Technical Issues for Water Quality in the 21st Century

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Background:

Acid mine drainage (AMD) forms when pyrite is exposed to oxygen and water. In the pre mining state, pyrite is only found in saturated conditions. With no oxygen, the pyrite is inert. Surface mining increases the porosity of spoil which ensures that the post mining water table establishes at a much lower elevation. This, in turn, exposes most of the spoil to oxygen. Underground mines introduce air into previously saturated coal seams. If the mines are below the regional water table, they will re saturate after mining and quickly stop producing new acid. If, however, the mines are above the water table, they will continue producing AMD for many decades.

Since the amount of pyrite in a mine is finite, so is AMD production. The last day of mining the amount of pyrite which will be weathered is at a maximum. That value declines at a rapid or slow rate based on the oxygen infiltration rate. Porous low pyrite materials such as sandstone spoil tend to generate AMD rapidly at first then decline rapidly. Tightly packed, high pyrite materials such as coal refuse and pyritic shales, tend to produce AMD for much longer periods.

AMD Production Settings

The quality, quantity and duration of AMD is largely a function of the mining environment. This controls the type of rock, the hydrology and access of oxygen to the pyrite. Following is a summary of key AMD producing settings:

Surface Mine		
Sandstone	strongly acid,	short (~30 year)
Shale	strongly acid,	long (+100 year)
Coal Refuse		
Mixed refuse	strongly acid,	very long
Coarse refuse	very strongly acid,	long
Refuse slurry	mildly acid,	long
Underground Mine		
Above drainage	strongly acid,	long
Below drainage	alkaline with Iron	very long

Each of the above represent very different settings. To be successful, AMD technologies need to be matched to the correct setting.

Acid mine drainage technology can be divided into three categories:

1. Prediction: evaluation of pre mining geology and assessing the potential for AMD generation.

    Examples: Static and kinetic testing
    Product: Identification of rock units which will produce AMD and those which will neutralize AMD. Tests should identify whether the total site is, on balance, likely to produce net acid or net alkaline water.
    Status: Acid Base Accounting (ABA) is widely used and effective in coal mining.
    R&D needs: Validation, characterization of long term AMD production trends.

2. Avoidance: development and implementation of mining plans which avoid creation of AMD discharges.

    Examples: Selective material handling, alkaline amendment, hydraulic controls (barriers), in-situ treatment.
    Status: Selective material handling, alkaline amendment and hydraulic controls are widely used. In-situ treatment is an emerging technology.
    R&D needs: Document effectiveness of selective material handling. Identification, demonstration and certification of appropriate, low-cost alkaline byproducts.

3. Remediation: treatment of AMD discharges from mines.

    Examples: Active treatment: use of mechanical systems to dispense alkaline chemicals. This also normally includes aeration and collection of precipitated metal flocs in settlement basins. Active treatment systems require continuous maintenance for chemical replacement and for floc removal.

    Passive Treatment: non mechanical treatment with alkaline material-generally limestone. Passive treatment systems require less maintenance than active systems though reliability and performance can be low.

    Indirect Treatment: increasing alkalinity in channels upstream of the AMD source. These systems require almost no maintenance since AMD and metals do not contact the alkaline media. Depending on the alkalinity requirements, limestone or steel slag may be used.

    In situ Treatment: addition of alkalinity to surface or underground mine voids after mining. The objective is to add enough alkalinity to match acid production for extended period and to ensure that alkalinity is placed in the critical AMD flow paths.

Status: Active Treatment: Mature, effective and widely practiced technology.
Avoidance: Widely practiced, new approaches and alkaline materials under development.
Passive Treatment: Mature technology, costs and performance vary widely.

Indirect Treatment: Promising results on a few demonstration watersheds.
In situ Treatment: Promising results on a few demonstration projects.

Directions for New Technology

Current technology is very good at predicting AMD risk for new developments and for active or chemical treatment of AMD discharges. Methods for avoiding or controlling AMD on active mines are well understood and reliable. However, our ability to deal successfully with AMD from abandoned mines is mainly limited to low efficiency systems for low flow settings. Major improvements are needed in reliability and performance.

Very few passive treatment methods are suitable for the massive flow regimes typical of large underground mines. And, while many of these will be acid, those which fully flood will typically produce a net alkaline water with between 25 and 100 mg/L of ferrous iron. These are very different settings than those which have been studied for the past 20 years and new, almost regionally scaled approaches will be needed.

It is becoming clear that acid production from surface mines declines dramatically after about 20 years. A better understanding of the natural attenuation rate of AMD will help us determine how much alkalinity will be needed in alkaline amendment and for in situ treatment schemes.

It is also clear that the efficiency of any AMD treatment scheme (measured in $/ton acid treated) declines as the pH increases and the acidity decreases. So, as a rule, the first ton of acid removed from a watershed is the cheapest and the last ton is the most expensive. This is because limestone or any solid base dissolves most rapidly under strong acid attack and iron fouling does not occur until the pH moves above 3.

Implementation of TMDLs may provide opportunities for companies to trade low cost acid treatment at AML or bond forfeiture sites at locations in the watershed for adoption, for example, of technology based limits. An equivalent dollar investment would thus yield far greater positive impact on the watershed.

Summary

The breakthroughs in AMD technology are likely to occur in the following areas:

- In situ surface mine treatment,
- In situ underground mine treatment,
- Avoidance technologies such as capping and other hydraulic controls.