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Geochemical Criteria for the Selection of Sites for Radioactive Waste Repository[1]

KHNP Training Program
Module 4: Repository Siting and Characterization

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NNSA National Nuclear Security Administration

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US Definitions of Radioactive Waste

Spent fuel

- Unreprocessed, irradiated reactor fuel

High level waste (HLW)

- Liquid or solid waste from reprocessing spent fuel

Transuranic (TRU) waste

- Waste with > 100 nCi of α-emitting TRU radioelements with half lives > 20 years per g of waste

Low-level waste (LLW)

- Not spent fuel, HLW, nor TRU
- Acceptable for disposal in shallow, land-disposal facilities

Geochemical Criteria – One of the Categories of Criteria

Geologic stability

Low population density and low potential for future population growth

Low probability of exploration for and development of natural resources

Geochemical characteristics

- **Nature of the response of the near field to high T and radiation during the thermal period**
- **Transport properties of far field**

Criteria for Repository Site Selection

No site satisfies all of the criteria

- **There is no perfect site!**

Geochemical Criteria for Repository Site Selection

Some important geochemical characteristics

- **Redox**
  - **Reducing conditions strongly preferred**
- **Groundwater composition**
  - **Low-ionic-strength (low-I) groundwaters are easier to model than high-I groundwaters**
- **Transport properties of host rock**
  - **Capable of sorbing radionuclides strongly**
  - **High sorptive capacity of host-rock minerals**

Effects of Redox Conditions

Many radioelements are much less mobile (lower solubilities, higher K_ds) if they speciate in their lower or lowest oxidation state

Relative mobilities

- **Tc(IV) < Tc(VII)**
- **U(IV) < U(VI)**
- **Np(IV) < Np(V)**
- **Pu(III) and Pu(IV) < Pu(V) and Pu(VI)**
- **Am(III) < Am(V)**

Site Selection for the Subseabed Disposal Program (SDP)

- SDP was an alternative US program for HLW and/or spent fuel from the mid 1970s until 1987
- Developed into an international program under the Organization for Economic Cooperation and Development's Nuclear Energy Agency (OECD/NEA)
- Collaboration among the European Union, France, Japan, Netherlands, UK, and US

Criteria for Selection of SDP Sites for Spent Fuel and HLW

Mid-plate, mid-gyre (MPG) regions

- Remote from mid-ocean ridges, subduction zones, etc.
  - ➢ Tectonic stability
- Remote from regions with ice-rafted debris
  - ➢ Climatic stability

Low probability of exploration for and development of natural resources

Criteria for Selection of SDP Sites for Spent Fuel and HLW

Unlithified (soft), fine-grained (clay) sediments with favorable transport properties

- **Low permeabilities**
- **High K_ds and low D_{eff}s**
- **Homogeneous, isotropic media**

Observed Geochemical Characteristics of SDP Sites

Acidification of the near field during the thermal period

Possible lithification of the sediments in the near field during the thermal period

Low permeabilities, high K_ds, and low D_{eff}s were measured

- **Evidence for pore water advection was observed in some locations**

Reductive immobilization of some radioelements was observed in experiments with reducing sediments

Geochemical Characteristics of Salt Sites Relevant to HLW

Salt is not as dry as the NAS thought in 1957

Brine migration

- **Fluid inclusions migrate up thermal gradient toward heat source**

Corrosion of waste packages and waste forms by brine

H_2 build-up from anoxic corrosion

Geochemical Characteristics of Salt Sites Relevant to HLW (cont.)

Reactions between brines and room contents control chemical conditions (brine composition, f_{O_2}, f_{CO_2}, pH, etc.) at least prior to human intrusion

- **A consequence of the low permeabilities and low H_2O contents of salt formations**