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Persistence Of Uranium Groundwater Plumes: Contrasting Mechanisms At Two Contaminated Doe Sites

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PERSISTENCE OF URANIUM GROUNDWATER PLUMES: CONTRASTING MECHANISMS AT TWO CONTAMINATED DOE SITES

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We examine subsurface uranium (U) plumes at two U.S. Department of Energy sites located near large river systems. Following excavation of contaminated materials, both sites were projected to naturally flush remnant uranium contamination to levels below regulatory limits (e.g., 30 µg/L), within 10 years at the Hanford 300 Area (Columbia River) and 12 years at the Rifle site (Colorado River). The observed rate of attenuation was much lower than expected at both sites. Current understanding suggests that the two sites have common, but also differing mechanisms controlling plume persistence. At Hanford, the persistent source is adsorbed U(VI) in the deep vadose zone, released to the aquifer during water table excursions associated with spring high-water in the Columbia River. The release of U(VI) from the vadose zone and its transport within the oxic, coarse-textured aquifer sediments is dominated by kinetically-limited surface complexation. While the U sources sustaining the plume at the Rifle site are multiple, there is evidence that slow oxidation of naturally reduced contaminant U(IV) in the saturated zone, as well as a continuous influx of natural U(VI) from up-gradient sources, is important. Equilibrium surface complexation controls the U(VI) migration rate in the sub-oxic Rifle groundwater. Microbiologic activity is diverse at both sites. Strains of *Geobacter* and other metal reducing bacteria are present, typically at low natural abundance, capable of enzymatic U(VI) reduction in localized zones of accumulated detrital organic carbon, or after organic carbon amendment. Major differences between the sites include the geochemical nature of residual contaminant U; the nature of mineral adsorbents and the rates of kinetic processes (biotic and abiotic) influencing U(VI) solid-liquid distribution; the presence of detrital organic matter and the spatial heterogeneity in microbially-driven redox properties; and the magnitude of groundwater hydrologic dynamics controlled by river-stage fluctuations and aquifer properties (e.g., hydraulic gradient and conductivity). The comparative analysis of these sites provides important guidance to the

characterization, modeling, and remediation of groundwater contaminant plumes influenced by surface water interaction that are common worldwide.

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