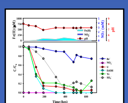
The Oak Ridge Field Research Center : Advancing Scientific Understanding of the Transportation, Fate, and Remediation of Subsurface Contamination Sources and Plumes

Historical research, development, and testing of nuclear materials across this country resulted in subsurface contamination that has been identified at over 7,000 discrete sites across the U.S. Department of Energy (DOE) complex. With the end of the Cold War threat, DOE has shifted its emphasis to remediation, decommissioning, and decontamination of the immense volumes of contaminated groundwater, sediments, and structures at its sites. DOE currently is responsible for remediating 1.7 trillion gallons of contaminated groundwater, an amount equal to approximately four times the daily U.S. water consumption, and 40 million cubic meters of contaminated soil, enough to fill approximately 17 professional sports stadiums.* DOE also sponsors research intended to improve or develop remediation technologies, especially for difficult, currently intractable contaminants or conditions.

The Oak Ridge FRC is representative of some difficult sites, contaminants, and conditions. Buried wastes in contact with a shallow water table have created huge reservoirs of contamination. Rainfall patterns affect the water table level seasonally and over time. Further, the hydrogeology of the area, with its fractures and karst geology, affects the movement of contaminant plumes. Plumes have migrated long distances and to surface discharge points through ill-defined preferred flowpaths created by the fractures and karst conditions. From the standpoint of technical effectiveness, remediation options are limited, especially for contaminated groundwater. Moreover, current remediation practices for the source areas, such as capping, can affect coupled processes that, in turn, may affect the movement of subsurface contaminants in unknown ways. Research conducted at the FRC or with FRC samples therefore promotes understanding of the processes that influence the transport and fate of subsurface contaminants, the effectiveness and long-term consequences of extant remediation options, and the development of improved remediation strategies.

*Status Report on Paths to Closure, DOE/EM 0526, U.S. Department of Energy, Washington, D.C., March 2000.

FRC research to date:



Simultaneous uranium and technetium immobilization during field push-pull tests with addition of electron donor (ethanol)

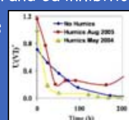
Achieved microbially mediated reduction of U, Tc-99, and nitrate

Maintained U and Tc reduction in flow cells for ~ 2 years, simulating a subsurface biocurtain

Observed nitrate and NO_x inhibition and reoxidation and Ca inhibition

Identified microbial toxicity by Ni and other metals

Obtained increased U reduction in lab and field by adding humic acid, even in presence of Ca or Ni inhibitors



U reduction rates increase during push-pull tests with FRC HA

Found lower microbial biomass, diversity in contaminated vs. uncontaminated areas

Isolated bacterial strains of metal- and nitrate-reducers in contaminated areas

Discovered metal resistance genes in isolates; a functional gene array is being developed to screen for metal resistance

Observed discrepancies between laboratory and field rates of microbial reduction (1,000 to 100,000 times slower in the field)

Compiling rate data in tables and report; incorporated into numerical modeling

Coupons or bug traps

Portable immunoassay biosensor for U

Solid phase characterization

Microbial analysis

Geophysical characterization and monitoring

Novel hydraulic and tracer testing

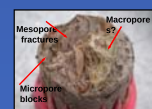
Current FRC research opportunities:

Field-scale reduction

PNNL's Area 2 manipulations (mirobarriers)

New Area 3 field plot proposed by OSU

Plots in new Areas 4 and 5 (U, Tc, nitrate, organics)



Multiple pore domains

Inhibition/Reoxidation

Stanford's Area 3 experiments will focus on reoxidation

OSU's U sequestration via sulfate reduction + co-precipitation with sulfides

Impact of aging U, other precipitates on sequestration and reoxidation

Aquifer and well-screen clogging from mineral precipitation, gas production

Uranium (VI) reduction/reoxidation experiments in Area 3 field plot

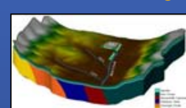
Microbial Communities

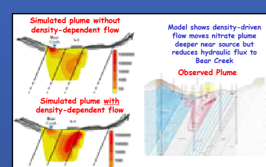
Physiology of organisms relevant to bioremediation

Overlap and competition of microbial communities catalyzing metal or nitrate reduction, or destruction of organics

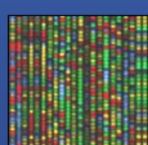
Impacts of sampling artifacts—e.g., well diameter, attached vs. detached organisms, heterogeneity, spatial distribution of microorganisms vs. scale of sampling

Rates and mechanisms, numerical modeling





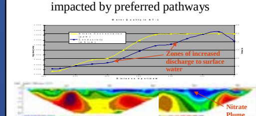
Development of characterization and monitoring tools



Microarray (ORNL)

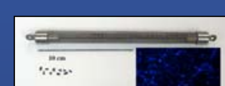
Susan Hubbard (LBNL) conducting cross-well geophysics

Discharge at Bear Creek Tributary is impacted by preferred pathways



Correlating surface resistivity tomography profile at NT-1 and surface water quality helps locate preferred pathways and discharge

Field portable immunoassay biosensor developed for detection of U *in situ* (Blake of Tulane University)



Coupons, or "bug traps," for rapidly assessing *in situ* microbial activity (INEL)

Future FRC research opportunities:

Stewardship

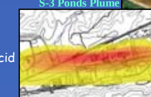
Understanding attenuation and enhanced attenuation of large, diffuse, mixed waste contaminant plumes and sources

- **Interactions of U, Tc, nitrate, other inorganics and organics**

PCE	Vinyl chloride	Freon	Phenol
TCE	Carbon tetrachloride	Citrate	Butanone
DCE	Acetone	Acetate	Benzoic acid

- **Multiple hydrobiogeochemical environments**

S-3 Ponds Plume



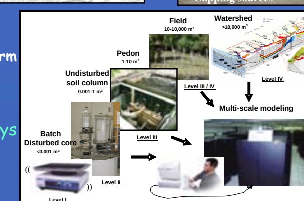
Capping sources

Heterogeneity and scaling

- **Parameters for understanding and predicting long-term attenuation and remediation**
- **Impact of coupled processes on reactive transport**

Characterization and imaging of preferred pathways

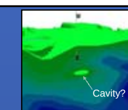
- **Understanding long-term impacts on transport**
- **Relationship with matrix and source**



Improved characterization, sensors, monitoring tools, and model predictions

Hg transport, fate, and remediation

- **Contaminated and Background Areas identified**
- **Vapor and dissolved phase transport**
- **Bacterial mercury resistance tolerance/capacity**
- **Culture mercury-resistant bacteria, and characterize plasmids Hg resistance gene**



Preferred pathway appearing as seismic anomaly in Area 5 (2070m/sec contour)

Field research — David Watson

Stanford and ORNL — Craig Criddle, Phil Jardine, Wei-Min Wu, Peter Kitanidis, and Mike Fienen

OSU/OU — Jack Istok, Lee Krumholz, Jim McKinley, and Baohua Gu

PNNL/ORNL/UA — Tim Scheibe, Scott Brooks, Eric Roden

Working Groups — Phil Jardine

Geochemical/Geophysical Characterization — Phil Jardine

Microbial Community Analysis — Joel Kostka

Rates and Mechanisms of Microbially Mediated Metal Reduction — Bill Burgos

Numerical Modeling — Jack Parker

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