Field Performance of Engineered SRB Reactors for Removing Heavy Metals

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Abstract: Performance of three sulfate-reducing bacteria (SRB) reactors during a 2-year operational period is reported in this paper. The reactors were constructed to demonstrate the removal of heavy metals from water by SRB. The stream on which the technology was tested emanates from an abandoned hard-rock mine dump. Sulfate-reducing bacteria are capable of immobilizing dissolved metals in the influent by precipitating them as sulfides and reducing acidity, if a favorable biochemical environment is created. Such an environment was engineered within the three field bioreactors that differ in size, content, and an above or below-ground placement. There is also indication that the reactor's performance is sensitive to construction details including the amount of organic carbon source and its placement method.

Background Information: Acid mine drainage (AMD) emanates from many abandoned mines in the Western United States, causing significant environmental problems by contaminating surface waters and groundwater with dissolved metals and raising their acidity. Acid mine drainage is a typical result of mining of sulfide-rich ore bodies containing pyrite, and exposing them to oxygen and water that together produce sulfate, ferric hydroxide, and hydrogen ion.

Conventional treatment of AMD is often not feasible due to the lack of power, and limited access. For such sites, there is a need for a passive remedial technology to immobilize metals and increase the pH of the AMD. Sulfate-reducing bacteria have these abilities, if provided with an organic carbon source. Sulfate-reducing bacteria reduce the dissolved sulfate to soluble sulfide by using sulfate as a terminal electron acceptor, and the produced bicarbonate ions increase pH and alkalinity of the water. The soluble sulfide reacts with the metals in the AMD to form insoluble metal sulfides. Such biochemical conditions were engineered within three field bioreactors (reactors) that were built at an abandoned mine site.

Site Features: The abandoned Calliope mine site, located near Butte, Montana, includes a collapsed adit discharging water into a large (66,000 cubic yards) waste rock pile that is considered a source of AMD. This AMD has been diverted to three reactors (denoted II, III, and IV) designed and constructed (Zaluski et al., 1999) in parallel configuration (Figure 1). The reactors, treating a maximum of 2 gallons per minute (gpm) each of AMD, were designed to evaluate the SRB technology applied in slightly different environmental conditions.

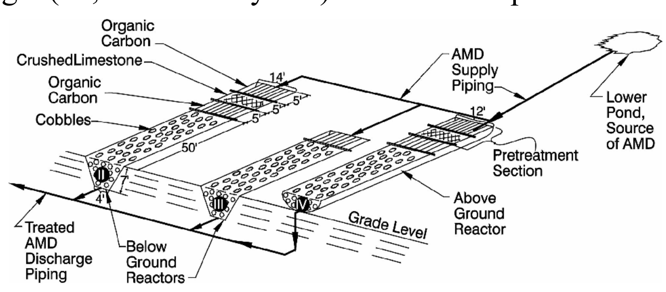

Figure 1. Layout of bioreactors.

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Performance of Bioreactors: Performance of each reactor has been monitored by monthly sampling of the influent and effluent and continuous monitoring of selected parameters using appropriate sensors and data loggers. Samples have been analyzed for sulfate; alkalinity; SRB count; heterotrophic bacteria count; dissolved oxygen (DO); E_H (with silver/silver chloride reference electrode); and metals including aluminum, zinc, cadmium, copper, iron, manganese, and cadmium (Zaluski et al., 2000 and 2001). Selected results are presented in Figures 2 through 5.

Performance of the reactors can be summarized below:

- The initial increase in effluent pH (Figure 2) can largely be attributed to alkalinity present within the organic substrate. As the SRB became established and the effluent pH from each reactor dropped to the range of 7 to 8, the pH differential between the influent and effluent can be attributed to SRB activity.
- Much of the metals removal observed during the first 7 months of operation can be attributed to adsorption. Once sorption sites filled, many metals, e.g., zinc, cadmium, and copper, were removed through SRB activity. These metals were removed from the AMD to threshold levels that were approximately 500 micrograms per liter (µg/L) to 800 µg/L for zinc (Figure 3, in log scale), 5 µg/L for cadmium (Figure 4), and 80 µg/L for copper (Figure 5, in log scale).
- A slightly lower metal removal efficiency of Reactor III that contained only one chamber with organic matter may indicate that for reactors constructed in cold-climate regions a residence time of 10 hours is close to minimal.
- Winter freezing of a well-established SRB population had little or no effect on their activity for the remainder of the year.
- Although it appears a limestone chamber slightly increased effluent pH, its role was not dominant for the overall performance of the reactors.

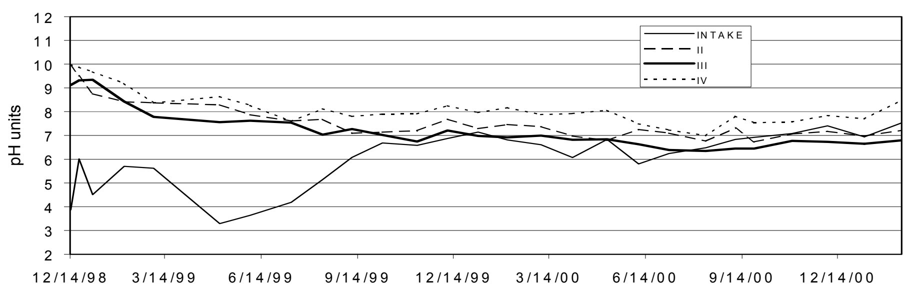

Figure 2. pH trends.

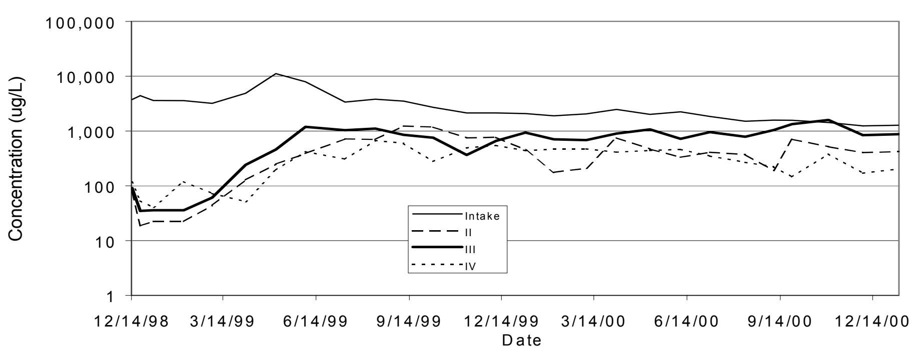

Figure 3. Concentration of zinc.

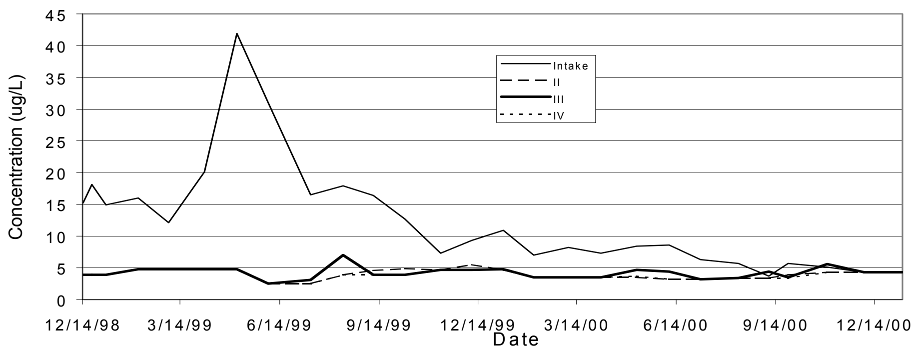

Figure 4. Concentration of cadmium.

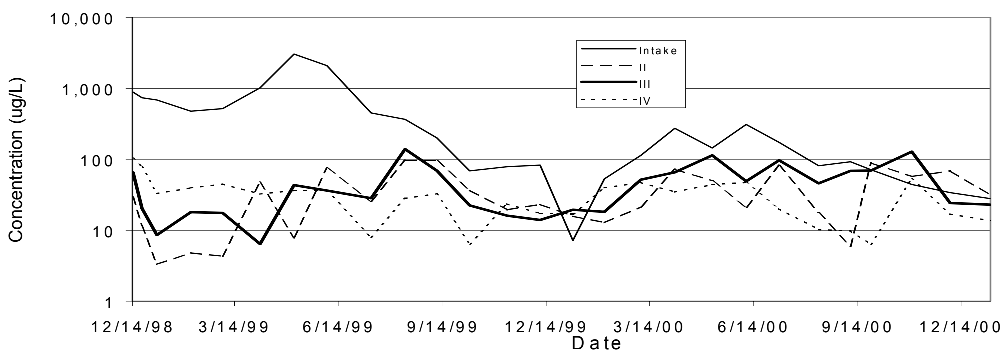

Figure 5. Concentration of copper.

- Observation of the reactors to date indicates that cobble sections were not important for the efficiency of SRB reactors.
- To avoid self-plugging (biofouling) of the reactor during its operation, a detailed specification of organic carbon placement is necessary.

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