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A Preliminary Performance Assessment for Salt Disposal of High-Level Nuclear Waste

Joon H. Lee*, Dan Clayton, Carlos Jove-Colon, Malcolm Siegel, and Yifeng Wang
Sandia National Laboratories, Albuquerque, NM 87185
*Contact author e-mail: jlee@sandia.gov

The U.S. is currently re-evaluating the policy on commercial used nuclear fuel (UNF) and high-level radioactive waste (HLW) management. As part of the Fuel Cycle Research and Development (FCRD) program supported by the U.S. DOE Office of Nuclear Energy, the Used Fuel Disposition (UFD) campaign has been studying generic disposal system environment (GDSE) concepts to support the development of a long-term strategy for geologic disposal of commercial UNF and HLW. The GDSE study focuses on the comparative analysis of different GDSE options, and a salt repository is one of the options currently under study.

The immediate goal of the generic salt repository study is to develop the necessary modeling tools to evaluate and improve the understanding of the repository system response and processes relevant to long-term disposal of UNF and HLW in salt formation. The current phase of this study considers representative geologic settings and features adopted from previous studies for salt repository sites. These studies were also used to develop a conceptual model and scenario for radionuclide release and transport.

The model assumes that repository is located in a saturated bedded salt formation with a geochemically reducing environment. A horizontal interbed with a significant thickness of relatively permeable anhydrite is assumed to exist below the repository, and runs in parallel with the repository horizon to an extended distance. It is assumed that a carbonate aquifer exists above the repository, and a pressurized brine reservoir is located beneath the repository. Two scenarios are considered for radionuclide release and transport: the reference (or nominal) case, and the disturbed case.

The reference case releases radionuclides by a sequence of typical processes that are expected to occur in a generic salt repository; the case assumes that the underlying interbed provides the major pathway for radionuclide release and transport from the repository. The disturbed case considers a process that results in a fast pathway for radionuclides to the far-field. This case is represented by a “stylized” human intrusion scenario, which assumes that a single borehole penetrates a waste package and the underlying pressurized brine reservoir and dissolved radionuclides are released directly into the overlying aquifer.

The current salt performance assessment model consists of four major model components: source-term, near-field, far-field, and biosphere. The source-term and near-field model include the following components: (1) waste package configurations, (2) inventory for different waste types (commercial UNF, existing DOE HLW (DHLW), and hypothetical commercial reprocessing HLW (CHLW)), (3) repository layout, (4) waste form degradation, (5) solubility of

key radionuclides, (6) near-field volume, (7) repository waste inventory scenarios, and (8) repository radionuclide release scenarios. Detailed analyses were conducted to estimate the brine flow rate out of the waste disposal area and in the underlying interbed. The brine flow rates resulting from this analysis are abstracted and input to the salt repository performance analysis. Radiation dose to a receptor in the biosphere is used as a performance metric for the generic salt repository. The model includes a hypothetical reference biosphere that is assumed to be located at 5-km down-gradient from the salt repository boundary.

The salt generic repository model was implemented with the GoldSim software code. A probabilistic repository performance analysis was conducted, with 100 realizations for each case and for a time period of one million years. The preliminary analysis for demonstration of model capability is for ambient (isothermal) temperature conditions in the near field. The analysis emphasizes key attributes of a salt repository that are potentially important to the long-term safe disposal of UNF and HLW. The analysis presents and discusses the results showing repository responses to different waste types (commercial UNF, DHLW, and hypothetical CHLW), and radionuclide release scenarios (undisturbed and human intrusion). In addition, the paper discusses the identified knowledge gaps and paths forward for future R&D efforts to advance understanding of salt repository system performance for UNF and HLW disposal.

For the reference (or undisturbed) scenario, the brine flow rates in the repository and underlying interbeds are very low, and transport of radionuclides in the transport pathways is dominated by diffusion and greatly retarded by sorption on the interbed filling materials. I-129 (non-sorbing and unlimited solubility with a very long half-life) is the dominant annual dose contributor at the hypothetical accessible environment, but the calculated mean annual dose is negligibly small such that there is no meaningful consequence for the repository performance. For the human intrusion (or disturbed) scenario analysis, the mean mass release rate and mean annual dose histories are very different from those for the reference scenario analysis. Actinides including Pu-239, Pu-242 and Np-237 are major annual dose contributors, and the calculated peak mean annual dose is acceptably low.

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