At every discharge point, coal mine drainage is a special case needing special treatment.

Clean Water From Coal Mines

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Through a progressive laboratory and pilot-plant program, Jones & Laughlin Steel Corp. has analyzed and corrected mine drainage pollution problems at all of its coal mines. In conducting this program, the company found no "typical" drainage discharge. Each discharge point at each mine was unique, so that varied approaches were needed to eliminate stream pollution. To illustrate the variety of these approaches, the treatment of drainage from four discharge points at three mines in Pennsylvania will be considered here. The flows and critical analyses of the drainage sources and treated effluents are shown in Table I.

Hydrated Lime Works at Thompson Borehole

The discharge stream from the Thompson borehole at the Vesta No. 5 mine flowed into a small branch creek where it created a "yellowboy" deposit and affected aquatic life. Investigation indicated that hydrated lime would neutralize the acid and precipitate ferric iron without aeration. Treatment of the 150,000-gpd flow, however, created about 4000 gpd of wet sludge for which there was no nearby accumulation site. With State approval, this sludge was deposited through an unused borehole into an abandoned section of the Vesta No. 6 mine several miles away.

Since the flow from Vesta No. 5 is variable, drainage is pumped to a 750,000-gal holding basin to assure a steady flow of fairly constant composition to the neutralization unit (Fig. 1). Flow from the holding lagoon through the system is by gravity. Feed to the neutralization unit, manually set at about 110 gpm, is introduced to a mixing tank. Here a lime slurry is added from the lime mixer at a controlled rate. The mixed acid water and lime slurry pass through a baffled tank to an overflow pipe. A pH electrode in this pipe controls the rate of flow from the lime mixer, maintaining the discharge at pH 8. The pH control has a high and low limit switch controlling an air-operated valve in the feed line. This stops plant operation if the pH goes out of control, thus preventing untreated drainage from reaching the lagoon.

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From the overflow pipe, the treated drainage enters the 90,000-gal settling lagoon, where the sludge settles out. The clean overflow, alkaline and essentially free of iron, flows to the receiving stream. The settled sludge, at 4-5% solids by weight, is periodically pumped into trucks and hauled to Vesta No. 6.

When alkaline water formerly pumped at another borehole was diverted underground to the Thompson borehole, flow increased from 150,000 to about 360,000 gpd, while pH increased about 2 points and iron content decreased 50%. Table II shows analyses of feed and overflow before and after this diversion. The quality of the treated effluent was unchanged.

Table III shows a typical analysis of the sludge. Although the control analyses are only for acidity and iron content, there are many other elements resulting from the variety of material and the reactions taking place. The expanded operation consumes about 400 lb of lime a day, producing 5500 gal of sludge at about 5% solids. The plant has operated successfully for over four years. In the receiving stream, the yellow deposits have disappeared and aquatic life is back right up to the discharge point.

Aeration Does the Trick At Bercik Borehole

At the Vesta No. 4 mine, the Bercik borehole discharges about 1000 gpm. The water is clear and alkaline but its iron content is high. Thus, as the drainage underwent aeration, the soluble ferrous iron was oxidized to insoluble ferric iron with the precipitation of yellowboy for some distance downstream. What the drainage needed here was adequate contact with air and sufficient time for oxidation and precipitation before it entered the stream. Neutralization was unnecessary.

The remote location of the borehole precluded an installation requiring much maintenance, but allowed for a system of three lagoons in series. With volumes of 240,000, 140,000 and 660,000 cu ft, these lagoons provide a total holding time of five days. A simple baffled aerator starts aeration at the borehole discharge. It is anticipated that 800,000 cu ft of sludge will be produced over the ten-year life of the property, so that at the end, holding time will be one day—still enough for full oxidation and settling.

Shannopin No. 1 Air Shaft Borehole Is No. 1 Problem

With a discharge of 1,000,000 gpd that is highly acid and high in dissolved iron content, the No. 1 air shaft borehole at the Shannopin mine has been J&L's most serious drainage problem. The extremely high ferrous iron content necessitated aeration to form a stable ferric iron precipitate. Moreover, aeration had to follow neutralization because the iron did not oxidize readily in the acid medium. The lack of nearby underground storage space for the immense anticipated sludge volume of 40,000 gpd made permanent lagoon storage appear most feasible.

The treatment flow scheme selected was relatively simple. The mine drainage is pumped to a holding basin from which it flows by gravity to a neutralizing tank, where it mixes with milk of lime made by slaking quicklime with water in a separate slaker unit. Initially, a tank and surface aerator were used for aeration, but it was then found that the neutralized water was sufficiently aerated in flowing through an open trough and down the bank to the settling lagoons. The two lagoons, in which minimum settling time is 24 hr, are used alternately—the unused one being drained of clear water so the sludge can dry and compact.

The borehole is located in a narrow valley, and hence a massive earthmoving job was required to make room for the settling lagoons. Two 8-in. pipelines 2600 ft long convey the drainage to the 1.5-million-gal holding lagoon. For permanent impoundment of the sludge, over 10 million cu ft of settling lagoon were needed. One lagoon in an open cut from a strip mine is 1000 x 80 ft x 50 ft deep. The second, formed by a natural slope and dikes, is 600 x 800 ft with a 0-60-ft depth that averages 20 ft.

Manual rather than automatic pH control is used because the long holding time in the holding basin provides a more uniform water composition to the unit. An automatic system was unsuccessful because of excessive gypsum deposits on the probes.

Table I. Characteristics of Mine Drainage

Source	Flow (gpd)	Untreated pH	Untreated Fe (mg per l)	Treated pH	Treated Fe (mg per l)
Thompson	360,000	6.7	60.0	7.8	5.0
Bercik	1,500,000	7.3	29.0	7.7	3.5
No. 1 Air Shaft	1,000,000	2.9	340.0	7.5	1.0
No. 3 Air Shaft	100,000	7.4	3.6	—	—

Table II. Thompson Shaft Borehole Treatment Efficiency

	1966-67 Feed	1966-67 Effluent	1968-70 Feed	1968-70 Effluent
pH	4.5	8.0	6.7	7.8
Fe (mg per l)	130	5	60	5
Flow (gpd)	150,000		360,000	

Table III. Thompson Shaft Borehole Sludge Analysis

		Percent
Calcium Sulfate	$CaSO_4$	40
Magnesium Sulfate	$MgSO_4$	5
Free Lime	CaO	3
Magnesia	MgO	1
Ferric Oxide	Fe_2O_3	15
Manganese Oxide	Mn_2O_3	4
Silica	SiO_2	20
Aluminum Oxide	Al_2O_3	12

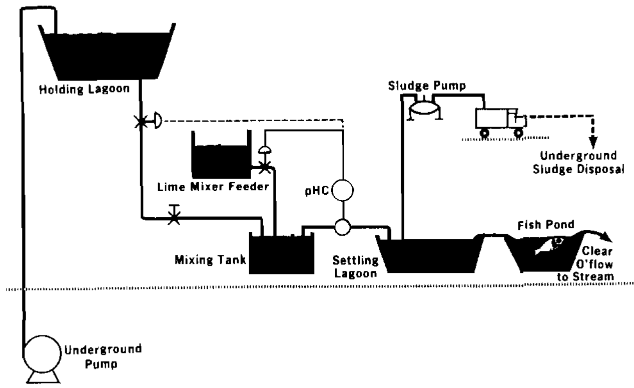

Fig. 1—After being pumped to a 750,000-gal holding lagoon, acid mine drainage from the Thompson borehole flows through its treatment cycle by gravity. The 150,000-gpd flow creates 4000 gal of sludge a day.

Gypsum deposition has been the source of several operating problems. Transfer pipes and pumps became clogged with solid deposits. This problem has been solved by mounting the pump on a raft so that it can be lifted from the water and drained when not in use. Vertical lifts are pumped through flexible hose which can be cleared by rapping, and gravity flows are conducted through open flumes which can be shoveled out.

Shannopin No. 3 Was Right From the Start

At the Shannopin No. 3 air shaft borehole, pollution was prevented from the outset. More recently installed than the other boreholes, No. 3 was located in a new section of the mine where the following drainage practices recommended by S. A. Braley of the Mellon Institute are closely followed:

(1) Where practical, water is diverted to prevent its entry into or reduce its flow through workings.

(2) In working areas, sumps are dug in low spots and kept pumped out to keep water from the acid-forming pyritic material on the face. Numerous pick-ups are employed for each pump.

(3) Where possible, pipes instead of ditches conduct water by gravity. This keeps exposure to acid-forming material on the mine floor to a minimum.

(4) Gathering sumps are provided in the mine by driving separate sump entries or by digging up the bottom. These keep water from accumulating in the local low gob areas with large acid-producing surface areas exposed and also provide reservoir capacity to prevent surges of mine water from entering a stream.

(5) Discharges into the stream are regulated to equalize daily accumulation throughout a 24-hr period insofar as practical.

All Systems Are Working Well

By progressively analyzing the problems and developing corrective measures suited to each drainage, J&L's Coal Mine Division has succeeded in bringing all of its discharges into compliance with the requirements of the Pennsylvania Sanitary Water Board. Surveillance of these discharges is continually maintained both to assure correct operation of existing facilities and to detect changes which may dictate the development of modifications as mining progresses. ME