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Analyses of Releases due to Drilling at the Potential Yucca Mountain Repository*

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Introduction

Human Intrusion into the potential repository at Yucca Mountain, Nevada, was modeled in the Total-System Performance Assessment ("TSPA-91") recently completed for the Yucca Mountain Site Characterization Project Office of the DOE[1]. The scenario modeled assumed that the repository would be penetrated at random locations by a number of boreholes drilled using twentieth-century rotary drilling techniques.

The probabilities of this scenario occurring depend on several factors. For these analyses, it was assumed that there was a probability of 1.0 that people would be drilling at the site for 10,000 years. The probability of a drill bit intersecting waste packages in the repository was based on two assumptions. The probability of a hit was assumed to be proportional to the horizontal projections of the areas of the drill and the waste package. The probability also depended on the emplacement density of the waste packages in the repository. If the drill string penetrated the waste package, a random amount of spent-fuel waste would be entrained in the drilling fluid and be brought to the surface. In addition, it was assumed that the drill could pass through rock surrounding the waste package that had been contaminated by a plume of waste diffusing from the waste package (a "near miss"). A more detailed discussion of the analysis is given in Chapter 6 of Ref. 1. Both TSPA-91 and the total-system performance assessment currently being done (TSPA-2) are investigating different aspects of the same scenario.

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Analysis Definition

Whereas TSPA-91 assumed that the nuclear waste was 10-year old LWR spent fuel vertically emplaced in thin-wall waste packages, TSPA-2 uses the inventory and emplacement configurations currently under consideration as alternatives to the design originallly given in the SCP[2]. These alternatives evaluate the use of multipurpose containers for storing waste, and the potential benefits of operating the potential repository at higher temperatures. Table 1 compares the configurations.

Table 1

Inventory and Emplacement Configurations

Waste-Package Design	Emplacement Configuration	Areal Power Density	Inventory	Age
		TSPA-91		
Thin-wall stainless steel	vertical, in floor .71 m diameter	141 kW/Ha (57 kW/Ac)	33000 Spent-Fuel waste packages (~2.1 MTU/package)	10 year
		TSPA-2		
Thin-wall stainless steel (alternative spent-fuel container from SCP)	vertical, in floor .71 m diameter	141 kW/Ha	~31700 Spent-Fuel waste packages (~2.0 MTU/package) and ~9000 glassified HLW canisters (0.5–2 MTHM/canister)	30 year
Thin-wall stainless steel	vertical, in floor .71 m diameter	282 kW/Ha (114 kW/Ac)	~31700 Spent-Fuel waste packages (~2.0 MTU/package) and ~9000 glassified HLW canisters (0.5–2 MTHM/canister)	30 year
Thin-wall stainless steel with thick steel overpack	horizontal, in drift 1.47 m wide, 4.5 m long	141 kW/Ha	~7640 Spent-Fuel waste packages (8.2 MTU/package) and ~2250 glassified HLW packages (2–8 MTHM/package)	30 year
Thin-wall stainless steel with thick steel overpack	horizontal, in drift 1.47 m wide, 4.5 m long	282 kW/Ha	~7640 Spent-Fuel waste packages (8.2 MTU/package) and ~2250 glassified HLW packages (2–8 MTHM/package)	30 year

To achieve the higher thermal power density for TSPA-2, the waste packages are assumed to be placed closer together; additionally, older waste requires closer emplacement spacing to achieve the same thermal load as younger waste. Consequently, the area of the potential repository is considerably smaller for TSPA-2. The probabilities for the drill hitting a waste package are generally larger for TSPA-2 because of the smaller repository and the larger waste packages. Table 2 lists the pertinent parameters (for a discussion of the calculation of P_{hit} and the expected number of boreholes to be drilled, N_{drill}, see Chapter 6 of Ref. 1).

Table 2
Drilling Analysis Parameters

Configuration	Repository Area (km^2)	P_{hit} (spent-fuel packages only)	N_{drill}*
TSPA-91			
141 kW/Ha, vertical	5.61	.0075	17
TSPA-2			
141 kW/Ha, vertical	3.32	.0171	10
141 kW/Ha, horiz.	3.32	.0324	10
282 kW/Ha, vertical	1.94	.0292	6
282 kW/Ha, horiz.	1.66	.0648	5

* Drilling density based on 3 boreholes/km^2/10,000 years (Ref. 3)

Results

Comparing the probability for TSPA-91 with the corresponding one for TSPA-2 (i.e., 141 kW/Ha, vertical emplacement), we see that the probability of an individual drilling event hitting a waste package is more that twice as great. The expected number of boreholes drilled is about half, but the expected amounts of waste brought to the surface are the same. Monte Carlo simulations of 10,000-year drilling histories of the two repository configurations show that releases are comparable.

The probabilities of drilling intersecting the horizontal waste packages are much higher, although there are expected to be fewer holes drilled into the repository. There

is considerably more waste in each package that can be brought to the surface; consequently, the maximum releases that do occur in the Monte Carlo simulations are 4–6 times larger than occurred in TSPA-91. Releases from spent fuel dominate over those from HLW. Surface releases from near misses are not significant for any of the cases analyzed. As measured by a complementary cumulative distribution function relating releases to probabilities of occurrence, human-intrusion drilling activities do not exceed the guidelines given in 40 CFR Part 191[3].

Conclusions

These analyses show that the choice of repository and waste package configuration can have a large impact on surface releases of radionuclides. The assumed benefits of an alternative waste package design must be weighed against the possible impacts on drilling scenarios. The human intrusion analyses are only one of many aspects being considered. Other factors, such as dose effects, susceptibility to other disruptive events, and operational considerations will all be evaluated. Because the design and the configuration of the potential Yucca Mountain nuclear waste repository are still being evaluated, performance assessment analyses such as this will provide valuable insight and guidance.

References

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