EVALUATION OF COUPLED PROCESSES FOR DEEP DISPOSAL IN DIFFERENT GEOLOGIC MEDIA

Chandrika Manepally
Center for Nuclear Waste Regulatory Analyses
Southwest Research Institute®
San Antonio, Texas

Randall W. Fedors
Division of High-Level Waste Repository Safety
U.S. Nuclear Regulatory Commission
Washington, DC

International High–Level Radioactive Waste
Management Conference 2011
Albuquerque, New Mexico
April 10–14, 2011

Outline

- Introduction
- Salt Formations
- Crystalline Rocks
- Argillaceous Formations
- Engineered Barrier System
- Summary

Introduction

- Enhance U.S. Nuclear Regulatory Commission (NRC) Knowledge and Insights
- NRC Staff Current and Future Regulatory Framework for Disposal of High-Level Waste Will Be Informed by Insights Gained From International Programs
- Focus on Evolution of Thermal-Hydrological-Mechanical-Chemical (THMC) Coupled Processes in Different Geologic Media
- Role of Host Media
- Type of Host Media
  - Salt formations
  - Crystalline rocks
  - Argillaceous rocks
- Thermal Effects
  - Hydrology
  - Chemistry
  - Geomechanics

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Introduction (continued)

Properties of Potential Host Media Relevant for Disposal

Property	Salt Formations	Crystalline Rocks	Argillaceous Formations
Thermal Conductivity	High	Medium	Low
Permeability	Practically impermeable	Very low (unfractured) to permeable (fractured)	Very low to low
Deformation Behavior*	Visco-plastic (Creep)	Brittle	Plastic to brittle
Strength	Medium	High	Low to medium
Dissolution Behavior*	High	Very low	Very low
Sorption Behavior*	Very low	Medium to high	Very high

Source: Federal Ministry of Economics and Technology, "Final Disposal of High-Level Radioactive Waste in Germany—The Gorleben Repository Project," Germany (October 2008).
*Does not include changes because of thermal perturbation.

Favorable | Average | Unfavorable

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Host Media—Salt Formations

- Favorable Characteristics—Very Low Permeability, Self-Sealing (Creep) Process and Diffusive Transport

- Thermal Effects
  - Hydrology
    - Migration of fluid inclusions and effects on corrosion
    - Temperature gradients could result in thermally induced brine flow or two-phase flow
  - Chemistry
    - Chemical reactions in the seals and surrounding regions
    - Increased actinide solubilities and alteration of mineral assemblages leading to altered sorption characteristics
  - Geomechanics
    - Thermally induced stress could result in creation of new fractures or enhance existing pathways
    - Elevated temperatures could accelerate the rate of salt creep and mitigate fracture development

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Host Media- Crystalline Rocks

- Favorable Characteristics—Low Permeability in Unfractured Rocks, High Strength, High Sorption, and Low Dissolution

- Thermal Effects
  - Hydrology
    - Creation of thermo convective cells in fractures and faults could impact the flow regime
      - Depends on continuity and connectivity of fractures
  - Geomechanics
    - Differential mechanical stresses, changes to fracture apertures, and the subsequent modification of hydraulic behavior

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Host Media- Argillaceous Formations

- Favorable Characteristics —Low Permeability, Self-Sealing Fractures, Low Diffusion Coefficient, and High Sorption
- Thermal Effects
  - Chemistry
    - Increase in chemical reactivity of argillites (mineralogical transformations)
    - Soret Effect
    - Temperature-dependent parameters—solubilities, sorption coefficients, diffusivity, and density
    - Impact radionuclide transport in the near field
  - Hydromechanical
    - Thermal expansion of the clay and the pore water
    - Pore pressure increase
    - Strength reduction of the material
    - Lowering of threshold value for the onset of creep and increase in creep rate

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Engineered Barrier System

- Bentonite or a Bentonite-Sand Mixture
- Favorable Characteristics—Low Hydraulic Conductivity, Very Low Diffusion, High Sorption, Good Colloid Filtration Capability, High Swelling Potential
- Thermal Effects
  - Hydro-Mechanical-Chemical
    - Steam generation during buffer resaturation can induce significant shrinkage
    - Cementation of the clay could cause brittleness and loss of expansion
    - Vapor and gas migration could lead to new fractures and fissures

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Points to Emphasize

- The Significance and Duration of Coupled Processes are Dependent on the Heat Load and Thermal Characteristics of the EBS and the Host Media
- Review of International and Collaborative Research Programs are Essential for Knowledge and Insights
  - Conceptualization of THMC coupled processes
  - Bounding calculations
- Limiting the Maximum Allowable Temperatures Resulted in THMC Processes of Limited Spatial Extent and Duration
  - Several features, events, and processes related to thermal perturbation were not evaluated, because of potentially low probability of occurrence or low consequence
  - Sparse field and laboratory data for temperature conditions above boiling in the host media
- The Maximum Temperature Limit of Below Boiling Appears Appropriate for Countries That Have Relatively Small Amounts of Waste with Low Thermal Loads (Especially if Reprocessing is Considered)
- Disposal of Relatively Large Amounts of High-Level Waste With Temperature Limits
  - Likely requires lowering of heat load to meet the temperature limit
  - May need longer temporary storage times
  - Might have repository designs with larger areal extension

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