Quantification of Hydrological, Geochemical, and Mineralogical Processes Governing the Fate and Transport of Uranium over Multiple Scales in Hanford Sediments

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This study is motivated by the scientific and technological needs of DOE sites in which contaminant transport is influenced by coupled anisotropic lateral flow, and by mineralogical and geochemical heterogeneities in layered subsurface sediments. The objective of this research is to provide validated scaling strategies which can be applied to existing contaminant distributions and migration scenarios at Hanford and related DOE sites. We will accomplish this through an integrated multi-scale approach involving (1) Quantifying unsaturated hydraulic, mineralogical, and geochemical transport parameters within small intact cores of sedimentary layers, (2) Upscaling these parameters using a combination of numerical, composite medium, and fractal approaches to compute effective coupled hydraulic and uranium transport parameters, and (3) Validating this methodology by application of the effective parameters to progressively larger scales consisting of intact multiple sedimentary beds that encompass both lateral and vertical transport of uranium. The unique aspects of our experiments include using an innovative Ultra Rock Centrifuge (URC) to measure moisture retention, hysteresis, and unsaturated hydraulic conductivity, novel surface analysis techniques (e.g., x-ray absorption and micro-Raman spectroscopy), and real-time uranium transport in a natural, multi-layered, instrumented system.

We will implement a multi-scale sampling strategy at Hanford in Fall 2006 or Spring 2007 to collect samples at scales ranging from 20 to 1,000,000 cm^3. Intact and disturbed samples (20 cm^3) collected from single sedimentary beds will be analyzed using the URC, representing the first application of a technology widely used in the oil and gas industry to environmental problems. The resultant hydraulic parameters will be coupled with small-scale geochemical and mineralogical studies to determine the geochemical environment of contaminant immobilization and to relate this environment to sedimentary heterogeneities, e.g., clay lenses, silt beds, and/or calcite cementation. A combination of numerical, composite medium, and fractal approaches will be applied to the small-scale data to compute effective coupled hydraulic and reactive transport parameters. These parameters will be subsequently applied to U(VI) transport data on larger intact samples (8000 cm^3) (previously funded by ERSP and the Tank Farm Vadose Zone Group), and to new U(VI) transport studies on meter-scale intact samples (1,000,000 cm^3) to determine scaling factors that extend from the pore- to the meter-scale. Our results will consist of an integrated dataset and validated coupled hydrological, mineralogical, and geochemical process models at molecular- to meter- scales in field-relevant, intact sediments. New strategies for coupling reactive transport with complex hydrology will be developed that are directly applicable to prediction and remediation of contaminant migration throughout the western U.S.