Characterization Approaches for Radionuclide-Contaminated Subsurface Sites

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Conceptual model framework

Characterization for factors controlling fate and transport and remedy selection

- Vadose Zone
  - Disposal chemistry affects
  - Transport factors

- Groundwater
  - Speciation and biogeochemistry
  - Secondary sources
  - Groundwater dynamics
  - Natural attenuation processes

Conclusions
Conceptual Model Framework

Surface Source

Vadose Source

Plume System

Plume Segment 1

Plume Segment 2

Saturated Zone Source

Sandy aquifer material with lenses of silt and clay

Fine deposits in valley near stream

Truex et al. 2011
Conceptual Model Framework

Segment 1
- High redox
- Fe rich sand
- High CEC (lenses)

Segment 2
- Low redox
- High CEC (lenses)

Reactive Facies: Fe-coated sand, High CEC lenses (Sandy aquifer material with lenses of silt and clay)

Reactive Facies:
- Soil organic material
- Clay minerals
(Fine deposits in valley near stream)

Truex et al. 2011
Disposal Chemistry

- Co-contaminants and other characteristics of the disposed waste may impact transport for the contaminant of interest. These effects may be most intense near the disposal location (vadose zone).

Transport Factors

- For surface waste disposal, transport of contaminants through the vadose zone affects the nature of the source to groundwater.
Disposal Chemistry

Szecsody et al. 2013
Truex et al. 2014
<table>
<thead>
<tr>
<th>Extraction Solution</th>
<th>Hypothesized targeted sediment components</th>
<th>Interpreted uranium mobility of extracted fraction</th>
<th>Color Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Aqueous: uncontaminated Hanford groundwater</td>
<td>Uranium in pore water and a portion of sorbed uranium</td>
<td>Mobile phase</td>
<td></td>
</tr>
<tr>
<td>2. Ion Exch.: 1M Mg-nitrate</td>
<td>Readily desorbed uranium</td>
<td>Readily mobile through equilibrium partitioning</td>
<td></td>
</tr>
<tr>
<td>3. Acetate pH 5: 1 hour in pH 5 sodium acetate solution</td>
<td>Uranium associated with surface exposed carbonate precipitates, including uranium carbonates, or other readily dissolved precipitates</td>
<td>Moderately mobile through rapid dissolution processes</td>
<td></td>
</tr>
<tr>
<td>4. Acetate pH 2.3: 1 week in pH 2.3 acetic acid</td>
<td>Dissolution of most carbonate compounds, including uranium carbonates, and sodium boltwoodite</td>
<td>Slow dissolution processes are associated with uranium release from this fraction such that uranium mobility is low with respect to impacting groundwater</td>
<td></td>
</tr>
<tr>
<td>5. 8M HNO₃: 2 hours in 8M nitric acid at 95°C</td>
<td>Dissolution of most minerals expected to contain uranium, considered to represent total uranium extraction for this study¹</td>
<td>Very slow dissolution processes are associated with uranium release from this fraction such that uranium mobility is very low with respect to impacting groundwater</td>
<td></td>
</tr>
</tbody>
</table>

Szecsody et al. 2010, 2012
Disposal Chemistry

Szecsody et al. 2010

Serne et al. 2010
There are characteristic behaviors that are useful in assessing the nature of contaminant transport from aqueous waste disposal/leaks to the vadose zone.

There are two primary categories of transport behavior:

- Category I: small volume disposed compared to vadose zone thickness
- Category II: large volume disposed compared to vadose zone thickness
Category I

- Disposal site
- Contaminated zone

Category II

- Disposal site
- Contaminated zone

Graphs showing solute discharge over time for Category I and II, with discharge rates for 10 m and 25 m.

Truex et al. 2015a
### Analysis/Characterization Framework

<table>
<thead>
<tr>
<th>Vadose Zone Parameters</th>
<th>Waste Disposal Parameters</th>
<th>Groundwater Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness ($L_v$)</td>
<td>Aqueous volume ($V_{wd}$)</td>
<td>Groundwater Darcy flux ($q_a$)</td>
</tr>
<tr>
<td>Recharge rate (historical, current, and estimated future rates) ($R$)</td>
<td>Disposed mass ($M_{wd}$)</td>
<td>Contaminant mixing thickness in aquifer ($L_a$)</td>
</tr>
<tr>
<td>Porosity ($n_v$)</td>
<td>Rate of waste disposal ($R_{wd}$)</td>
<td>Monitoring well screen length for compliance ($s$)</td>
</tr>
<tr>
<td>Contaminant retardation coefficient ($R_{cv}$)</td>
<td>Contaminant concentration ($C_{wd}$)</td>
<td>Porosity ($n_a$)</td>
</tr>
<tr>
<td>Current vertical distribution of contamination</td>
<td>Surface area of aqueous disposal ($SA_{wd}$)</td>
<td>Contaminant retardation coefficient ($R_{ca}$)</td>
</tr>
<tr>
<td>Moisture content profile ($\theta_v$)</td>
<td>Acidity or alkalinity of the waste</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ionic strength and co-contaminants/species in the waste</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Timing of waste disposal</td>
<td></td>
</tr>
</tbody>
</table>

Truex et al. 2015a

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Evaluation of VZ Transport

Contaminant Distribution Characterization Tools

- Geophysical logging
  - Spectral gamma log
  - Neutron moisture log
- Borehole sediment samples
- Geophysics
  - Electrical Resistivity Tomography

Johnson and Wellman 2013
Speciation and biogeochemistry

- Characterization of a plume as $^{129}$I can be augmented with speciation information to provide insight into mobility.
- Iodide and iodate have different transport characteristics.

### Table: Iodine and DOC Concentrations in Sediments

<table>
<thead>
<tr>
<th>Composite Sediment</th>
<th>Organic Carbon (%)</th>
<th>Inorganic Carbon (%)</th>
<th>Total Sediment Iodine (µg/g)</th>
<th>Total DOC (µM)</th>
<th>Iodide-spiked $K_d$ (mL/g)</th>
<th>Iodate-spiked $K_d$ (mL/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>0.12</td>
<td>0.92</td>
<td>4.79</td>
<td>284 ± 33</td>
<td>0.08</td>
<td>1.78</td>
</tr>
<tr>
<td>H2</td>
<td>0.04</td>
<td>0.01</td>
<td>0.68</td>
<td>0</td>
<td>0.00</td>
<td>0.83</td>
</tr>
<tr>
<td>H3</td>
<td>0.15</td>
<td>0.18</td>
<td>2.10</td>
<td>94 ± 17</td>
<td>3.38</td>
<td>3.94</td>
</tr>
</tbody>
</table>

Xu et al. 2015
Truex et al. 2015b
Groundwater Elements

- Secondary sources (leaching)
  - Uranium sources related to periodic rewetting and leaching

Peterson et al. 2008
Groundwater Elements

Secondary sources (leaching)

- Uranium sources related to periodic rewetting and leaching
- Relevant for other inorganic contaminants (e.g., I, Cr)

Example Sediment

Szeicsody et al. 2010, 2012
Groundwater dynamics

- Hydrologic information can be augmented with geophysical techniques such as Electrical Resistivity Tomography.

Peterson and Connelly 2001
Groundwater Elements

- Groundwater dynamics
  - Hydrologic information can be augmented with geophysical techniques such as Electrical Resistivity Tomography

Johnson et al. 2015
Slater et al. 2010
Groundwater Elements

- Natural attenuation processes
  - EPA MNA Technical Protocol
    - “Scenarios” conceptual model document
    - Sediment biogeochemical factors

- Monitoring data
  - Temporal data provides insights not possible with static data
  - Natural or induced perturbations aid the interpretation of temporal data
Conclusions

- Conceptual model framework
  - Technical basis and organization of efforts
  - Communication

- Assess controlling factors
  - Fate and transport assessment
  - Technical focus
    - Characterization
    - Monitoring
    - Remediation
References

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