Multiple Tracer Testing Approaches for Improved Groundwater Flow and Reactive Transport Modeling Input Parameters

Raymond Johnson, Ph.D., Senior Geochemist/Hydrogeologist
Navarro Research and Engineering, Inc.
Contractor to the U.S. Department of Energy (DOE) Office of Legacy Management (LM)
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Co-authors
- Los Alamos National Lab
  - Paul Reimus, Ph.D.
  - William Dam
  - William Frazier
  - Richard Bush
- Navarro Research and Engineering, Inc.
  - Aaron Tigar
  - Sarah Morris
  - Kara Tafoya

Uranium Ore-Processing Sites Past Modeling of Natural Flushing
- Tailings have been removed, assumed source removed
- Contaminant plume in alluvial sands and gravels, assumed limited attenuation (uranium moving only slightly slower than groundwater flow rates)
- Examples: Rifle, Riverton, Grand Junction, Naturita, etc.

Actual Data Compared to Model Predictions

New Data (20+ Years of Hindsight)
- Natural flushing not occurring as previously modeled
  - Persistent secondary sources
- Solid-phase uranium sources that were not accounted for in prior modeling, related to:
  a) Precipitates with associated uranium below the former tailings
  b) Evaporites above the water table due to plume wicking into the silt
  c) Organic zones near the river

Grand Junction, Colorado, Site
Three Areas for Tracer Testing

- Gypsum below water table
- Evaporites in the unsaturated zone
- Naturally reduced zone (NRZ) with organics

Former Tailings Deposition Area
Former Uranium Pilot Mill

Column Test Results and Modeling

- Key processes: dual porosity, sorption, and mineral dissolution

Stop-flow U increase and fission track radiography indicates the need to consider dual porosity

Tracer Testing Objectives

- Evaluation of tracer testing methods to better understand contaminant release and transport processes at the field scale related to plume persistence
- Provide data for revising site conceptual models and estimating reactive transport modeling parameters
- Compare field-scale uranium release and transport process parameters with those derived from existing column tests
- Ultimate goal: improved predictions of contaminant transport (especially uranium)
- Approach is applicable at other sites, but first use Grand Junction site as a demonstration

Tracer Testing Methods and Derived Data

- Borehole dilution
  - Groundwater flow velocity and direction, vertical stratification
- Saturated zone push-pull test (single well injection and extraction)
  - Dispersion, dual porosity, adsorption/desorption
- Saturated zone cross-hole test (inject in one well and extract from another well)
  - Same as push-pull test plus mineral precipitation/dissolution
- Unsaturated zone infiltration with saturated zone cross-hole test
  - Adds data on unsaturated zone release rates/processes

Borehole Dilution

Replace well bore water with deionized water and then let it drift

Push-Pull

"Push" river water with tracers, followed by river water without tracers, could allow for some "drift" time. Then "pull" it all back.
Dispersion and Sorption Influence

- Five-hour injection, 45-hour chase, two-hour drift

Dual Porosity Influence

- Five-hour injection, 45-hour chase, two-hour drift

Cross Hole

- Use borehole dilution results to align injection well with groundwater flow direction

Theoretical Results

- Use pumping longer than injection

Dispersion and Sorption Influence

Example Data (Injecting Cl, SO₄, and U)
Summary and Conclusions

- Goal: improved predictions of contaminant transport
- Need to revise past conceptual and numerical models with new information
- Column testing and modeling indicates need for dual porosity, sorption, and mineral dissolution processes
- Multiple tracer testing approaches are proposed to test multiple processes at the field scale
- Tracer testing results will be used to revise or develop new input parameters for predictions (reactive transport modeling)
- Stay tuned for Grand Junction site results next year