

ADVANCES IN THE PREDICTION AND CONTROL OF ACID MINE DRAINAGE ¹

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ABSTRACT. Over the past five years a research team at West Virginia University has developed a mathematical model: the SSPE/PSM which appears to yield significant improvement over current methods of predicting the production of acidity from pyritic coal spoils. The team has also developed a technology which, at the laboratory and small scale field level controls the formation of acid mine drainage (AMD). Another technology may significantly reduce the cost and upgrade the performance of AMD water treatment systems. The objective of these projects is to move laboratory technologies to the field test stage and to identify whether they have the potential for development into practical, effective systems for the coal industry.

This paper discusses the status of these technologies and the strategy being used to test them and, if proven practical, to bring them to application.

Additional key words: Acid mine drainage, phosphate, prediction model.

Introduction

Acid mine drainage (AMD) is the most significant environmental impact resulting from both surface and underground mining in the northern appalachian coal basin. AMD ruins fisheries and recreational lakes, damages structures, increases the cost of municipal water treatment, degrades the value of lands for the citizens of the state and lowers its potential for tourism.

Current AMD control technologies are expensive and they require an indefinite period of maintenance. On active mining sites costs are borne by the company. On abandoned mine lands the polluted water generally flows directly into adjacent streams. Some appalachian coal reserves are simply too prone to AMD production to consider mining. Companies are reluctant to assume indefinite liabilities associated

with development of the coal fields and governments are reluctant to approve permit applications which are likely to result in bond forfeiture. Such reserves are effectively sterilized until successful AMD control technologies are developed and implemented.

AMD results from the weathering of pyrites in mine spoil and refuse. Weathering results in production of acid forming salts which, over time, combine with water to yield AMD. Current AMD treatment technology for active mine sites involves the continual addition of alkaline materials such as hydrated lime, lye or ammonia to drainage waters in an effort to neutralize their acidity. This current technology allows the acid forming process to run its course and then, as rainwater and snow melt percolate through the dump, it treats the resulting discharge. Many products have

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been evaluated over the years to control and several have shown promise. While several products are under evaluation, there is presently no widely accepted technology which controls AMD production at the source without indefinite maintenance.

The AMD problem is subject to increasing public scrutiny and controversy. In fact, a regulatory issue exists because there is no technical solution to the AMD problem. Regulatory solutions to the problem will tend to be ineffective and punitive as long as there is no practical control technology.

The objective of this discussion is to describe development and field testing of two promising AMD control technologies: Phosphate application and a low-voltage electrolytic cell technique.

Phosphate Technology

A team of researchers at West Virginia University has been studying the AMD problem for several years. The team, consisting of J.J. Renton, A.H. Stiller and T.E. Rymer, has recently completed several breakthroughs which may radically change the AMD picture in the future.

1. The team has developed a means of significantly restricting the reaction in mine refuse. The method involves addition of small amounts (2-3%) of rock phosphate to the refuse. The effectiveness of rock phosphate has been demonstrated in laboratory and small scale field trials.
2. A simulation model has been developed which predicts the rate at which given rock units will produce AMD. This model further has the capability to predict the rate at which AMD will leach from a given dump. Used in conjunction with the ability to restrict AMD production through rock phosphate addition, this model estimates how much phosphate will be necessary to control AMD production on a given site. This model would permit a reliable estimate of: a) the AMD hazard for any new development and b) the costs associated with controlling AMD.

Status of Phosphate Technology: The effectiveness of the AMD chemical model has been verified against historical AMD field sites. Predictions made by the model regarding the status of AMD at a given time after dump construction have been highly accurate. To date, however, most of these sites have been dormant for some years so it has not been possible to determine the early pattern of AMD discharge.

Before recommending acceptance of phosphate, however, five major issues need to be resolved:

1. Source of phosphate-in addition to commercial rock phosphate, the potential of low grade (low cost) phosphate rejects or ores is of great interest;

2. Application methods under mining conditions;
3. Impacts on prep plant and material handling systems at the mine;
4. Costs in terms of capital and operating outlays and in terms of any reduced efficiencies at the mine;
5. Effectiveness in controlling AMD production under operating conditions.

Evaluation of these factors can only be made by applying phosphate in conjunction with an operating mine/prep plant. It should also be stressed that phosphate is not being used as an acid neutralizing agent, like limestone. Rather, it coats pyrite particles and their air channels with insoluble iron phosphate salts physically isolating pyrite from water and oxygen. Neutralizing agents such as limestone, on the other hand permit the oxidation of pyrite to occur, then react with the products. This is why neutralizing agents are usually required in large amounts.

Pyrite oxidation in coal wastes tends to be a rapid process (Rymer et al. 1988 reported 65% oxidation within 200 days after initial exposure to air). So, it is unlikely that addition of low rates of phosphate to already oxidized rock will have much beneficial effect.

The Phosphate Study

Several companies and government agencies are participating with West Virginia University in testing this technology. This is an important point because it is nearly impossible to develop a practical reclamation technology without the advice, guidance and financial support of the regulatory agencies and the industry.

Major financial support has been provided by the West Virginia Department of Energy, Mr. George E. Dials, Commissioner. The Department's participation will ensure that the program addresses the key issues facing the regulatory agencies. Two coal companies are participating in the phosphate evaluation program: Island Creek Coal Co. and Leckie Smokeless Coal Co. In addition, Texasgulf Inc. the supplier of the phosphate is a major contributor to the program. Analabs Inc., of Beckley, West Virginia, is contributing through its sampling and analytical support to the project. This group of companies will ensure that project technology will be transferred directly to each of the key elements within the industry.

Refuse piles will be constructed at each mine. At one site a series of 4000 Ton piles of run of plant refuse are being constructed on prepared, plastic lined

foundations. Each pile has a single drainage point for collecting and monitoring of effluent. These piles will be treated with three levels of phosphate: 0%, 2% and 4% commercial rock phosphate added per ton of refuse. At the other site, two 100 000 Ton piles will be constructed in similar manner. One will be treated with 3% phosphate and the other will be the untreated control. Both mining operations are primarily underground operations mining high to mid-sulfur coals.

The refuse will consist of a blend of refuse materials as produced by each company's preparation plant.

Application of the phosphate will be tailored to the company's operations. At one site phosphate will be applied as a slurry and at the other site it will be applied dry to the prep plant's refuse bin via a pneumatic feed.

In addition to testing the effectiveness of phosphate application, the project will allow us to verify model's estimates against field observations. If successful, this package will allow site-specific estimates of refuse pile behavior during the permitting phase of the development.

This project will generate a tremendous volume of data. Without sophisticated data handling and treatment systems the project would generate clouds of incomprehensible numbers. The value of a systematic approach to data collection, storage, retrieval, reduction and analysis is recognized by treating data processing as a distinct task. Five database management programs will be applied to the project. In addition, ten data processing software packages will be used, seven of which will either be developed specifically for the project or modified for the project.

Electrolytic Control of AMD

Many abandoned underground coal mines continue to discharge large volumes of AMD decades after abandonment. Once an underground mine is completed the company is left with few options in the event that AMD becomes a problem. The general solution is to institute an AMD neutralization program consisting of the addition of an alkaline agent such as soda ash briquettes, caustic, ammonia or quicklime coupled with a sedimentation pond to capture the resulting iron flocs (yellowboy).

These systems are expensive to operate and the duration of treatment is indefinite. The less expensive neutralizing agents such as quicklime require large, capital intensive treatment plants while the more expensive agents such as caustic and ammonia can operate on inexpensive capital facilities. Costs in the range of \$5,000 to \$20,000 per month are not uncommon for mid scale AMD neutralization systems.

AMD Control for Abandoned Underground Mines

Nearly 80% of West Virginia's AMD comes from underground mines. Many were abandoned decades ago and continue to produce toxic discharges. While the previous discussion on phosphate described a method for preventing AMD production from fresh refuse, this discussion focuses on an inexpensive method for treating AMD both for active and abandoned operations. If successful, it would have application to AMD environments where oxidation had already occurred or where the acid producing rock was inaccessible.

After completion of mining, the portals are usually sealed and a pool of groundwater forms in the downstream section of the old workings.

This water often does not meet state water quality specifications with respect to acidity, iron and manganese. Typically, a neutralizing agent is added to the water upstream of a settling pond which removes the flocculated metal sludge. The neutralizing agents are expensive but they serve two purposes when admixed to AMD streams: (1) They complex the soluble iron which drives ferrous oxidation to the ferric ion. (2) They increase the pH in the near vicinity of the addition site very dramatically. The total effect is to force the precipitation of ferric oxide and further neutralize the water. The sediment quality of the precipitate is strongly dependent upon the availability of dissolved oxygen. At the addition site ammonia replaces the dissolved oxygen so the rate of floc consolidation is slow. This can be shortened by rapid aeration immediately after ammonia addition.

An electrolytic process has been developed at the Chemical Engineering Department of West Virginia University as an alternative to chemical neutralization. It is known as the AMD-CELL SYSTEM. Electrolytic processes have been attempted in the past but have usually failed to operate economically due to their high current consumption. The proposed technology operates on a low current (<2 amps) format and has been developed and run successfully in a lab bench demonstration unit. The objective of this project is to evaluate, in a joint effort with the mining industry, the scale-up potential of this technology, its effectiveness and practicality under operational field conditions. As of this writing a large scale field trial is being developed with a West Virginia coal mining company.

A local AMD water which is both acidic and high in manganese and iron has been used to evaluate the prototype unit. The prototype is a short unit and it

compensates by recirculating the AMD. Results indicate that within two minutes of treatment both iron and manganese ions have been precipitated below State water quality specifications and the pH has been raised from about 2.5 to 4.2. This alone would lower by two thirds the amount of neutralizing agent required to bring the water into compliance. More significantly, it removes the iron and manganese.

There remain several issues which need to be evaluated. The first is ion concentration. This is important because it determines the voltage requirement for the cell. Ideal voltages at standard conditions can be found in tables; however, these voltages change according to ion concentrations. After these are known a simple calculation can be used to determine the voltage required to activate the AMD-CELL SYSTEM to a specific type of AMD (e.g. simultaneously oxidize ferrous iron and reduce hydrogen ion).

The total conductivity and specific ion conductivity must also be determined. These values can be obtained from solution analysis and standard tables. The conductances are important because they set the current requirement, which, in turn will be coupled to the AMD flow rate. This should make sense, since current and flow rate are time dependent functions.

Once the voltage and current parameters are determined the cell can be tailored to the specific AMD discharge point. A circuit can be made which prevents the voltage from exceeding the required potential. This unit will be analogous to a voltage regulator. It is important to prevent side reactions, for example, reduction of ferric ion back to ferrous ion.

The next step tests the specific AMD water in the bench scale unit. The unit is used to design the voltage and residence time required of the field system.

Experimental Design

The electrolysis system should precipitate iron from the water as ferric oxide. The other electrode reaction is the reduction of hydrogen ion. In other words the hydrogen ion, which is responsible for the low pH would be removed from the stream as insoluble gaseous elemental hydrogen. The end result would be a stream which is low in soluble iron, ferrous ion, and high in pH.

The AMD stream will be passed into one or the other of two tubes. One of the tubes is a electrolysis cell, the other is a control tube. This will ensure accurate evaluations of the effects of electrolysis of the water. Each tube is constructed from 10 inch or 8 inch internal diameter ABS or PVC tubing. The tubes are 10 feet long. This will provide a working space of about 8 feet for the electrodes. The

reactors will be constructed in a manner identical to that of the laboratory prototype.

Electronic circuits may have to be designed and constructed so the ideal lab parameters can be duplicated in the field units. At the present time it is not possible to define the circuit without any lab data.

Laboratory Experimentation

A series of tests at different voltages, residence times, and frequencies will be run to determine the most effective conditions for metal and hydrogen removal. These experiments will demand a complete analysis of iron ion, sulfate ion and sodium hydroxide equivalents to overcome buffering and to achieve neutrality for each sample. From these data the most effective configuration for the particular company's AMD system can be developed.

Field Work

The field work will involve the construction of a scaled up field unit. The circuitry which would provide the proper voltage at the ideal frequency and permit current flow would be built. The AMD stream would be allowed to flow through the cell. The flow rate would be recorded. These data would be compared to the expected values calculated from the lab bench scale experiments. Samples of mine effluent would be obtained for comparison to demonstrate the effectiveness of the system. The flow rate could be varied by splitting the incoming stream and the effectiveness of the treatment could be validated at different flows. These again could be used to test the validity of the laboratory bench tests.

Literature Cited

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