

Chemistry and mineralogy of Fe-rich precipitates from an acid mine drainage-treatment system

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The role of Fe(III) and Al(III) precipitates in controlling the fate of nutrients, metals and metalloids was studied using six sediment cores collected in July 2013 from a bioreactor treating coal-generated AMD at the Tab-Simco site, located in Southern Illinois. These sediments formed on top of organic substrates over a 6½ year period during which the bioreactor had actively treated acidic, Fe-, SO₄⁻, and Al-rich AMD. Chemical characterization involved ICP-MS analysis of sediments and two chemically extracted fractions (ammonium oxalate extraction of poorly-crystalline Fe (III) oxides and NH₄OH/NH₄Cl extraction of surface bound species). Mineralogical characterization involved X-ray diffraction (XRD), scanning electron microscopy (SEM), and Fourier transform infrared spectroscopy (FTIR).

Results reveal major downcore changes in both mineralogy and chemistry. Significantly, there was a negative correlation between the concentration of Fe and Al in sediments, which correspond to a distinctly-layered mineralogy. The upper-most layer was dominated by poorly-crystallized and amorphous Fe and Al oxides, 1:1 phyllosilicates, & hydroxysulfates (e.g., goethite, ferrihydrate, lepidocrocite, Al hydroxide, lizardite, and schwertmannite). Increasing Al content downcore was associated with the appearance of both 1:1 (kaolin group) and 2:1 (smectite and illite) clays, whose speciation continued to change with increasing depth. Geochemical analysis shows that, with the exception of Fe, the concentrations of nutrients and metals (e.g., P, Al, As, Cu, Co, Cd, Mn, Pb, U, Th and Zn) increased with depth. Selective extractions revealed that only P, Cl, Br, Si, Cu, Zn, Ni and As were bound to surface adsorption sites in sizable amounts. In schwertmannites, goethites and clays the metals were predominantly structurally bound, substituting for Fe in Fe oxyhydroxide & hydroxysulfate structures or incorporated into the clay interlayer.

Data obtained in this work demonstrates that the long-term sequestration of metals and metalloids in AMD-impacted environments critically depend diagenetic processes and the formation of stable minerals that can incorporate chemical elements in their structure.