Passive Bioremediation of Mining Influenced Water Using Sulfate Reducing Bioreactors

Ilsu Lee[1], Linda Figueroa[2], Erick Weiland[1], Dan Ramey[1]

[1]Freeport-McMoRan Copper & Gold Inc., [2]Colorado School of Mines

Abstract

Passive Sulfate Reducing Bioreactors (SRBRs) are a promising method to treat low flow mining influenced water (MIW) at closed or remote mine sites. However, the necessity for a more robust design process has been observed and thus design parameters must be determined experimentally. Evaluations at both laboratory- and field-scale were needed to develop the design guidance needed for a more rigorous design process. The scope of this presentation is the analysis of a laboratory column experiment and the design and performance of a full-scale SRBR to understand design parameters and the design process required to implement successful SRBRs in the field.

At the laboratory scale, a holistic evaluation of sulfate and zinc removal efficiency among different substrate compositions was performed that included analysis of the microbial community structure, precipitate composition, stoichiometric analysis of competing electron acceptors and material costs. Eight (8) 18-liter bench-scale SRBRs received MIW containing sulfate (5,000 mg/L) and zinc (170 mg/L) were operated for over 1 year. These SRBRs were operated in continuous down-flow mode using peristaltic pumps at different flow rates. SRBRs contained single substrates (alfalfa hay (AH), sawdust (SD), woodchips (WC) or walnut shell (WS)) or a combination of substrate mixtures (AH/SD/WC, AH/SD, AH/WC or SD/WC SRBRs containing alfalfa hay or walnut shell have shown sulfate removal rates of 0.14 to 1.12 mole/m^3-day and zinc removal rates of 0.06 to 0.17 mole/m^3-day. In contrast, SRBRs containing only sawdust and wood chips did not support biological sulfate reduction well (<0.1 mole/m^3-day). At a flow rate of 1.2 L/day, 100 % zinc removal was achieved in SRBRs containing alfalfa hay or walnut shell, however, the volumetric zinc removal (and loading) rate (0.17 mole/m^3-day) is still lower than sulfate reduction rates (0.47-0.71 mole/m^3-day). The results suggests that complete zinc removal can be achieved at a higher flow rate than 1.2 L/day (15 days of empty bed contact time) for a majority of the substrate mixtures tested.

To understand the metal removal mechanism, the microbial community structure of each SRBR was investigated and elemental composition (zinc, calcium, and sulfur) of precipitates collected from the solid substrates during SRBR operation. A clear relationship was observed between well performing SRBR and specific sulfate reducing bacteria populations. A shift also was

observed in the precipitate composition from calcium-sulfur to zinc-sulfur precipitate as the sulfate and zinc reduction capacity in the SRBRs increased. Furthermore, this work demonstrated the effect of empty bed contact time (EBCT) and flow rate on the mass oxygen influx and the impact on sulfate reduction rate, metal removal and cost effectiveness of passive SRBR operation.

The full-scale SRBR had a volume of ~1,300 m^3 and contained a mixture of woodchips, sawdust, hay and manure. The influent flow rate varied from approximately 0.4 to 30 liters per minute and influent iron and zinc concentrations varied by more than an order of magnitude.

The performance of the full-scale SRBR, put into operation in 2009, was initially impacted by the accumulation of aluminum and iron precipitates at the inlet piping and distribution system. The influent zone was modified in the first year and after three additional years of operation aluminum and iron minerals have continued to precipitate in the distribution piping, albeit at a lesser rate. From an investigation of full-scale SRBR operation, the necessity of pre- and post-treatment for more efficient treatment of MIW has been recommended.