DISPOSAL OF PARTITIONING-TRANSMUTATION WASTES WITH SEPARATE MANAGEMENT OF HIGH-HEAT RADIONUCLIDES

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Introduction

The United States is investigating the Accelerator Transmutation of Waste (ATW)—a type of waste partitioning and transmutation (P-T). An alternative repository concept[1,2] is proposed for disposal of P-T wastes to (1) significantly reduce repository costs and (2) improve repository performance. These benefits are independent of the reduction of radiotoxicity caused by the destruction of selected radionuclides by a P-T fuel cycle.

The waste characteristic that primarily controls repository cost and performance is decay heat. To ensure waste package (WP) integrity and repository performance, temperatures in a repository are limited by spreading the wastes over a large area. For example, to avoid high local temperatures, the proposed U.S. repository would spread the volume of high-level waste (HLW) and spent nuclear fuel (SNF) over -10,000 WPs and 100 km of tunnel. Because decay heat controls repository design, P-T by itself will not significantly impact repository costs.

If the decay heat was small, all wastes could be placed in a few, large, low-cost underground silos. It is proposed that P-T wastes be separated into a high-heat radionuclide (HHR) fraction and a low-heat radionuclide (LHR) fraction. The repository would be divided into three sections for separate disposal of: (a) HHRs, (b) intermediate-heat radionuclides (IHRs), and (c) LHRs. The different characteristics of each waste allow for different disposal methods for each. Separate disposal of each wastes may improve repository performance and reduce costs.

HHR Waste Disposal

There are five HHRs in SNF: cesium, strontium, plutonium, americium, and curium. HLW contains four HHRs: cesium, strontium, americium, and curium. P-T, by destroying the long-lived HHRs (plutonium, americium, and curium), is an enabling technology for separate HHR disposal. This creates an HHR waste that contains only ^{137}Cs and ^{90}Sr with limited half-lives ($T_{1/2}$. 30 year). Within 50 years after SNF from the reactor, the ^{137}Cs and ^{90}Sr are 99% of the heat generation from HLW. Because of their limited half-lives, small volumes, and high heat generation rates, there are less expensive methods to dispose of HHR wastes.

There are many HHR disposal options: (1) long-term dry storage similar to that of SNF storage; (2) modified conventional repository; (3) extended-dry repository—HHRs are placed close together in underground boreholes to create a high-temperature zone above the boiling point of water, which, in turn, keeps groundwater away from packages containing the HHRs until they decay; (4) saltdiver—the placement of HHRs in a special canister designed to sink to great depth in a salt dome; (5) rock melting; (6) conventional borehole; (7) high-heat borehole—modified borehole, where the high temperatures induce changes in rock properties that reduce the permeability of the rock to water flow; and (8) seabed disposal. Each of these options has been considered for SNF or HLW disposal; however, the viability and costs are significantly different than those for HHRs. Different waste properties imply different functional requirements for the WP (required lifetime) and disposal site that, in turn, strongly impact costs and performance. Each of these options is characterized and assessed.

LHR Disposal

Removal of heat-generating wastes allows disposal of the remaining LHRs in a few large silos—somewhat similar to the Swedish Final Repository (SFR) for reactor wastes silos under the Baltic Sea near Forsmark, Sweden. The SFR silos have diameters of -25 m and heights of -50 m. For LHRs, the silos would be constructed in a conventional repository at repository depth. Disposal of wastes in silos is much less expensive than disposal in conventional WPs.

The replacement of WPs with large silos may result in major improvements in repository performance. The release of radionuclides from a failed WP is proportional to (1) the groundwater flow through the WP and (2) the solubility limits of the radionuclides in groundwater. By concentrating the wastes from up to 10,000 tons of SNF in one silo rather than spreading it over -1,000 WPs, the groundwater flow through the wastes per unit volume is reduced by a factor of 100 to 1,000. With the reduction of groundwater flow per unit quantity of waste, radionuclide releases are proportionally reduced. The large waste silo has a smaller surface-to-volume ratio than the many thousands of WPs that it replaces.

IHR Disposal

Conventional repositories are designed for IHR wastes—HLW and SNF. Existing HLW and some types of P-T wastes may be disposed of as IHR wastes. It may not be practical to recover low concentrations of actinides from a high-quality HLW glass. While HHR recovery during SNF processing is relatively straightforward, there are some P-T wastes that are candidate IHR wastes: (1) wastes from actinide target processing where cesium or strontium separations are difficult and (2) deep-burn P-T targets that may be directly disposed of as waste.

Conclusions

P-T is potentially an enabling technology to reduce repository costs and improve performance by destroying longer-lived heat generators in the waste: plutonium, americium, and curium isotopes. Destroying the longer-lived heat generating isotopes in wastes creates a HHR waste that can be disposed of via several low-cost options. LHRs can be disposed of in a lower-cost silo. The cost for these benefits is the requirement to separate the cesium and strontium from the other wastes. Reducing heat-loads in the repository may be as important for improving disposal of radioactive wastes as is the reduction of radiotoxicity by P-T. Significant work is required to understand the full implications of this alternative approach to radioactive waste management.

References

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