Overview of Remediation Technologies for Radionuclides in Soil and Groundwater

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Context
- Remediation technologies operate at the intersection of
  - radionuclide characteristics
  - the target problem
  - remedy functionality
  - remediation objectives

Outline
- Radionuclide characteristics related to remediation
- Considering end states and attenuation in remedy decisions
- Remedy technologies and approaches
- Remedy implementation
- Discussion focused on
  - Uranium, Tc-99, Sr-90, I-129, tritium
  - Groundwater protection and groundwater remediation

Radionuclide Characteristics (Friend or Foe)
- Half-life
  - Shorter is better (when exposure is controlled)
  - Sr-90 or tritium compared to uranium, I-129, or Tc-99
- Mobility (sorption)
  - Very low mobility generally good
  - Medium or high mobility - depends on the situation
    - Attenuated transport can be helpful (vadose zone contamination) or problematic (P&T)
    - Secondary sources are problematic unless balanced by attenuation

Radionuclide Characteristics (Friend or Foe)
- Biogeochemical interactions
  - Helpful
    - Uranium and Sr-90 interactions with phosphate
    - Uranium silicate precipitates
  - Mixed
    - Uranium and I-129 (and Cr) interactions with carbonate
      - Depends on location/extent
    - I-129 species transformation
      - Depends on change in mobility and potential for attenuation/sequestration
    - Uranium and Tc-99 redox
      - Depends on setting and role in a remedy
  - No interactions
  - Tritium

Disposal Chemistry

Szecsody et al. 2013
Truc et al. 2014
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Radionuclide Characteristics
(Friend or Foe)

- The Conceptual Site Model helps us decide:
  - Friend or foe for risk and transport
  - Friend or foe for remediation

![Diagram of Conceptual Site Model](Truex et al. 2017a)

Considering End States and Attenuation in Remedy Selection

- Systems-Based Assessment
  - Site Data
  - Source Terms

- Conceptual Model
  - MNA-style investigation
  (Attenuation/transport processes)

- Refined Conceptual Model
  - Assess risk and appropriate end state

- Remedial Strategy
  - Minimal impact (MNA)
  - Full remedy

- Partial remedy
  - Enhancements and targeted actions

![Diagram of Remedial Strategy](Truex et al. 2017a)

Remedy Technologies and Approaches

- Vadose zone
  - Attenuation
    - Consider transport processes in the vadose zone
    - Flux control (enhanced attenuation)
    - Physical stabilization
    - Hydraulic control
    - Biogeochemical stabilization
    - Extraction (e.g., excavation, soil flushing)
    - Cost/benefit
    - Groundwater treatment (e.g., phosphate)
    - Consider vadose zone source characteristics for groundwater impact

![Diagram of Vadose Zone Attenuation](Dresel et al. 2011)

Attenuation

- Source and Flux to Groundwater
  - Natural Attenuation

- MNA for Vadose Zone/Groundwater System
  - Source
  - Flux
  - Natural Attenuation Capacity

![Diagram of MNA for Vadose Zone/Groundwater System](Dresel et al. 2011)

Desiccation

- Desiccation as hydraulic control

![Diagram of Desiccation](Truex et al. 2017b)

Geochemical stabilization – vadose zone

- Ammonia gas for uranium sequestration

![Diagram of Geochemical Stabilization](Szecsody et al. 2012)
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Uranium source zone

- Periodically rewetted zone

Geochemical stabilization – periodically rewetted zone

- Phosphate treatment for uranium

Remedy Technologies and Approaches

- Groundwater
  - Attenuation
  - EPA guidance
  - Enhanced Attenuation and Source Control
  - Physical stabilization
  - Hydraulic control
  - Biogeochemical stabilization
  - Extraction (P&T)
  - Cost/benefit
  - Volumetric Treatment/Permeable Reactive Barriers
  - Scale, transport, attenuation

Carbonate interactions

- Uranium, iodate, and chromate co-precipitates with calcite

100-N Strontium

- Only near-river strontium is a risk to the river
- Monitoring linked to remedy approach

Remedy Implementation

- Amendment distribution
  - Vadose zone gas phase
  - Phosphate mobility
  - Particles
  - Bioremediation amendments
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Reductants

- ZVI
- SMI

Truex et al. 2011a
Truex et al. 2011b

Remedy Implementation

- Adaptive Site Management
  - National Research Council
  - ITRC
    - Remediation Management of Complex Sites
    - http://rmcs-1.itrcweb.org/
- Exit Strategies (P&T)
  - http://bioprocess.pnnl.gov/Pump-and-Treat.htm


References


Truex, MJ et al. 2014. Conceptual Model of Uranium in the Vadose Zone for Acidic and Alkaline Wastes Discharged at the Hanford Site Central Plateau. PNNL-23666, Pacific Northwest National Laboratory, Richland, WA.