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Mechanisms controlling the release and transport of arsenic in circumneutral and acidic mine tailings and removal using passive treatment systems

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The release of As and other toxic elements from mine wastes is a global environmental issue. Many Au-mine wastes consist of complex mixtures of gangue minerals and As-bearing phases (e.g., arsenian pyrite, arsenopyrite, and As-bearing calcine roaster wastes). A comprehensive understanding of acid-neutralization mechanisms together with biogeochemical processes controlling redox conditions is crucial to develop effective management strategies to limit As release to the environment.

A comparison of detailed field investigations in both circumneutral and acidic mine wastes illustrates the similarities and differences in mechanisms controlling As release. At both types of sites, oxidation of As-bearing sulfide phases by atmospheric O_2 results in release of dissolved As in near surface wastes. At circumneutral sites, adsorption or uptake of As by secondary Fe(III) phases decreases the extent of downward transport of As. At low-pH sites, Fe(III) oxides are less stable and As is initially attenuated through precipitation of scorodite, which becomes unstable over prolonged time scales providing an ongoing source of As. In O_2 depleted zones, reductive dissolution of Fe(III)-phases, especially calcine roaster wastes, results in increased As concentrations. At all study sites, sulfate-reducing conditions, as indicated by decreased concentrations of SO_4^{2-} and Fe, shifts in S isotopes, develop at greater depths leading to the precipitation of low-solubility secondary As-sulfide phases. Application of synchrotron-based spectroscopy, microbiological characterization, and measurements of C, O and S stable isotopes further refine understanding of dominant biogeochemical processes. These results illustrate As behaviour in the shallow zones are strongly linked to Fe(III) oxide stability. At depth, where sulfate reducing conditions are established, the differences in constraints on As transport become much less pronounced.

At sites where sulfate reducing conditions are established, concentrations of As may exceed regulatory limits. Promotion of more extensive sulfate reducing conditions through addition of solid-phase organic carbon, zero-valent iron, and limestone as reactive media, in permeable reactive barriers or other passive treatment systems, resulted in much lower concentrations of dissolved As to <10 μg L^{-1}, representing >99.9% removal. Synchrotron-based solid-phase analyses show As removal occurred through precipitation of a poorly crystalline As-Fe sulfide phase combined with adsorption as As(V) onto ferrihydrite.