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Integration of Traditional and Non-Traditional Isotope Measurements to Elucidate Mechanisms Controlling Metal(loid) Transport in Mine-Waste Systems

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The release, transport and attenuation of metals in mine-waste systems is controlled by a complex series of physical and biogeochemical processes. Microbially-mediated sulfide-mineral oxidation releases H^+ and dissolved sulfate, iron and other metal(loid)s. Frequently the acid generated by sulfide oxidation is neutralized by dissolution of carbonate minerals at some depth within the mine waste system. Dissolved sulfate, iron and other elements are displaced downwards by infiltrating recharge water through the vadose zone into the underlying groundwater flow system. Dissolved metals may be attenuated by interactions with mine-waste solids and aquifer materials. Understanding the processes that control the concentrations of dissolved sulfate, iron and other metals, and metalloids is critical to developing rigorous forecasts of environmental impacts of mine wastes, and to implementing effective strategies for preventing and mediating environmental degradation.

Measurements of environmental isotopes (CHNOS) have been applied extensively to assist in delineating hydrologic and biogeochemical processes. Water isotopes (^2H, ^3H, ^{18}O) are used to identify and quantify recharge mechanisms and estimate pore-water velocities. Carbon isotopes provide information on sources and sinks of dissolved inorganic and organic carbon and provide information on the role of biogeochemical mechanisms affecting carbon, sulfur and metal(loid) dynamics. Sulfur isotope measurements provide a sensitive indicator of sulfur cycling and its importance in the release and attenuation of dissolved metal(loid)s in mine waste systems.

Non-traditional isotope (*e.g.*, Cr, Cu, Fe, Ni, Pb, Sb, Se, Zn) measurements provide meaningful information regarding the mechanisms controlling the concentrations of dissolved contaminants. Theoretical calculations and focused laboratory studies can be used to define the extent of fractionation associated with specific mechanisms. Integration of isotope measurements with comprehensive field sampling programs and mineralogical studies can provide further constraints on the processes controlling contaminant migration in mine-waste systems.