Innovative, In Situ Use of Sulfate Reducing Bacteria to Remove Heavy Metals from Acid Mine Drainage

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Abstract: Unregulated heavy-metal mining in the West during the early to mid-1900s resulted in the generation of acid mine drainage (AMD) at many locations. AMD is characterized by low pH and high concentrations of heavy metals. Results are presented that were gathered during on-going field-scale testing of an innovative technology, the use of sulfate-reducing bacteria (SRB), designed to treat and control acid mine drainage (AMD). The project was performed under the Mine Waste Technology Program (MWTP) which is funded by the U.S. Environmental Protection Agency (EPA) and jointly administered by the EPA and the U.S. Department of Energy. SRB produce hydrogen sulfide and bicarbonate when supplied with sources of carbon and sulfate. Hydrogen sulfide reacts with metal ions in AMD, precipitating them as metal sulfides; the bicarbonate serves to help neutralize the drainage. After thorough pilot-scale testing, the field demonstration is being performed at an abandoned, hard rock mine where a flooded underground mine is being used as an in situ biological reactor. Data collected during the first seven years of operation will be presented. Although seasonal variation is observed, significant pH increase and high removal efficiencies are seen for Al, Cd, Cu, and Zn (70% to nearly 100%).

Background: Because acid generation typically accompanies sulfide-related mining activities, it is a widespread problem. In the United States, 10,000 miles of streams and 29,000 surface acres of impoundments are estimated to be seriously affected by AMD (Hunter, 1989). AMD results when metal sulfide minerals, particularly pyrite (FeS_2), come in contact with oxygen and water. Acid generation occurs when metal sulfide minerals are oxidized resulting in increased metal mobility and increased acidity of the water. A need clearly exists for a low-cost, low-maintenance treatment alternative to relatively expensive conventional treatment technologies, such as lime neutralization.

Site Description: The Lilly/Orphan Boy Mine, located 11 miles south of Elliston, Montana, was selected as the demonstration site. This abandoned mining operation consists of a 250-foot shaft, four horizontal workings, and some stoping. Prior to the field implementation of the SRB technology, the shaft was flooded with AMD to the 74-foot level and discharged approximately three gallons per minute of pH 3 water from the portal associated with this level. Elevated concentrations of aluminum, arsenic, cadmium, copper, manganese, iron, and zinc, and sulfate were measured.

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Performance: The design of the SRB field demonstration consisted of using the flooded subsurface mine workings of the mine as an "in situ biological reactor" (Figure 1). Two platforms were suspended by cables in both sides of the two-compartment shaft 30 feet below the static water level and were secured at the surface. An organic substrate used to nourish the SRB was placed in the shaft and supported by the platforms. Two wells were drilled into the main tunnel of the mine so that additional substrate could be injected into this underground space. Consequently, AMD flows upward through the substrate in the shaft (artesian effects have been observed) and horizontally through the substrate in the tunnel. The biological reaction takes place in the substrate and the treated water subsequently flows out of the mine through the portal. The technology inhibits further acid generation by creating a reducing environment and raising the pH of the water. Field monitoring began once the substrate was placed in late August 1994 and will continue for at least a 7 1/2-year period.

The pH of the mine water prior to the installation of the field demonstration was about 3. After implementation, the pH in the tunnel rose to approximately 7 and remained there during the first 4 years of monitoring. The pH at the mine portal rose to approximately 6 after the technology implementation but fell to 3.5 during each spring runoff. After flow rates returned to normal levels (after each spring runoff), the pH at the portal rose to nearly 6. Within the tunnel of the mine, however, the pH remained near 7 during each spring runoff.

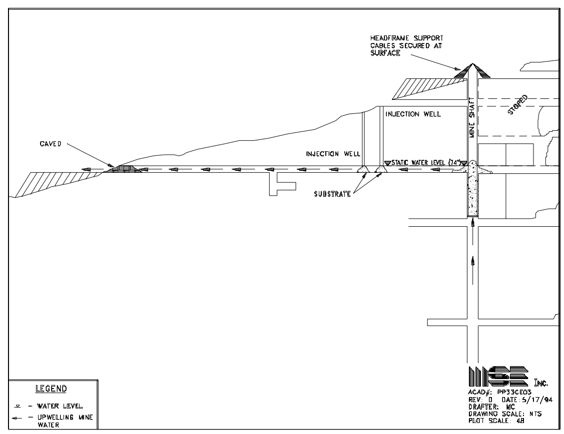

Figure 1. Cross- section of the Lilly/ Orphan Boy Mine.

Dissolved metal removal efficiencies measured at the mine portal are presented in Figure 2. Dissolved metals concentrations were compared to background concentrations in the mine water prior to the technology implementation. Aluminum, cadmium, and copper had high removal efficiencies (85% to near 100%) during the first eight months of the field demonstration. All three of these metals underwent a significant reduction in metal removal efficiency during the high spring runoff observed in May and June of 1995. As flow rates returned to normal levels, these metals were again removed, reaching removal efficiencies representative of the months prior to spring runoff. This cycle was repeated during each subsequent spring runoff.

Zinc and manganese were not as effectively removed as aluminum, cadmium, and copper. Prior to the first spring runoff, zinc was consistently removed at approximately 70% while the manganese removal efficiency was less than 20%. Zinc and manganese also underwent a reduction in removal efficiency during each spring runoff. Zinc and manganese were again removed as flow rates returned to normal levels.

Interestingly, metal removal efficiencies within the mine tunnel (Figure 3) did not display a drastic decrease during spring runoff as observed at the portal of the mine. Aluminum, cadmium, copper, and zinc were removed at high efficiencies within the tunnel throughout the duration of monitoring. A steady decrease was observed in the removal of manganese (approximately 80% to 30%); however, a sharp increase in the removal of manganese was observed during November and December 1995. On average, the manganese removal efficiency tended to be 30% to 50%. Overall, results indicate the technology offers a cost-effective, passive alternative to conventional technology.

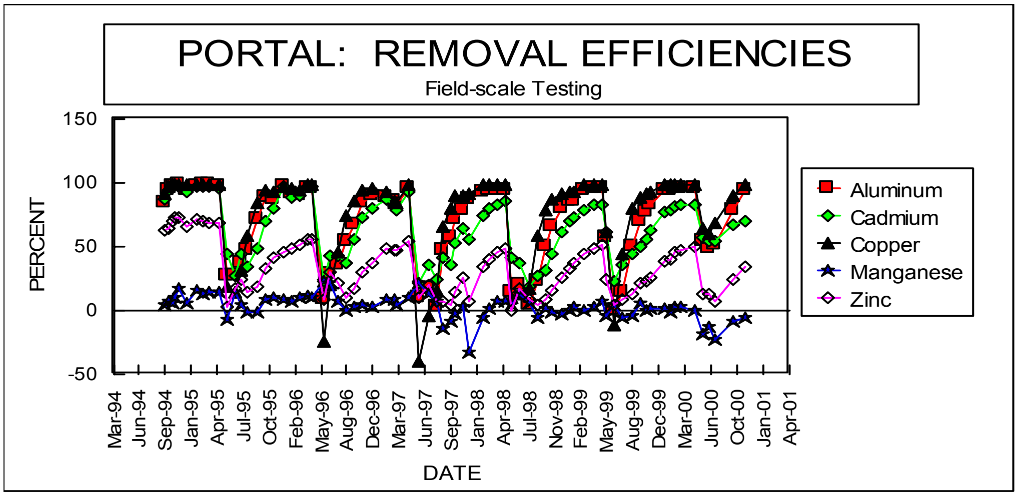

Figure 2. Portal Removal Efficiencies

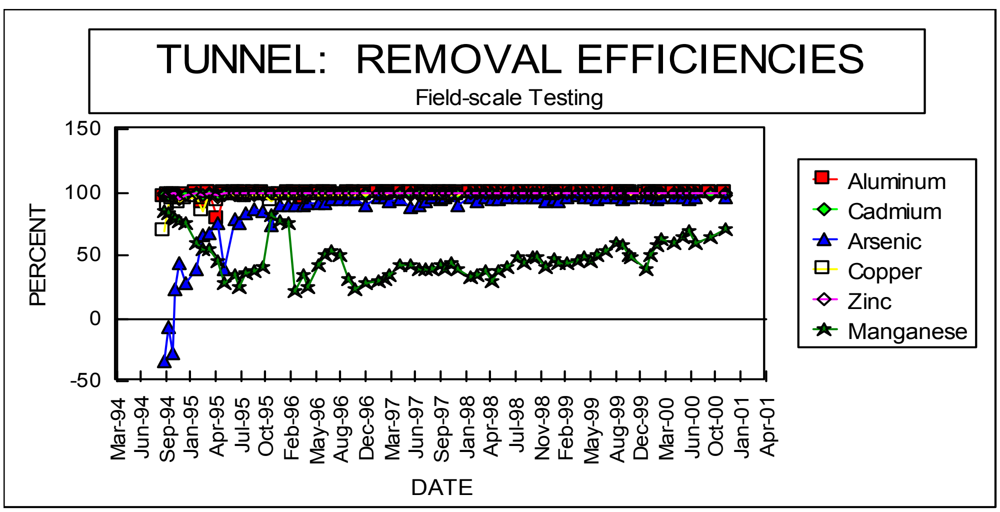

Figure 3. Tunnel Removal Efficiencies

Reference:

Hunter, R. M., *Biocatalyzed Partial Demineralization of Acidic Metal Sulfate Solutions*, Doctoral Thesis, Montana State University, Bozeman, Montana, 1989.