Environmental Sciences

INTEGRATED FIFLD CHALLENGE SITE Hanford 300 Area

U.S. Department of Energy Office of Science

Open-framework Coarse-san

Environmental Remediation Sciences Program



Multi-Scale Mass Transfer Processes Controlling Natural Attenuation and Engineered Remediation: An IFC Focused on Hanford's 300 Area Uranium Plume

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Overall Multiscale, multi-rate mass transfer influencing field-scale

- Secondary

 ➤ Physical, chemical, and microbiologic factors controlling fieldscale mass transfer

 Transferring laboratory kinetic data to field
- Iransterring laboratory kinetic data to held
 Kinetic effects of transients in water chemistry
 Microbiologic stability of remediation products
 Process evolution along flow paths
 Characterization and modeling approaches for mass-transfer dominated field systems
 Fundamental to applied science transfer

ANTICIPATED OUTCOMES

BACKGROUND 300 Area Uran

SCIENCE THEMES

► Outstanding, multidisciplinary collaborative effort that significantly

TISIOUY

Site received effluents from REDOX and PUREX process development (1944-1954) and N-reactor fuels fabrication (1976 – 1986)
Neutralized U(IV)-Cu(II) intric acid solutions were primary waste stream

37,00 – 55,000 kg of U and 255,000 – 300,000 kg of Cu
Wasted signosed to North (NPI) and South (SPI) Process Ponds

- advances science
 Characterization, experiment design, interpretation
 Basic underprinnings of EM-20 activities
 Enduring and accessible field experiment data sets for hypothesis and model testing

Linked groundwater – river system
 Groundwater trajectory and composition shifts between

fall/winter and spring/summer

- ► Improved linked multi-scale mass transfer/biogeochemical
 - models for reactive contaminants

 New conceptual understanding of mass transfer processes at different scales influencing field behavior
 - Desorption, dissolution, dissipation Effective reaction kinetics

Contaminant immobilization

EXPERIMENTAL SITE, MONITORING, AND CHARACTERIZATION



- Passive experiments will exploit natural gradients in aqueous chemistry resulting from river water intrusion.
 Continual water level monitoring at 12 locations will provide necessary hydrologic linkages.

MODELS AND MODELING STRATEGY

Evaluate role of mass transfer and microbiological processes on different forms of phosphate used to precipitate and immobilize U.

PLANNED EXPERIMENTAL PROGRAM

Injection experiments with varying HCO₃ and U(VI) concentrations, and U(VI) isotopic ratios

 Scale-dependent mass transfer, geochemical kinetics (adsorption/desorption) and wate pathway effects on U(VI) fluxes to groundwater. Infiltration experiments with varying water application rates, volumes, and composition (pH, HCO₂, Na/Ca)

Passive experiments to explore rising and falling water table effects on U(VI) solubilization and release from lower vadose zone

Injection experiments with polyphosphate, Ca-citrate/PO₄³⁻, organic P with HCO₃
 Collaborate with EM-22 and team if timing allows.

Passive experiments follow vadose zone pulses, or inland riverwater -

►U(VI) concentration dynamics within the groundwater plume (FY09 – FY10) Scale—dependent mass transfer involved in forward (adsorption), backward (desorp and steady-state (isotopic exchange) reaction processes in flow paths with different traiectories and residence times.

groundwater gradients ▶U(VI) fluxes from the vadose zone (FY10 - FY11)

- STOMP as the primary project model that integrates site-wide hydrogeochemical resu different types and newly developed process models for 3-D, reaction-based reactive transport calculations used in experiment planning, interpretation, and evaluation of future remediation actions
- remediation actions.

 Other codes developed by project participants with different and/or special capabilities for individual experiment interpretation, hypothesis testing, and inter-model comparisons (e.g., FLOTRAN for multi-continuum, mass-transfer limited geochemical calculations; and
- MODFLO for multi-scale mass transfer). Stochastic modeling of hydraulic conductivity, sorbent, mass transfer rate, and sorbed U(VI)
- distributions (e.g., hydro- and chemo-facies) by project experts, as well as spatial momen analyses of plumes resulting from different subsurface manipulations.

EXAMPLE OPPORTUNITIES FOR COLLABORATIVE RESEARCH

In-situ adsorption/desorption experiments of various types

▶Optimized and sustained remediation strategies (FY11 – FY12)

- ▶ In-situ adsorption/desorption experiments of various types

 Laboratory to fide comparisors.

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 ▶ Mass transfer processes of different types at different scales.

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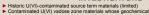
 ▶ Microbiology of hinked groundwater-river systems of low to high transmissivity.

 ▶ Geologic, hydrologic, geochemical, and biogeochemical modeling of different types.

 ▶ Microbiology and geochemistry of phosphate amended systems.

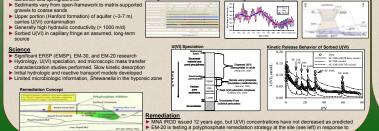
- Core materials and grab samples from vadose zone and aquifer experimental plots
 Aseptic samples of vadose zone and Hanford and Ringold formation aquifer sediments (for microbiological studies TBC, limited)
- * TBC = to be collected, see website for details: http://ifchanford.pnl.gov

MATERIALS AVAILABLE TO EXTERNAL INVESTIGATORS

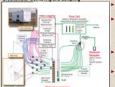




- ► Historic U(VI)-contaminated source term materials (limited)
 ▶ Contaminated U(VI) vadose zone materials whose geochemical speciation and mass transfer properties have been determined (limited)
 ▶ Uncontaminated vadose zone and aquifer sediments from various locations
 ▶ Circumneutial site groundwaters with variable U(VI), HCO₂, and Ca concentrations



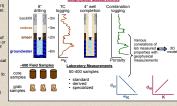
The site met our selection criteria and is outside of the polyphosphate flow path (PFP)



The monitoring wells have downhole instrumentation for temperature and electrical resistances tomography (ERT). Remotely activated pumps allow for timed sampling of individual wells for plume capture. Pumper waters pass through a manifold system to flow cells in the field laboratory for ion selective electrode (ISE) measurement and additional sampling for fab analysis.



Scientific questions examine the rate (a) of





>SOH + UO₂²⁺ + H₂O = >SOUO₂OH + 2H⁺ >SOH + UO₂2+ + CO₃2- = >SOUO₂HCO₃ I LIFF L LIFFF

U(V)) as a function of aqueous chemistry (AC) (below left).

Ii) Alessomement for locatized (VIV) groundwest concentrations and composition using a multi-level well water sampler (MLS) iii) Latorotory column or meter-scale flow-cell experiments where groundwaters with higher (-U) or lower (U) U(VI) concentrations, or those with different queues chemistry (AAC) are advected through contaminated sediment, in V) Up-scaled representations of equilibrium andor kinetic reaction parameters based on relationships to grain size, porosily, or other primary properties. The 3-D distribution of hydraulic conductivity (K) and porosity (particle volume distribution, PVD) will be established thro

A linked characterization and modeling strategy will allow rigorous field experimental interpretation and simulation.

A field-cable reactive transport model for U(V) will be developed with kinetic adsorption and desorption controlled by complexation to innerial surface sites (SOH) and mass transfer between mobile and immobile fluid domains at different propriets transport model will be established from:

particle size delibution (PSD), particle volume distribution (PVD), and hydratic conductivity (R) (below right). In J. Downhole measurements of localized groundwater velocities usign a electromagnetic borehole flow neither (EEF). III, J. Norneactive tracer experiments (temperature, Br. PFBA, and other tracers) over different flow paths. The UVI) reaction model will be established from: 1). Facilies scale measurements of total contaminant U (U_{thata}), and equilibrium (P_d) and kinetic (P_{uut}) reaction parameters of UVI) as a function of aqueous chemistry (C), (below left 1).

i.) Correlations between down-hole geophysical measurements and facies-scale laboratory hydrophy particle size distribution (PSD), particle volume distribution (PVD), and hydraulic conductivity (IX) rheat