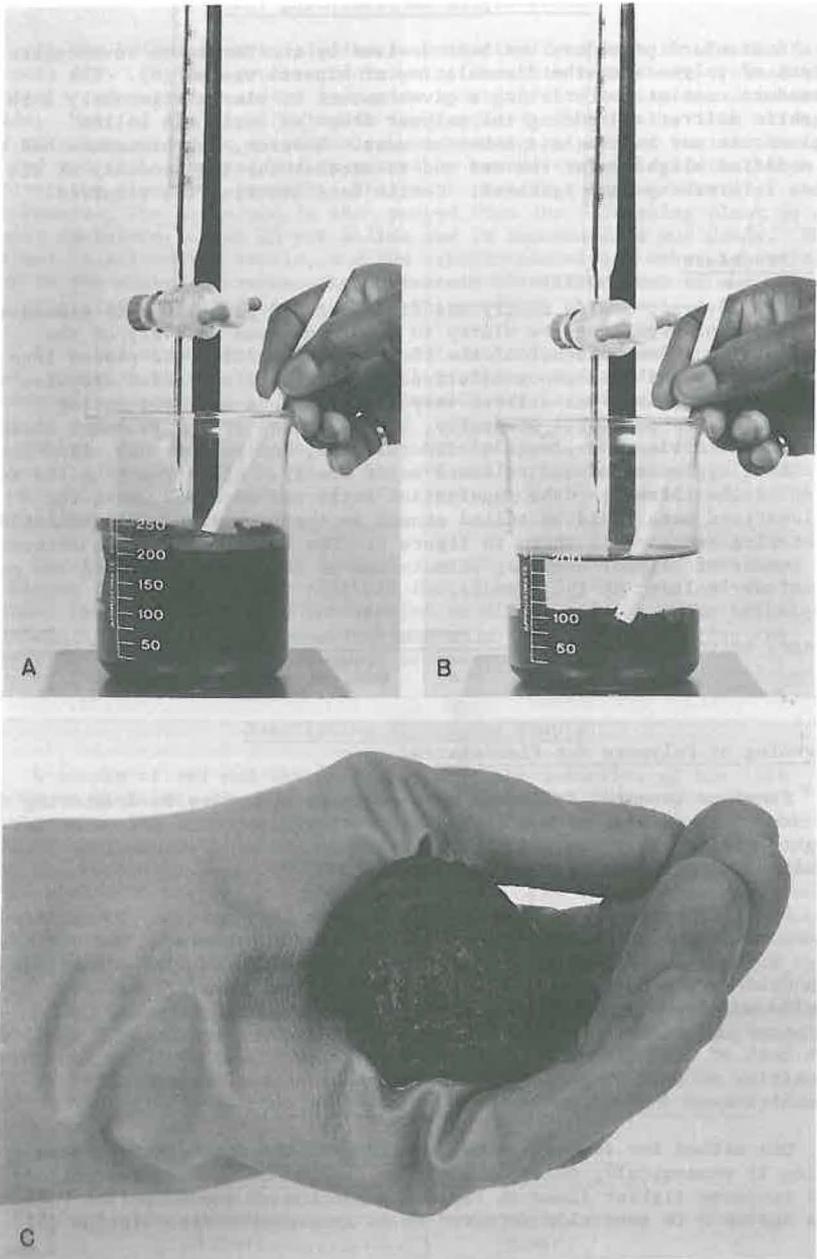


Figure 1 - Laboratory flocculation-dewatering of red mud.  
A, Flocculation during initial stages; B, flocculation during final stages; C, dewatered product.

Several polymers and reagents were investigated for possible synergistic effects with very little success. Experiments performed by Sato (6) to compare the efficiencies of powder and emulsion polymers proved that the emulsion polymer is superior to the powder polymer in respect to settling rate, slurry compression, turbidity of the supernatant water and tightness of flocs. Therefore, several emulsion polymers were investigated. Superfloc 1202, a high anionic, high molecular weight (in excess of 10 million) emulsion polymer produced very tight stable flocs, but lacked the cohesiveness required for the flocs to agglomerate to form a united mass when used alone. However, when used synergistically with Hercofloc 1021, a very stable floc system was formed which could be handled mechanically. Also, the price of Superfloc 1202, quoted on March 27, 1985, at \$1.44/kg, makes this synergistic dewatering technique economically attractive.

Synergistic Dewatering With Hercofloc 1021 and Superfloc 1202

Tests designed to reduce the amount of Hercofloc 1021 required to dewater red mud consisted of replacing percentages of the amount initially required for dewatering with equivalent amounts of Superfloc 1202. Dewatering tests were conducted on 100-mL samples of red mud in which the amount of Hercofloc 1021 and Superfloc 1202 were varied. The results of these tests are summarized in table II.

Table II. Effect of Hercofloc 1021-Superfloc 1202 Dosage Ratio on Dewatering

Flocculant dosage, kg/ton		Hercofloc 1021 dosage percent of polymer used	Solids content <sup>1</sup> of dewatered product, pct
Hercofloc 1021	Superfloc 1202		
0.30	0	100	30.8
.27	0.03	90	32.3
.24	.06	80	32.5
.21	.09	70	33.0
.18	.12	60	33.4
.15	.15	50	33.9
.12	.18	40	34.4
.09	.21	30	31.0
.06	.24	20	26.9
.03	.27	10	23.1
0	.30	0	22.7

<sup>1</sup>Initial solids content of 10 pct.

The data show that the solids content increased from 30.8 to 34.4 pct as the percentage of Hercofloc 1021 used was varied from 100 to 40 pct. The solids decreased from 34.4 to 22.7 pct as the percentage of Hercofloc 1021 was reduced from 40 to 0 pct. The results of these tests indicate that a polymer ratio of 4 parts Hercofloc 1021 and 6 parts Superfloc 1202 is required for maximum dewatering.

There is a significant economic advantage for the mixture over using Hercofloc 1021 alone. For example, a Hercofloc 1021 dosage reduction of 60 was obtained with 0.18 kg/ton of Superfloc 1202, while 0.30 kg/ton of Hercofloc 1021 was required alone. Superfloc 1202 sells for \$1.44/kg and Hercofloc 1021 for \$4.50/kg. When using this polymer mixture, the savings would be \$0.55/ton or 40.7 pct.

## Continuous Dewatering Tests

Small-scale continuous tests were conducted using the Bureau-devised trommel dewatering technique. Instead of the standard agitator-type mixer used in previous dewatering research, a baffled vessel with a rotating baffled stirrer was used to mix the flocculant with the red mud slurry.

The mixer vessel was constructed from a 30.5-cm acrylic tube with a diameter of 10.5 cm. Twenty-four baffles, 3 x 2.5 x 0.60 cm, were cemented inside the tube in four rows, as shown in figure 2. The bottom of the tube was sealed with an acrylic disk. The stirrer was a 2.5-cm-diam acrylic tube with four rows of six baffles, also measuring 3 x 2.5 x 0.60 cm. The baffles in each row were 4.5 cm apart. These baffles, however, were tilted at 45° angles to facilitate mixing of the flocculant with the red mud slurry.

The trommel, made of 304 stainless steel, was 15.2 cm in diameter, 68.6 cm long, and had 10-mesh openings. A catch basin was placed on the end of the trommel to collect the dewatered product.

### Test Procedure

The red mud slurry, diluted to 10 pct solids, was pumped into the mixer at a rate of 1,000 mL/min. Polymer solutions, consisting of 50-50, 40-60 and 30-70 pct combinations of Hercofloc 1021 and Superfloc 1202, which had given good results in laboratory tests, were used. The flocculant was prepared as a 0.10 pct solution in deionized water and pumped into the mixer using a peristaltic pump. The rotating baffled stirrer of the mixer assembly and the rotating trommel were driven by low-horsepower motors.

A sample of the dewatered material discharged from the trommel was weighed, dried, and weighed again to determine the solids content. Also, two 76.2-cm cylindrical columns with 10-mesh screens as bottoms were each filled to equal heights with discharge material from the trommel. The material in one of the columns was capped with 5.0 cm of sand. After allowing the material to drain for 360 h, the solids contents of each column was calculated to determine the effects of time, drainage and sand capping on consolidation.

### Experimental Results

Several tests were conducted using 50-50, 40-60 and 30-70 pct combinations of Hercofloc 1021 and Superfloc 1202. The dosage of added polymer was varied to determine the minimum amount required for successful dewatering. Dosages were calculated according to the formula,

$$\text{Dosage, kg/ton} = \frac{\text{vol polymer, mL/min} \times \text{conc polymer, g/mL} \times 1,000 \text{ kg/ton}}{\text{vol red mud, mL/min} \times \text{conc red mud, wt pct} \times \frac{0.26 \text{ g/mL}}{23.4 \text{ wt pct}}} \quad (2)$$

Tests were conducted at several trommel and mixer rotation rates and the mixer was operated at 30, 60, and 100 pct of mixer capacity.

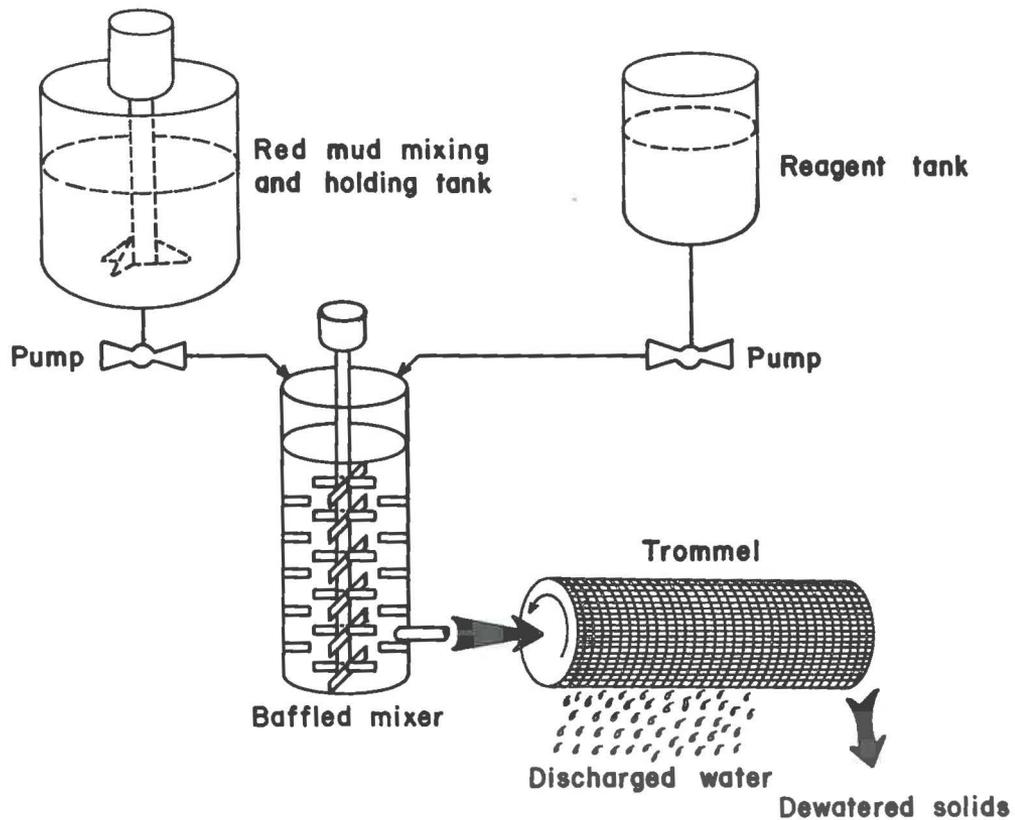


Figure 2 - Schematic of baffled mixer-trommel dewatering apparatus.

Table III. Effect of Hercofloc 1021-Superfloc 1202 Ratio on Dewatering  
(Trommel rotation rate, 6 r/min; mixer rotation rate, 24 r/min)

Test	Dosage, kg/ton	Solids content of dewatered product <sup>1</sup> , pct
50/50 PCT HERCOFLOC 1021-SUPERFLOC 1202 SOLUTION		
1	0.135	NAP <sup>2</sup>
2	.170	25.9
3	.200	26.4
4	.250	26.9
40/60 PCT HERCOFLOC 1021-SUPERFLOC 1202 SOLUTION		
5	0.135	24.9
6	.170	27.2
7	.200	29.5
8	.250	30.1
30/70 PCT HERCOFLOC 1021-SUPERFLOC 1202 SOLUTION		
9	0.135	NAP <sup>2</sup>
10	.170	24.7
11	.200	25.9
12	.250	26.2

NAP Not applicable.

<sup>1</sup>Initial solids content of 10 pct.

<sup>2</sup>No dewatering occurred; the flocs formed were very small and passed through the trommel screen.

Results of tests to determine the effect of Hercofloc 1021-Superfloc 1202 dosage ratio on dewatering (table III) indicated that maximum dewatering was achieved with the 40-60 polymer ratio. The lowest dosage that produced a dewatered product was 0.135 kg/ton. The product contained 24.9 pct solids, but appeared very soft and unstable at this dosage. Below 0.135 kg/ton the flocs were very weak and blinded the trommel screen to the extent that very little dewatering occurred.

The effects of mixer and trommel rotation rates on dewatering were also determined. The results of these tests, shown in tables IV and V, indicate that the optimum mixer and trommel rotation rates were 24 and 6 r/min, respectively. Tests conducted to determine the effect of the operating capacity of the mixer on dewatering showed that the best results were obtained when the mixer was run at 60 pct of capacity.

Results of column drainage tests to determine the effect of time, drainage, and sand capping on further consolidation of dewatered red mud indicated that the red mud continues to dewater with time and that sand capping enhances consolidation. After 360 h of draining time, red mud containing 27.2 pct solids was dewatered to 40.4 pct; the sand-capped material dewatered from 27.2 to 44 pct solids.

Table IV. Effect of Mixer Rotation Rate on Dewatering  
 (Hercofloc 1021 dosage of 0.80 kg/ton;  
 Superfloc 1202 dosage of 1.20 kg/ton;  
 Trommel rotation rate of 6 r/min)

Mixer rotation rate, r/min	Solids content of dewatered product <sup>1</sup> , pct	Solids content of trommel underflow, pct
18	27.3	1.21
22	27.4	.89
24	28.5	.86
30	27.5	1.11
40	NAP	NAP

NAP Not applicable.

<sup>1</sup>Initial solids content of 10 pct.

Table V. Effect of Trommel Rotation Rate on Dewatering  
 (Hercofloc 1021 dosage of 0.80 kg/ton;  
 Superfloc 1202 dosage of 1.20 kg/ton)

Trommel rotation rate, r/min	Solids content of dewatered product <sup>1</sup> , pct	Solids content of trommel underflow, pct
4	29.5	0.69
5	29.3	.74
6	28.5	.86
8	26.3	1.21
10	25.0	1.55
12	24.3	2.00

<sup>1</sup>Initial solids content of 10 pct.

<sup>2</sup>Solids overflowed entry port; rotation too slow.

The increase in percent solids for the experiment where a sand cap was used indicated that the application of pressure to the trommel discharge is beneficial since a higher solids content was achieved. To further investigate the use of pressure, samples were sent to a belt press manufacturer for laboratory evaluation for comparison. Kaiser submitted the underflow from the last thickener which was 20 pct solids and the Bureau submitted 27 pct solids material dewatered in the trommel. Results showed that the dewatered material reached 53 pct solids in the belt press, but the discharge from the thickener produced 43 pct solids. This indicates that trommel-treated material will reach a higher terminal density than would untreated material. Similar results had previously been observed for phosphatic clay waste (7).

#### Conclusions

Red mud slurry was flocculated with a polymer mixture containing 40 pct Hercofloc 1021 and 60 pct Superfloc 1202 and subsequently dewatered on a rotary trommel. Tests showed that the Hercofloc 1021-Superfloc 1202 mixture yielded products with higher percent solids than those obtained with Hercofloc 1021 and Superfloc 1202 when used separately. The

comparatively low cost of Superfloc 1202 makes the scheme economically attractive. Flocculation of the slurry to form strong flocs required very gentle mixing, which was achieved in a baffled mixer. Red mud containing 10 pct solids was dewatered to 27.2 pct solids using 0.20 kg of flocculant per ton of feed solids in small-scale continuous tests. After the trommel dewatering, the red mud continued to dewater to 40 pct solids (44 pct solids with sand capping) within 360 h.

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