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SAND2015-2823C

Qualitative Evaluation of Options for Disposal of SNF and HLW

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Presented at the International High-Level Radioactive Waste Management Conference

Charleston, SC

April 15, 2015

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Goals and Objectives

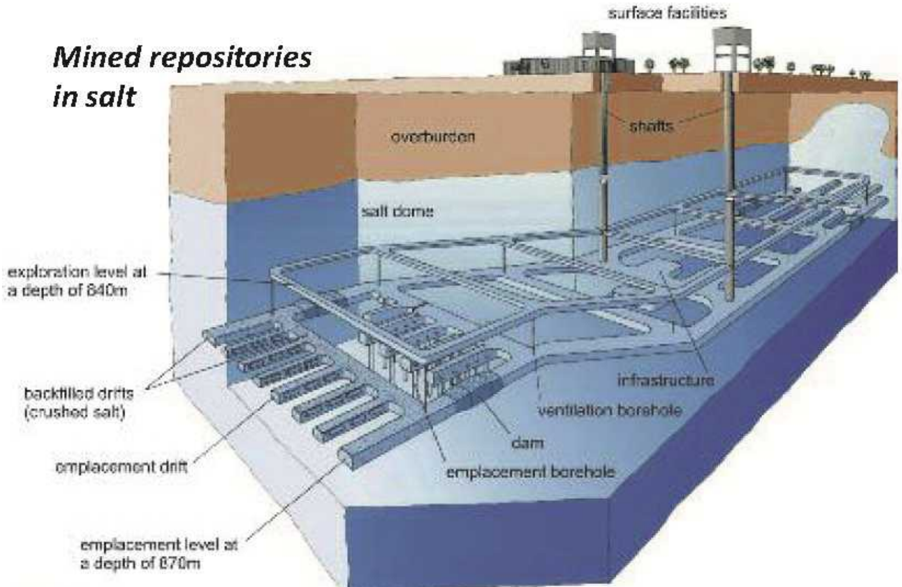
- Evaluate potential impacts of existing Spent Nuclear Fuel (SNF) and High Level Waste (HLW) on feasibility and performance of disposal options
- Provide answers to questions such as:
  - Is a "one-size-fits-all" repository a good strategic option?
  - Do different waste forms perform differently enough in different disposal environments to warrant different approaches?
  - Do some disposal concepts perform better with or without specific waste forms?
- Consideration of relative costs and benefits was deferred to another study
- Product was a report to the DOE NE Office of Fuel Cycle Technologies

Assumptions and Considerations

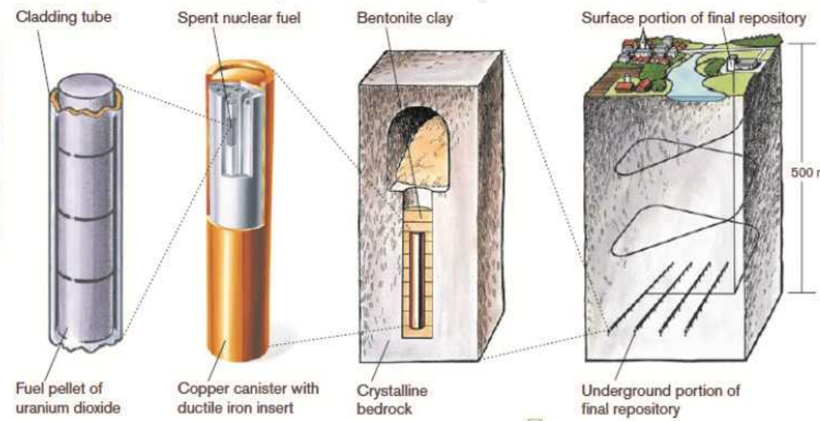
- Inventories of SNF and HLW represent those requiring deep geologic disposal
- Technologies limited to those that can be deployed in the near future
- Considered alternatives to planned treatments
- Programmatic constraints were not included in the evaluations
- Evaluation was qualitative

Disposal Concepts Considered

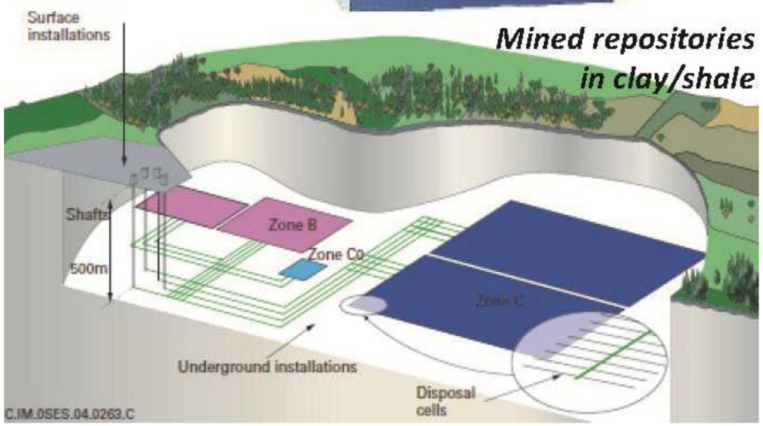
Mined repositories in salt



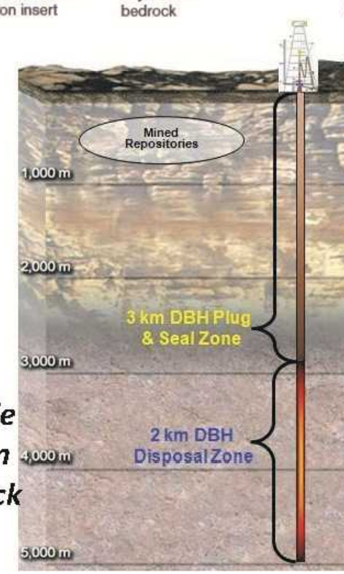
Mined repositories in crystalline rock



Mined repositories in clay/shale



Deep borehole repositories in crystalline rock



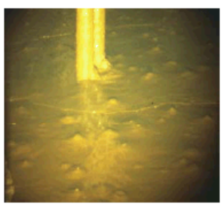
Waste Inventory

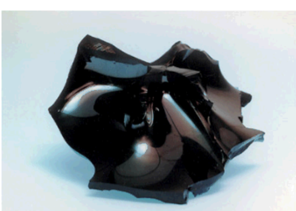
- SNF: Existing and reasonably foreseeable (as of 2048) SNF from existing commercial, defense, and research reactors (Wagner et al., 2012)
- HLW: Existing and projected (as of 2048) HLW from SRS, West Valley, Hanford and INL
- Waste types not presently planned for direct disposal without further treatment (e.g., calcine waste at INL; Cs-Sr capsules)
  - Some wastes have multiple alternative treatment options, including direct disposal, resulting in multiple possible waste forms for some waste types
- Final breakdown
  - 43 waste types
  - 50 possible waste forms
  - 50 waste forms grouped into 10 "Waste Groups" for analysis, based on similar properties

Waste Types, Waste Forms, and Waste Groups

Example of High-Level Waste Glass

Waste Type is what exists today





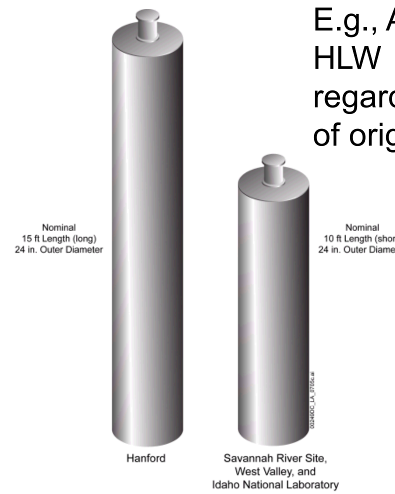
E.g., existing tank waste, existing HLW Glass

Waste Form is what could go underground

E.g., Canisters of HLW Glass from multiple sites and sources

Waste Group is an aggregation of Waste Forms with similar disposal characteristics

E.g., All HLW regardless of origin



Across the full inventory, this study identified
43 waste types, 50 waste forms, and 10 waste groups

Waste Groups Evaluated

- WG1: All Commercial SNF packaged in purpose-built disposal containers
- WG2: All Commercial SNF disposed of in dual-purpose containers of existing design
- WG3: All HLW glass (all types, existing and projected)
- WG4: Other engineered waste forms, including
  - Treated Na-bonded sodalite waste
  - Treated Na-bonded metal waste
  - Calcine waste treated by hot isotatic pressing (HIP), with and without additives
- WG5: Metallic and non-oxide spent fuels
  - E.g., N-reactor, various research reactors
- WG6: Na-bonded fuel
  - E.g., Fermi-1
- WG7: DOE oxide fuels
  - Includes some HEU (e.g., Shippingport)
- WG8: Salt, granular solids, powders
  - Includes salt wastes from electrorefining of Na-bonded fuel, untreated calcine, untreated Cs-Sr capsules
- WG9: Coated-particle fuel
  - E.g., Fort St. Vrain, Peach Bottom
- WG10: Naval fuel

Criteria and Metrics

Disposal Option Performance	Confidence in Expected Performance Bases	Operational Feasibility	Secondary Waste Generation	Technical Readiness	Safeguards and Security
Likely to comply with long-term standards? (Yes/No)	Additional EBS components needed above baseline for each design concept Robustness of information; simplicity vs. complexity; knowledge gaps	Ease in ensuring worker health and safety at all stages Special physical considerations at any stage based on physical characteristics	Amount of low-level waste generated during handling and treatment Amount of mixed waste generated	Status of waste form technologies Status of transportation and handling systems Status of disposal technologies	National security implementation difficulty Radiological dispersion device prevention implementation difficulty

Strong	Moderate	Weak/Uncertain	Not Feasible

Sample Results

Waste Group	Disposal Option Performance	Confidence in Expected Performance Bases	Operational Feasibility	Secondary Waste Generation	Technical Readiness	Safeguards and Security
WG1 - CSNF Purpose-built containers	Strong	Strong	Moderate	Weak/Uncertain	Strong	Strong
WG2 – CSNF DPCs	Strong	Moderate	Weak/Uncertain	Strong	Moderate	Strong
WG3 – HLW glass	Strong	Strong	Strong	Strong	Moderate	Strong
WG4 - Other engineered waste forms	Strong	Strong	Strong	Moderate	Moderate	Strong
WG5 – Metallic and non-oxide fuels	Strong	Strong	Moderate	Strong	Moderate	Strong
WG6 – Na-bonded fuel	Unknown					Strong
WG7 – DOE oxide fuels	Strong	Strong	Strong	Strong	Strong	Strong
WG8 - Salt, granular solids, powders	Strong	Strong	Moderate	Strong	Strong	Moderate
WG9 – Coated-particle spent fuel	Strong	Strong	Strong	Strong	Strong	Strong
WG10 – Naval Fuel	Strong	Moderate	Weak/Uncertain	Strong	Moderate	Strong

Legend: Strong | Moderate | Weak/Uncertain | Not Feasible

Disposal in Salt: Results

- Pros
  - Greater flexibility with respect to thermal management
  - Limited far-field transport increases confidence in estimates of long-term performance
  - Low permeability and reducing environment facilitate isolation of certain waste types
  - Suitable for some untreated waste types
  - Greater flexibility with respect to criticality concerns
- Cons
  - Operational challenges for very large waste packages
  - Knowledge gap with respect to response to thermal loads
  - Need for site-specific information

Disposal in Crystalline Rock: Results

- Pros
  - Significant world-wide experience with this medium
  - Stable rock properties enhance operational feasibility for very large packages
  - Stability of medium facilitates retrieval (if necessary)
  - Separation distances between waste forms can be maintained
- Cons
  - Less flexibility with respect to thermal management
  - Strong reliance on waste package lifetime results in lower confidence in long-term performance, presents design challenges
  - Some wastes may need to be segregated from others
  - Potential colloid transport in fracture networks
  - Movement and emplacement challenges for very large packages
  - Additional EBS components may be needed to address criticality concerns

Disposal in Clay/Shale: Results

- Pros
  - Significant world-wide experience with this medium
  - Limited far-field radionuclide transport reduces the reliance on the waste form and waste package lifetimes
  - Separation distance between waste forms can be maintained
- Cons
  - Keeping shafts and ramps open during the ventilation period presents a challenge, as does retrieval
  - Technologies for moving and emplacing very large packages have yet to be developed
  - Additional EBS components may be needed to address criticality concerns
  - Some wastes may need to be segregated from others

Disposal in Deep Boreholes: Results

- Pros
  - Depth of disposal simplifies thermal management
  - Less reliance on waste form and waste package performance increases confidence in performance bases
  - Smaller waste types are good candidates
  - Some untreated waste types may be good candidates
- Cons
  - Limited to disposal of very small packages
  - No detailed design or demonstration limits confidence
  - SNF would have to be repackaged or consolidated
  - Retrieval is difficult
  - Logistics for small volumes of waste presents new challenge
  - Disposal of small packages => handling more waste packages

Additional Insights

- Enough information does not exist to evaluate the direct disposal of Na-bonded SNF
- Disposal concepts similar with respect to safeguards and security
- Waste forms containing salt, granular solids, and powders raised moderate security concerns
- All waste-form treatment options have potential for increased generation of secondary waste

Conclusions

- Is a one-size-fits-all repository a good strategic option?
  - Any mined repository concept can accommodate all waste except Na-bonded SNF. Deep borehole is a good option for small waste packages.
- Do different waste forms perform differently enough in different disposal environments to warrant different approaches?
  - None were identified
  - Some waste forms may need to be segregated from others in a single repository
  - Small waste forms are potentially attractive candidates for deep borehole disposal
  - Salt provides more flexibility with respect to thermal management

Conclusions (cont'd)

- Did not identify technical issues with respect to disposal of mixed waste
- Disposal of SNF in DPCs can pose challenges in repository operations and demonstrating confidence in long-term performance

- Do some disposal concepts perform better with or without specific waste forms?
  - All disposal options considered can likely comply with applicable regulatory requirements
  - Untreated Na-bonded SNF was not evaluated
  - Large wastes are not suitable for deep borehole disposal
  - Implementation of disposal and demonstration of robust performance may be simpler for some disposal concepts than for others