

Creating Anaerobic Environments to Control Acid Generation in Pyritic Material

By Robert L. Kleinmann, Senior Mining Technologist, CH2M HILL Ltd and James G. Gusek, Senior Engineer, Sovereign Consulting Inc.



Acid rock drainage (ARD) generated by the oxidation of pyritic waste material from metal and coal mines is generally dealt with by water treatment. An attractive alternative to water treatment is to lower the rate of acid generation. One way this is commonly done is by adding alkalinity, which, if sufficient, reduces the catalytic activity of iron-oxidizing bacteria and precipitates dissolved iron as ferric hydroxide. A second option involves dramatically reducing the rate of water flow, since water is both the reaction medium and the principle contaminant mechanism. However, unless the site is in an arid environment, it can be very difficult and expensive to eliminate enough water to significantly reduce contaminant mobilization and migration, though reducing contaminant load is sometimes possible. A third option is to dramatically lower oxygen levels (reducing it below 0.5% will even curtail ferric oxidation of pyrite by inhibiting bacterial oxidation of ferrous iron). Depending on the site, it is sometimes possible to make the system virtually anaerobic (no oxygen) by inundating the pyritic material, which successfully reduces the rate of acid generation, but what if that is not possible? We propose a fourth option, which involves preventing or suppressing pyrite oxidation by simultaneously adding alkalinity and removing oxygen, while, coincidentally, precipitating dissolved contaminants out of the ARD. Moreover, all of this can be accomplished inexpensively, using agricultural, municipal, or industrial waste.

The reader may be familiar with the established passive alternatives to active chemical treatment and the creative use of bacteria and limestone to neutralize ARD and precipitate contaminants. Although not always an option, passive treatment is a technology that has evolved from simple ponding of water in constructed wetlands to treat near-neutral pH coal mine drainage into a fancy toolbox of options that are combined and strung together, as appropriate, on a site-specific basis to neutralize ARD and remove a wide ar-

ray of contaminants. Some contaminants, such as iron, aluminum, and manganese, are typically removed as oxides or hydroxides, which requires an aerobic environment, while others, such as copper, lead, zinc, sulfate, uranium, and selenium, can be removed by creating an anaerobic, reducing environment. To accomplish the latter, an appropriate mixture of organic materials (e.g., composted waste, wood chips, and straw) is placed in a basin and the contaminated water is directed to flow through it. Natural bacteria sequentially remove (consume) the oxygen and then extract energy by reducing the nitrate, then the iron, and then the sulfate. Sulfate reduction is the opposite of pyrite oxidation, generating alkalinity and sulfide; the sulfide reacts with the metals dissolved in the ARD and precipitates them as sulfides, thus closing the loop by which they entered the environment. The "basin" is commonly known to passive treatment practitioners as a biochemical reactor or BCR.

We can apply what we have learned by constructing anaerobic wetlands and BCRs to create a reducing environment in the pyritic waste rock and tailings, forestalling pyrite oxidation by altering the aerobic environment into a reducing one and, in addition, treating the ARD that has formed in place. This has been suggested in the technical literature for at least 30 years and we feel that it is time, given what we now know about creating reducing environments in ARD treatment systems (i.e., BCRs), to make this approach a reality. Like passive treatment technology, the approach will have to be tailored to the site and the geochemical characteristics of the ARD-generating waste. This would entail evaluating various options to develop sustainable conditions that both suppress the undesirable acidophilic bacteria that support ARD generation and displace or replace it with a microbial community that can be maintained by the natural processes inherent in a typical revegetated cover. Just as the mining industry typically perfects a process flow sheet in a mill or processing plant,

it makes sense to start with small-scale field tests and then to scale up the approach, but we are confident that this method will prove to be a relatively low cost option at many sites. Given the ease with which oxygen can penetrate waste rock, the technique should be perfected first at ARD-producing mine tailings and coal refuse (the reject material from a coal beneficiation or "washing" plant) sites.

Despite several successful small-scale and pilot-scale tests, there have been very few (perhaps only one) full-scale tests. For example, WISMUT (a former East German uranium mining company that is now responsible for reclaiming all of Germany's old uranium mining operations) saw dramatic decreases in dissolved copper, iron, zinc, and sulfate in some large lysimeters tests it conducted. Dr. Matt Lindsay, now at the University of Saskatchewan has published some great research that he did while at the University of Waterloo using this approach on a somewhat larger scale at a site where the drainage was circumneutral but contaminated. The approach appeared to be quite successful. And the Western Research Institute (WRI) successfully injected expired milk products into "hot spots," detected using surface geophysics, at the Sesquatchie Coal Mine in Tennessee, which apparently improved water quality at that site, which was slightly acidic. The goal of adding the waste milk was to encourage the growth of a protective biofilm on the pyrite grain surfaces that would out-compete the acidophilic community. Positive effects are still being observed seven years after the application event in 2007. However, we know of no examples (published or unpublished) where the technique has been tried (intentionally or unintentionally) at mine sites that are producing ARD, although we have heard anecdotal tales of success.

Implementing the concept on a large scale will depend on whether or not the waste site is revegetated. For sites with a healthy vegetative cover, surface applications would be limited to liquid

