LOW-pH FE(II) OXIDATION FOR PASSIVE TREATMENT OF COAL MINE DRAINAGE

William D. Burgos[1] and Jennifer L. Macalady[2]
The Pennsylvania State University,
[1] Department of Civil and Environmental Engineering
[2] Department of Geosciences

Project Description and Objectives

Terraced iron formations (TIFs) occur naturally and promote both low-pH Fe(II) oxidation and Fe(T) removal. TIFs can be incorporated into passive treatment systems but reliable performance criteria are required for their expanded use. The goals of this project were to measure the kinetics of Fe(II) oxidation and Fe(T) removal at 11 acid mine drainage (AMD) sites, and to develop design parameters for sizing TIFs for AMD treatment. Secondary goals were to characterize the microbial communities and mineral precipitates found on these TIFs to determine if they influence treatment performance.

Applicability to Mining and Reclamation:

Low-pH Fe(II) oxidation occurs with no human intervention and TIFs are found at coal mine, coal refuse, and metal mine sites around the world. Low-pH, high-metal AMD discharges are often classified as “untreatable” in decision trees used for the selection of appropriate passive treatment technologies. However, removal of high metal/iron sufficiently changes the classification of the AMD, e.g. now to low-pH, low-metal, such that conventional passive treatment options could become viable. Thus, low-pH Fe(II) oxidation could be widely used as a passive “pretreatment” technology.

Methodology:

Eight sites in the Appalachian Bituminous Coal Basin and three sites in the Iberian Pyrite Belt in Spain were selected for this project. Sites were sampled two to six times between September 2010 and May 2013. At all field sites, a suite of geochemical parameters were measured as a function of distance downstream from each AMD source. Water velocity was also measured at each sampling location and used to transform concentration-versus-distance plots to concentration-versus-time plots. Field-based Fe(II) oxidation rates were then calculated assuming each stream behaved as a plug flow reactor and that the rate was first-order with respect to Fe(II) concentration. Rates of Fe(T) removal were calculated as grams of Fe(T) per day per square meter of TIF area (GDM).

Highlights:

Engineered TIFs can be tailored to maximize both low-pH Fe(II) oxidation and total Fe removal by using natural TIFs followed with an alkaline channel (Figure 1).

Figure 1. Conceptual schematics of AMD treatment systems. A) Configuration for an extremely acidic discharge where the oxidation of Fe(II) to soluble Fe(III) (reaction 1) would be thermodynamically favored. Solid lines are observations, dashed lines are conceptual predictions. B) Configuration for a moderately acidic discharge where the oxidation of Fe(II) to insoluble Fe(III) (reaction 3) would be thermodynamically favored. From Larson et al., *Environ. Sci. Technol.* 2014. 48, 9246-9254.

Results/Findings:

We found that rates of Fe(II) oxidation were fastest at sites with the lowest pH values. Sites with the fastest rates also displayed a unique geochemical gradient where the pH increased across the TIF (Figure 1A). This result highlights a treatment tradeoff where Fe(II) will be oxidized very quickly at sites with low pH values (e.g., pH < 3.0) but not remove much total Fe. For design purposes, Fe(II) oxidation rate constants can be assumed to range from 0.035 – 0.399 min^{-1}, and Fe(T) removal rates can be assumed to range from 2.6 – 8.7 g Fe day^{-1} m^{-2} (GDM) at Appalachian sites.

Website Information:

The final project report and links to supporting documents can be found at:
http://www.osmre.gov/programs/tdt/appliedscience/projects.shtm

Principal Investigator:

William D. Burgos, Professor of Environmental Engineering, Department of Civil and Environmental Engineering, The Pennsylvania State University, University Park, PA
phone: (814)-863-0578
e-mail: wdb3@psu.edu

OSMRE Project Technical Representative:

Jay Hawkins
phone: (412) 937-2127
e-mail: jhawkins@osmre.gov