Trace element accumulation in schwertmannite-rich precipitate in a pipeline carying acid mine drainage at Iron Mountain Mine, CA, USA

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A pipeline at the Iron Mountain Mine (near Redding, CA, USA) carrying acid mine drainage (AMD) from a mine portal to a water treatment plant develops precipitate, or "scale," that causes occasional spillage and requires recurring, costly clean-out. The AMD water has low pH (~2.7), elevated concentrations of iron and sulfate from pyrite weathering, and substantial concentrations of associated trace elements. Scale and water samples were collected from four points along a 3.4 km reach of the pipeline to characterize spatial variation in biogeochemistry.

The mineralogy and microbial community (16S rRNA analysis of bacteria and archaea) of the scale were characterized. The scale was primarily schwertmannite (nominally $Fe_8O_8(OH)_6SO_4$) with minor amounts of goethite (FeOOH) and jarosite ($KFe_3(SO_4)_2(OH)_6$). The scale hosted a diverse group of acidophilic microorganisms, including several types of known Fe(II)-oxidizing microbes, and laboratory experiments confirmed that the scale is the result of microbial Fe(II) oxidation.

Although the bulk mineralogy was consistent throughout the pipeline, there were significant differences in bulk morphology and trace element content. The upstream samples were less consolidated and had higher biomass content than the downstream samples. There was enrichment in oxyanion-forming elements (As, Mo, Sb, Se), metals (Al, Cd, Co, Cu, Ga, Mn, Ni, Pb, Zn), and certain rare earth elements (REE: La, Nd, Eu, Gd, Pr, Sm, Tb, Tl) in the upstream scale samples. Generally, REE were low (<1 ppm) but measureable, consistent with the tendency for REE to not adsorb strongly at low pH. Conversely, oxyanions adsorb strongly onto schwertmannite at low pH, which accounts for elevated As (100-200 ppm), Mo, Se, and Sb (2-20ppm). Structural incorporation of metals and/or association with biomass may also be occurring. The partitioning of trace elements may also be dependent on the hydrology and rate of microbial iron oxidation, as scale morphology appears to play a role in metal and oxyanion-forming element accumulation.