ACID MINE DRAINAGE

U.S. BUREAU OF MINES RESEARCHES AND DEVELOPS CONTROL METHODS FOR BOTH COAL AND METAL MINES

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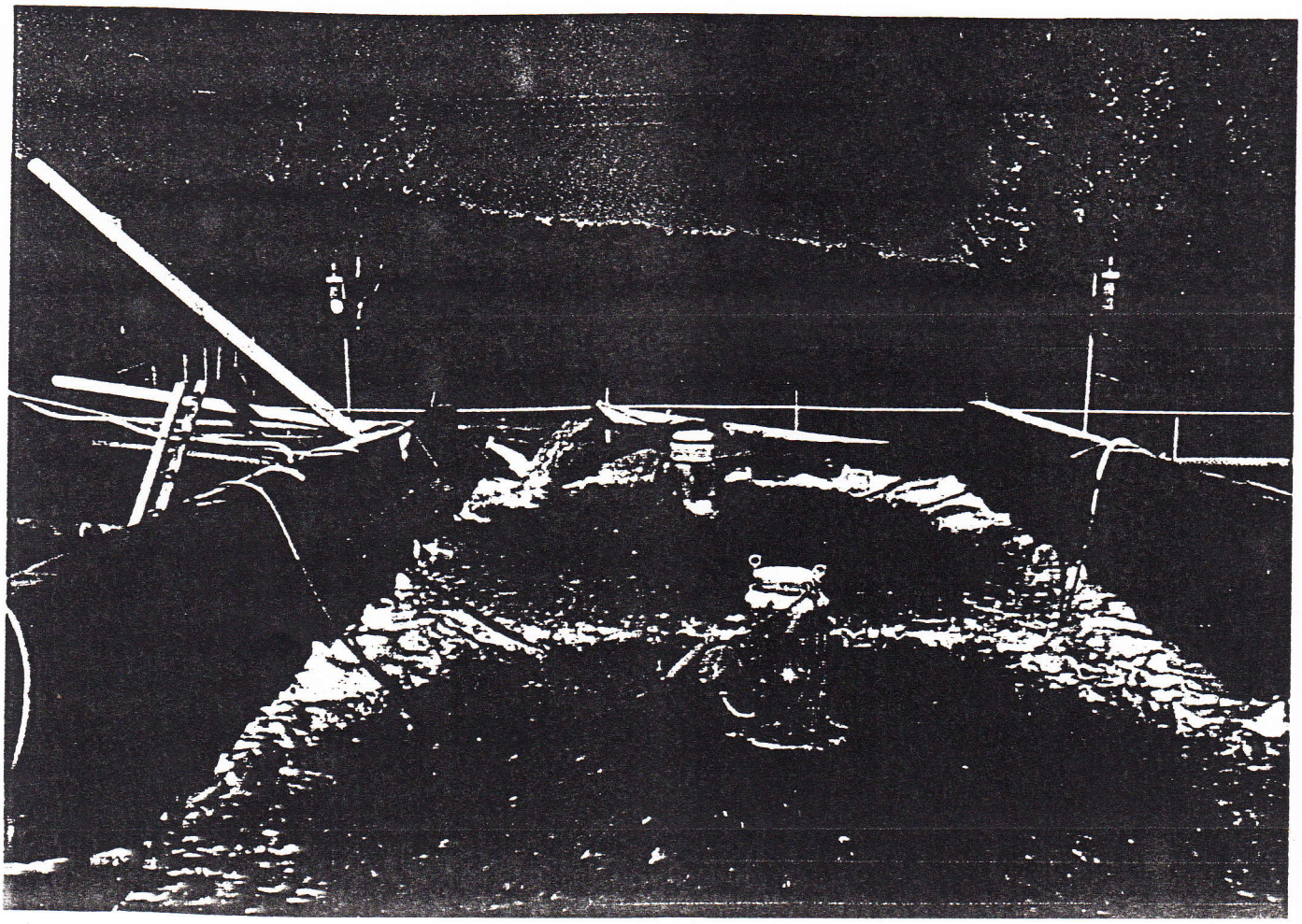
The U.S. mining industry spends over $1 million every day to treat acidic mine water. This water-treatment liability typically continues long after mining has ceased: acidic drainage continues to be a problem at many mines that have been inactive for over a century. Based on information recently provided by the states, the Bureau of Mines estimates that abandoned coal and metal mines and the associated piles of mine waste adversely affect over 12,000 mi of rivers and streams and over 180,000 acres of lakes and reservoirs in the United States. At least a third of these totals is directly attributable to acid mine drainage. The contamination associated with these abandoned mines is more than just a warning of potential future costs. As an environmental problem, the abandoned mines are a blemish on the industry's image and an impediment to future mining ventures.

The Bureau of Mines has therefore targeted the problem of acid mine drainage (AMD), aiming to both reduce the costs and future liability of water treatment for active operators and to develop ways to mitigate the AMD associated with abandoned mines. Low-cost alternatives to conventional water treatment, techniques to control the acid drainage at its source, and the problem of pre-mining prediction of AMD have been, and are continuing to be, addressed. During the past 10 years we have made several accomplishments, and we intend to continue our current work.

TREATMENT OF AMD

At most active mines where AMD is a problem, the water is pumped to a central location to be mixed with an alkaline chemical, such as lime or sodium hydroxide, and mechanically aerated in large basins (Fig. 1). Sufficient alkalinity is added to raise the pH to between 9 and 11, which causes most metals to hydrolyze and precipitate as a sludge. Some metals, such as iron, must be oxidized to be precipitated as a stable compound, which is why aeration is required. The resultant sludge-water mixture then flows to a clarifier



or a series of settling ponds. The process, though simple, is inefficient and expensive.

Research has produced two low-cost alternatives to conventional neutralization. The first, the In-Line Aeration and Neutralization System (ILS) is a pipeline version of a conventional water-treatment system (Fig. 2). It utilizes a jet pump or eductor, to entrain the air and alkaline chemical by Venturi action, and a static mixer. The ILS has no moving parts and operates by water pressure generated by the existing mine-water pumps. It is, at the same time, more efficient than conventional treatment systems and less expensive to install, operate, and maintain (Fig. 3).

Tests with acidic coal-mine drainage indicate that the increased efficiency is due to better aeration. In a conventional system, high pH is often used to compensate for inadequate replenishment of dissolved oxygen. The ILS homogeneously mixes and aerates all the AMD; as a result, the pH does not have to be raised as much. Also, as much as one-third of the lime used in a conventional treatment plant is wasted due to inefficient mixing, which does not occur with the ILS. For this reason, the ILS should also be applicable to metal-mine drainage; field tests to verify metal-mine applications are scheduled for this year.

The other inexpensive alternative to conventional water treatment is biological treatment. During the last few years, over 300 small wetlands have been constructed on mined land for the primary purpose of water treatment. In general, they consist of a series of shallow ponds planted with cattails (*Typha*) (Fig. 4). If the pH of the influent water is in the range of 3 to 5, some 6 in. of coarse limestone is recommended for the base of the system. Above that layer, 12 to 18 in. of composted organic material is emplaced as a substrate for the plants. To insure good contact between the contaminated water and the biologically active zone, a water depth of less than 6 in. is desirable; shallow water also discourages muskrats from moving in and decimating the new cattail growth.

The principal treatment process in most of the wetland system is bacterial oxidation of iron and, to a lesser extent, manganese. For this reason, most wetlands have been constructed at coal mines rather than metal mines. Metal uptake by plants, algae, and even the substrate contributes somewhat to, but is limited by, the amount of biomass. Some neutralization also occurs due to sulphate reduction and the gradual dissolution of limestone. It should be noted that at most sites, the con-

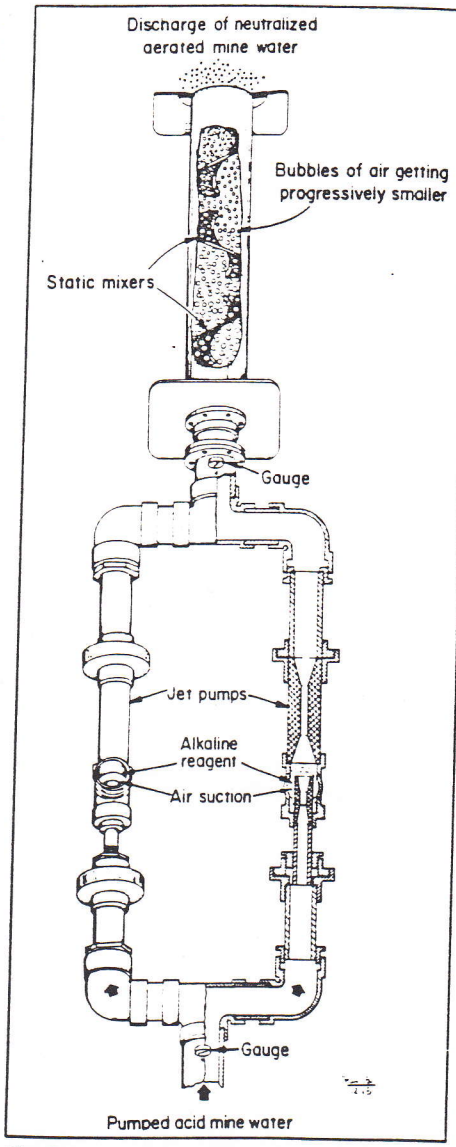


Fig. 2 A schematic of the In-Line System (ILS) used to aerate and neutralize Acid Mine Drainage.

structed wetlands are not by themselves sufficiently effective to meet effluent limitations. A final chemical treatment step is often required. In spite this fact, most operators have found that the wetland systems efficiently reduce chemical treatment costs to repay the cost of their construction in a year or less. The wetlands are also applicable to abandoned mine lands where even partial treatment is preferable to no treatment.

Currently, Bureau of Mines scientists are focusing on optimizing the activity of sulphate-reducing bacteria that thrive in the wetlands' anaerobic zones. Not only does the activity of these bacteria consume acidity, but the hydrogen sulphide produced reacts with most heavy metals to yield virtually insoluble precipitates. This would greatly increase water-treatment efficiency, avoid the problems of sludge accumulation associated with the oxidation and hydrolysis reactions, and extend the applicability of biological treatment to metal mines. It should also be noted that sulphate-reducing systems, when perfected, may not require a wetlands system. Within a few years, we hope to have developed septic systems that will function in abandoned pits or even abandoned underground entries, requiring only periodic addition of organic materials to fuel the sulphate-reducing reactions.

The generally accepted method of curtailing AMD at its source of generation is to inundate the pyritic material, thereby virtually eliminating pyrite oxidation. This has proven to be successful if inundation is complete. It

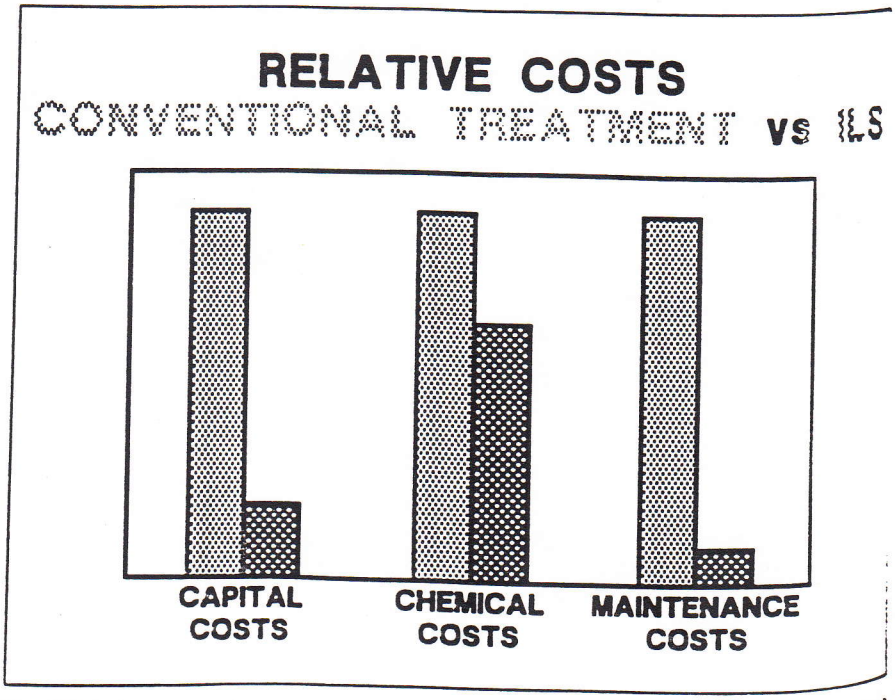


Fig. 3 Relative costs of conventional treatment with a mechanical aerator and the In-Line Aeration and Neutralization System.

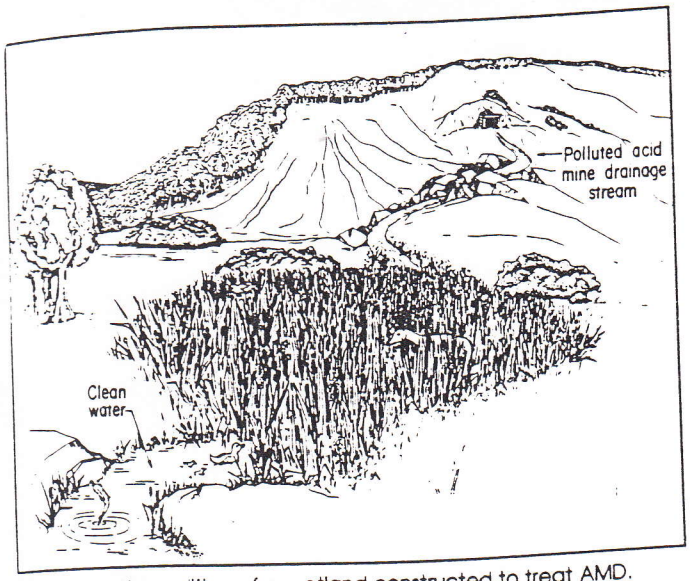


Fig. 4 Artist's rendition of a wetland constructed to treat AMD.

complete inundation, usually caused by the dip of the mined seam or vein, or gradient fluctuations, simply moves the active oxidation zone to a higher elevation in the mine or spoil without reducing acid formation.

An alternative approach developed by Bureau researchers several years ago involves the inhibition of the iron-oxidizing bacteria responsible for the rapidity of pyrite oxidation. Anionic surfactants (common cleansing detergents) can be used to decrease the activity of these bacteria and thereby retard pyrite oxidation. This approach is most applicable to coal refuse piles and isolated zones of fresh pyritic material at surface mines, where acid production has been reduced 60% to 95%. Laboratory tests with metal-mine waste indicate great variability in the significance of the iron-oxidizing bacteria in acid generation; small-scale tests should therefore be conducted before field trials are considered.

The surfactant can be sprayed on (three times a year) or applied in controlled-release formulations that inhibit pyrite oxidation for 5 to 10 years. Both approaches are now commercially available. Research is continuing on possible ways to extend this technology for use underground.

Other approaches to at-source control utilize chemical additions to provide neutralization in place and to retard pyrite oxidation by armoring or precipitating reactants. Typically, an alkaline compound is used; one problem is that the volume of acidic water represents a large acid-load that must all be neutralized. Alkaline injection has generally proven inapplicable for surface mines, due to the relatively short-lived residence time and heterogeneous flow, but Bureau researchers are now considering its applicability for underground mines, where large pools of acid water could be periodically neutralized. Alternatively, at surface mines, surface application of alkalinity can be effective at sites where acid-formation rates are modest. Also, university researchers at West Virginia and Montana State are evaluating the economics of using phosphate rock to form iron phosphates, thereby curtailing pyrite oxidation.

Reducing pyrite-water contact can also reduce the volume of AMD that forms. One recent development reduces the volume of water that leaks into underground mines from streams by 90% or more. Leaking zones are pinpointed using terrain conductivity (a simple and rapid geophysical technique) and verified by conventional gauging methods. The fractured stream bed is then mended using a polyurethane grout injected beneath the sediment-water interface. The cost per linear foot is as low as half that of conventional [illegible] to the savings realized by specifi-

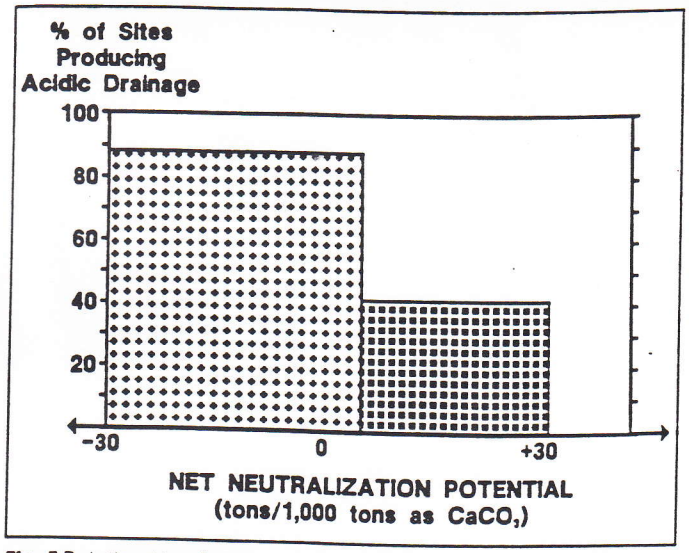


Fig. 5 Relationship of water quality at reclaimed coal mines to the net neutralization potential of overburden. Non-acid drainage could only be confidently predicted if the net neutralization potential exceeded 30 mt/1,000 mt.

are also superior, since the grout-sealed stream bed is not subject to damage by storms or tree growth. Tests in streams above active longwall operations and an old, abandoned, room-and-pillar mine have been extremely successful.

Considering the large potential liability associated with AMD, accurate pre-mining prediction of water quality during and after mining is desirable, even when it is not legally mandated. Unfortunately, recent research by the Bureau of Mines, West Virginia University, and Environment Canada indicates that techniques currently used for predictive purposes at surface mines are not as accurate as one would wish. Generally, for metal mines, predictions are qualitatively accurate most of the time. In other words, if lab tests predicted alkaline drainage, acid water was only occasionally an unpleasant surprise (and vice versa). The degree of water contamination cannot be predicted accurately.

At coal mines, the predictions are even less useful. Conventionally, a potential acidity (pyrite) and alkalinity (carbonates) in core samples are compared; up to 5 mt/1,000 mt of net neutralization potential (as $CaCO_3$) has been adopted from revegetation studies for use as a predictive boundary between acidic and alkaline mine-water generation. Recent research indicates that any negative net neutralization potential probably implies acid mine drainage.

Of even greater concern is the finding that overburden in the range of 5 to 30 mt/1,000 mt net neutralization potential frequently yielded acidic water after reclamation (Fig. 5). A recent analysis of permit applications in one northeastern U.S. regulatory office indicates that most of the permit applications submitted in that region had acid/base accounts in that range. In addition, conventional leaching tests did not appear to improve predictive capability.

Bureau researchers are now attempting to improve pre-mining predictive capability, looking both at new methods of overburden analysis and how site- and mining-related aspects can be factored into the predictive process. Laboratory tests are also underway to determine how best to evaluate the potential risk of contaminant release from metal-mine wastes. In addition, basic research is being conducted on mine hydrology and on the electrochemistry and surface chemistry aspects of pyrite oxidation reactions. Subsequent work should address the prediction problems of underground mines.

The last decade has seen a great increase in our knowledge, and the development of new techniques are already having an impact on AMD problems at active and aban-

doned mines. Mitigation technology that has proven to be effective on coal mines is now being adapted and tested for applicability to metal-mine drainage. AMD is not a problem that can be answered with a single solution but one that requires a multitude of options. It is hoped that the achievements of the last 10 years are only a prelude to future developments.■

The following reports can be obtained from the BuMines Publication office, P.O. Box 18070, Pittsburgh, PA 15236, USA. Copies of other papers addressing specific topics can be requested from the author at the same address.

1. Mine Drainage and Surface Mine Reclamation Vol.1: Mine Water and Mine Waste. BuMines IC 9083, 1988.
2. Control of Acid Drainage from Coal Refuse Using Anionic Surfactants. BuMines RI 8847, 1983.
3. Control of Acid Mine Drainage. BuMines IC 902 , 1985.

Reserve Mining to reopen, says Cyprus Minerals

Cyprus Minerals Co., in its first venture into iron ore mining, has acquired Reserve Mining of Minnesota for $52 million in a sale approved June 12 by a U.S. bankruptcy court judge in New York City.

Judge Barton Lifland accepted the Cyprus offer even though it actually was slightly less that the $53 million bid of Cleveland-Cliffs. Cyprus won out mainly because it agreed to pay real-estate taxes and closing costs, explained Bruce Scherling, the court-appointed trustee. Those costs are expected to be considerable, though court officials would not provide E&MJ an estimate of their amount. Scherling said the sale would produce a return acceptable to both the court and Reserve's creditors.

Although the closing was not expected until mid-August, Cyprus was granted permission by the court to enter Reserve's northern Minnesota property and refit immediately.

Cyprus already has sent letters to more than 1,100 former Reserve employees, notifying them of the impending ownership change. Cyprus, which also is handing out job applications in Minnesota, plans to hire 50 to 75 people as soon as the sale is closed. By early next year, it should have about 200 people on the payroll. Because Cyprus lacks expertise in iron ore mining, it expects to hire a number of former Reserve employees to take advantage of their experience and knowledge.

Cyprus' production next year is projected to reach 2 million lt of iron ore pellets. The company has set a target of 4 million lt in 1993, when a work force of 400 employees will be needed.

A Cyprus spokesman termed the sale a "strategic diversification into an area we think we can do well at." Another company official added, "We've bought it, now we're trying to figure out how to run it."

Cyprus already has made a sizeable investment in the property. Hoping to reopen the pit by early spring, the company spent about $24,000/d over a 4-mo period on a winterizing effort. Cyprus heated the mine's primary crusher throughout the winter to prevent ice from forming inside the unit and seriously damaging critical components. Cyprus began pumping water from the Peter Mitchell pit last November under a cost-sharing agreement with Reserve's bond holders and the state of Minnesota.

Iron ore production in 1988 increased from 1.01 billion lt to 1.28 billion lt in Minnesota, which long has been the U.S iron ore leader. Kathy Lewis, mineral leasing supervisor for the Minnesota Department of Natural Resources, said most of the state's iron ore producers are planning even higher production levels for this year.■