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Hydrological Tracer Studies at a DOE IFRC Site in Rifle, Colorado

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Research activities at the Department of Energy Integrated Field Research Challenge (IFRC) site in Rifle, Colorado, have repeatedly demonstrated that uranium can successfully be removed from groundwater through stimulation of indigenous metal-reducing bacteria, such as members of the *Geobacteraceae*. While such removal strategies may be effective over short timescales (100's of days), the large inventory of uranium sorbed to aquifer sediments contributes to a diffuse and widespread contaminant plume at the Rifle site, which leads to persistent uranium contamination of groundwater. Complicating the long-term plume behavior are seasonal changes in aquifer properties (e.g. fluctuating water levels, variations in dissolved oxygen and organic carbon, etc.) that accompany snowmelt and elevated river stage in the Colorado River, which borders the site to the south. As the impact of such changes on contaminant behavior at Rifle is poorly understood, development of novel methods, such as isotopic techniques, is warranted to better constrain aquifer flow properties and to resolve surface water-groundwater interactions that may influence long-term uranium mobility.

In addition to floodplain scale (ca. 10 hectare) studies of uranium mobility, ongoing research at Rifle is investigating coupled approaches to desorb and reductively immobilize pools of sorbed and aqueous uranium. Performed as part of the "Super 8" field experiment (2010), a variety of conservative and non-conservative chemical compounds were injected into the Rifle aquifer to assess transport properties and quantify rates of reductive immobilization of uranium under different alkalinity conditions. Conservative tracers included sodium bromide (20mM), deuterium (500‰), and O-18 (25‰), whereas reactive amendments included sodium bicarbonate (50mM) and sodium acetate (6mM); the latter two were designed to enhance desorption of uranium from sediments and stimulate the activity of uranium-reducing microorganisms, respectively. The need to introduce the reactive amendments at different times and locations necessitated the use of distinct conservative tracers to delineate the spatial distribution of the injected plumes within the aquifer as a function time. Here we report on the field measurements of groundwater stable isotopes (δD and δ^{18}O) and bromide concentrations during the injection experiments. The data indicate differences in groundwater transport pathways as a function of injection and highlight the value of using multiple conservation tracers to resolve overlapping injection source terms.