Uranium biogeochemistry: Nanometer to regional scales

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Uranium ore extraction and processing has produced groundwater contamination globally that is persistent and difficult if not impossible to remediate. The behavior of uranium at the landscape scale is goverened by a tapestry of interdependent biogeochemical reactions that occur in complex natural materials at the nanometer scale (1 to 1,000 nm). Microbial cells and cellular processes, nanominerals, and diffusive processes coexist within these small spaces and strongly interact in space and time. Relatively little is known about the spatial distributions of biogeochemical reaction sites and products at this scale, particularly for contaminant species such as uranium. This is due in part to the difficulty of imaging the distributions and speciation of metals and sulfur at distances of 1 to 1,000 nm in heterogeneous naural samples at environmentally-relevant concentrations under hydrated conditions.

Our group has been studying the speciation of U(IV) in the contaminated aquifer at the former uranium ore processing site at Rifle, Colorado, USA, following amendment of sediments with organic carbon (acetate) to promote bioreduction. We have also been studying uranium immobilization in organic-rich sediments naturally present in contaminated aquifers in the upper Colorado River Basin, USA. This work shows that uranium binding to organic matter plays a major role in uranium speciation, reactivity, and redox transition pathways. These nanometer-scale interactions appear to help mediate uranium behavior at the scale of the upper Colorado River Basin.