Radionuclide Plume Remediation Design and Implementation Considerations Based on Hanford Site Experiences

MICHAEL TRUEX
Pacific Northwest National Laboratory

Topical Outline

- **Permeable Reactive Barriers** – Implementation needs to be integrated with understanding of plume behavior
- **Persistent Plumes** – Contaminant source characteristics and driving forces for hydraulic conditions strongly impact plume behavior and remedy selection
- **Vadose Zone Remediation** – Vadose zone processes controlling contaminant fluxes to groundwater impact remediation approaches
- **Monitoring and Predictive Modeling** – Coupled applications of predictive modeling and monitoring provide effective remedy performance evaluation

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Hanford 100-N Area Disposal Crib

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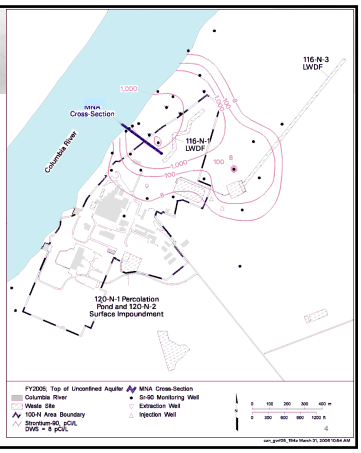
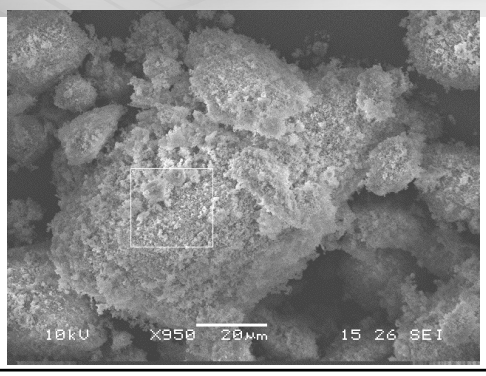
100-N Area Strontium Plume

- History
  - Large hydraulic driving force spreads Sr-90 during operations
  - Post-disposal: water table drops, Sr-90 plume is persistent
- Plume behavior
  - Sr-90 is strongly adsorbed to sediments, significantly slowing transport
  - Sr-90 has a half life of about 29 yr
  - Most of the Sr-90 contamination will decay before reaching the river



Precipitated Apatite as Strontium Treatment



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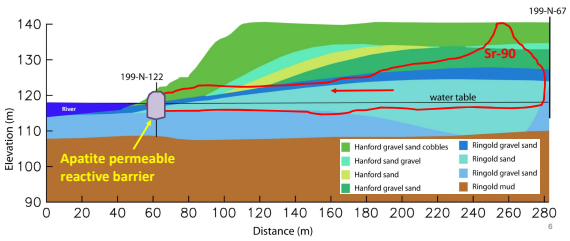
Permeable Reactive Barrier Conceptual Approach

- Apatite chemical injection formulation designed based on aquifer geochemistry
- Implementation design considers water table variation caused by adjacent river
- Lifetime of barrier designed based on plume transport and Sr-90 decay



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Key Points

- Natural attenuation occurs in most plumes and should be considered in remedy design
- Current and future plume behavior may be different than plume behavior during discharge or leak conditions
- Site geochemistry and hydraulic conditions are key factors in remedy design

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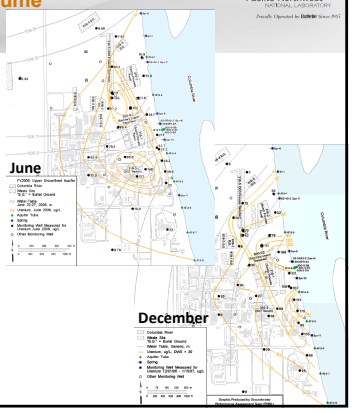
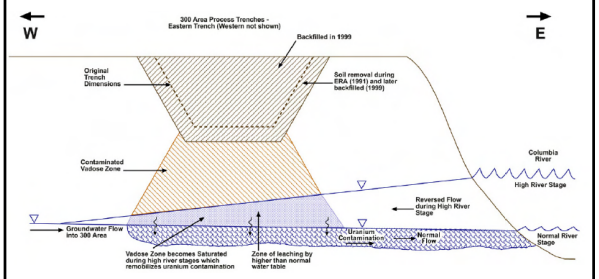
Persistent Uranium Plume

- Hanford 300 Area Example
  - Uranium waste solutions discharged to surface
  - Uranium plume adjacent to Columbia River
- Remedy History
  - Surface sites excavated and MNA selected as plume remedy
  - Plume is persistent and varies over time
  - Remedial investigation and re-evaluation of conceptual model
    - Uranium source present in lower vadose zone contacted by seasonal water table rise



Source and Boundary Conditions Control the Plume



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Key Points

- A conceptual site model is important to remedy design
- Monitoring over time may provide new information that should be incorporated into refinement of the conceptual site model and remedy design

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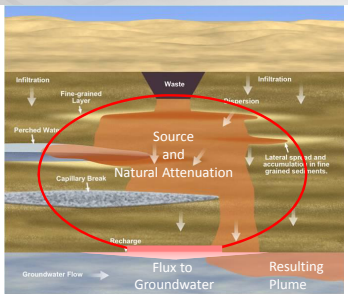
Contaminants in the Vadose Zone



Adapted from Dresel et al. 2011. *Environ. Sci. Technol.*

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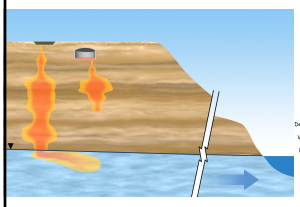
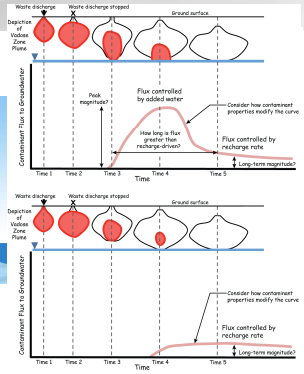
Vadose Zone Processes Impact Remedy Choice





Adapted from Truex and Carroll 2013, PNNL-21815.

Key Points

- Vadose zone physical, geochemical, and hydraulic characteristics in conjunction with the nature of the contaminant release need to be considered in evaluating the timing, duration, and intensity of contaminant discharge into groundwater
- Remedies need to consider the coupled vadose zone – groundwater system dynamics, including contaminant source flux and natural attenuation capacity, in selecting targets for actions in the context of the remediation goals

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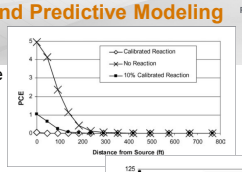
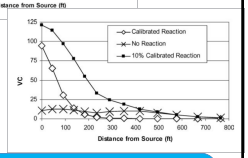
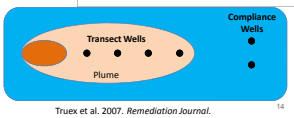
Coupling Monitoring and Predictive Modeling

- Model predictions for three scenarios
  - Base case natural attenuation
  - 10% natural attenuation
  - No attenuation
- Monitoring approach developed to compare observed concentration response to prediction scenarios
  - Evaluation at transect locations as early indication of performance
  - Enables monitoring of transient conditions







Truex et al. 2007. *Remediation Journal.*

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Conclusions

- Remedy Selection and Implementation Factors
  - Understand plume behavior
    - Natural attenuation
    - Hydraulic conditions
    - Source characteristics
    - Influence of vadose zone processes
  - Evaluate and integrate new data over time
    - Monitoring data
    - Initial remedy action can enhance understanding of plume behavior
  - Couple performance prediction with monitoring
    - Compare measured response to predicted response
    - Enable feedback for optimization or adaptive remedy approaches

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