An Application of the TPA Code to Evaluate Radionuclide Release Rates at the *Receptor Location* for the Proposed High-Level Radioactive Waste Disposal Site at Yucca Mountain

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INTRODUCTION (1)

The Nuclear Regulatory Commission (NRC) has the responsibility to review the license application for the proposed high-level radioactive waste (HLW) repository site at Yucca Mountain (YM). The NRC and the Center for Nuclear Waste Regulatory Analyses (CNWRA) have developed a Total-system Performance Assessment (TPA) code [3] as a review tool. An application of this tool is demonstrated in this paper.

Yucca Mountain is located in a semi-arid environment on the Nevada Test Site in southern Nevada, and rises several hundred meters above the surrounding land. The YM repository design is to dispose of spent nuclear fuel (SF) in waste packages (WPs) emplaced in drifts approximately 300 m below the top of YM and 300 m above the groundwater table. Figure 1 shows precipitation, infiltration from the ground surface, the location of the repository with WPs, the various YM hydrostratigraphic units, and the groundwater table.

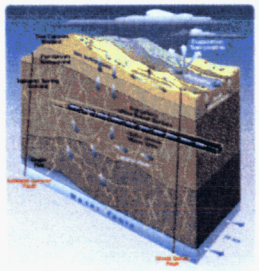

Figure 1

(2)

Waste Packages will eventually fail, and infiltrating water will contact the SF in the WP and cause SF dissolution. After the SF dissolves, the flowing water will transport radionuclides out of the engineered barrier system (EBS), through the hydrologically unsaturated zone (UZ) and saturated zone (SZ) to a hypothetical receptor group.

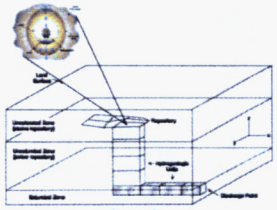

Figure 2

DISSOLUTION RATES (3)

Four SF dissolution models (alternative conceptual models) are used to compute the source term [3] for UZ and SZ transport. Model 1 estimates the SF dissolution rate in solutions containing carbonate anions. The SF dissolution rate in the presence of Ca and Si ions, which are found in YM groundwater, is calculated in Model 2. The user has the option of specifying a SF dissolution rate in Model 3, such as from a natural analog model. Model 4 considers secondary minerals.

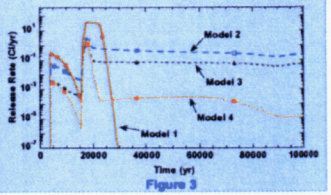

Figure 3

PROBLEM STATEMENT (4)

For models 1 and 4 (Group 1), release rates *at the receptor location* show a sinusoidal (undulated) behavior and decreasing trend compared to the release rates for models 2 and 3 (Group 2). This paper investigates the cause of this behavior.

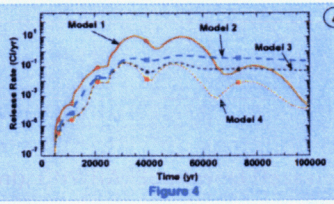

Figure 4

HYPOTHESIS OF POTENTIAL MECHANISMS (5)

Sinusoidal behavior and a decreasing trend may be caused by (i) solubility limits of the radionuclides, (ii) decay and ingrowth of the radionuclide inventory, (iii) inventory depletion of the SF in the WP, (iv) transport properties of the UZ and SZ, and (v) spatial discretization of the repository. The study identifies which mechanisms indeed contribute the most to trends in the *receptor location* release rates.

RESULTS (6)

The EBS release rates in figure 3 for the Group 1 models (Models 1 and 4) feature an increase to a peak value and thereafter decrease several orders of magnitude. This behavior is attributable to inventory depletion for Model 1 and to instantaneous releases from the gap inventory for Model 4 (i.e., portion of the radionuclide inventory assumed to be held loosely on the grain boundaries, cladding/fuel gap, and cladding). Group 2 models (Models 2 and 3) maintain an intermediate release rate which is not large enough to be dominated by inventory depletion or small enough to be dominated by instantaneous releases from the gap inventory. Analyses of the results indicates two of the five mechanisms, (i) SZ transport properties and (ii) spatial discretization, have the largest impact on *receptor location* release rates.

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(7)

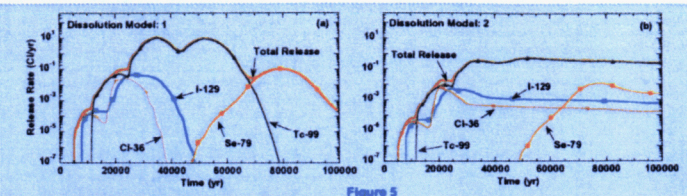

Figure 5

Saturated Zone Transport Properties

Figure 5 shows that Cl-36 has the largest contribution in total release prior to about 8,000 yr. From about 8,000 to 12,000 yr, both Cl-36 and I-129 contribute the most to total release. Between about 12,000 and 68,000 yr, Tc-99 dominates and, thereafter, Se-79 is the major contributor to total release. These differences are caused by retardation in the SZ alluvium. Radionuclides with the smallest retardation factors arrive earlier at the receptor location, while later arrival times correspond to radionuclides with larger retardation factors. The SZ alluvium retardation factors are 1.0, 2.0, 5.5, and 22.4 for Cl-36, I-129, Tc-99, and Se-79, respectively [3]. Thus, for Group 1 models, the sinusoidal behavior observed in figure 4 can be attributed to contributions from these radionuclides.

(8)

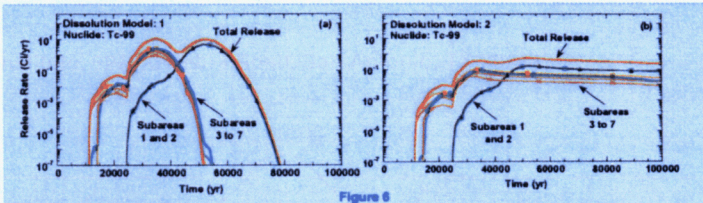

Figure 6

Spatial Discretization

The Tc-99 release rates in figure 6 for Group 1 and Group 2 models show the same behavior. Subarea 1 and 2 releases are delayed by about 15,000 yr compared to subareas 3 - 7. This delay causes two peak release rates at 30,000 and 50,000 yr in figure 6(a). These peaks are attributable to differences in the length of the SZ flow path and the groundwater travel time. For subareas 1 and 2, the SZ flow path length is 4,000 to 7,000 m greater than the length of the subarea 3 - 7 flow path length [3]. The differences in the flow path length produce a 6,000-yr SZ groundwater travel time for subareas 1 and 2, compared to 2,800 yr for subareas 3 - 7. Consequently, spatial discretization of the repository into subareas is also responsible for the Group 1 model sinusoidal behavior.

CONCLUSIONS (9)

The sinusoidal trend in the receptor location release rates calculated using Group 1 models may be attributed to differences in (1) SZ alluvium sorption and (2) spatial dependencies related to the length of the SZ flow path for each subarea. The SF dissolution rate model utilized in a TPA code simulation can strongly affect the trend in the release rates at the receptor location and is significant because release rates are used to compute dose to the receptor which is the performance measure for the HLW repository at YM. The NRC/CNWRA will use such analyses to probe the safety case presented in the DOE license application.

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