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Geochemical speciation and mineralogy influences metal bioavailability

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The geochemical environment is an important control on metal mobility and bioavailability when contaminants are released to freshwater systems. We show how integrating geochemical modeling, mineralogy, and bioavailability assessment using a model species of freshwater snail in laboratory experiments can elucidate the relative importance of exposure pathways (e.g., aqueous vs. dietary exposures). Aqueous complexation with inorganic (e.g., carbonate) and organic (e.g., dissolved organic carbon) ligands can affect metal adsorption onto mineral surfaces as well as mineral solubility, thus is a primary control on the partitioning of metals between the aqueous and solid phase. Aqueous complexation also affects the bioavailability of metals to aquatic organisms. For example, carbonate and organic carbon complexation can limit the bioavailability of uranium in surface waters with moderate hardness. In addition, solid-phase metal chemistry affects dietary uptake and bioavailability. Analysis of total metal concentrations in streambed sediments, tailings, and/or food sources is a key piece of information for understanding dietary exposure, but determination of the minerals that host the metals is equally important. For example, lead adsorbed onto iron oxyhydroxides or in a carbonate mineral (cerussite, $PbCO_3$) has significantly lower bioavailability than lead sulfate (anglesite, $PbSO_4$) or lead adsorbed onto diatoms. A detailed understanding of geochemical speciation, mineralogy, and associations with dissolved organic matter is important to understanding the bioavailability of metals, including uranium, copper, zinc, and lead. Applying this integrated approach to complex environmental systems with elevated metal concentrations, such as mine drainage and mine waste, can advance our understanding of the geochemical controls on bioavailability and ecosystem effects.