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A Probabilistic Consideration on Nuclide Releases from a Pyro-processed Waste Repository

Youn-Myoung Lee, Jongtae Jeong
Korea Atomic Energy Research Institute, 150 Dukjin, Yuseong, Daejeon, 305-353, *ymlee@kaeri.kr*

1. Introduction

Very recently, a GoldSim [1] template program, GSTSPA, for a safety assessment of a conceptual hybrid-typed repository system, called "A-KRS," in which two kinds of pyroprocessed radioactive wastes, low-level metal wastes and ceramic high-level wastes that arise from the pyroprocessing of PWR nuclear spent fuels, has been developed and is to be disposed of by "separate disposal" strategies. The A-KRS is considered to be constructed at two different depths in geological media: at a 200m depth, at which a possible human intrusion is considered to be limited after closure, for the pyroprocessed metal wastes with lower or no decay heat producing nuclides, and at a 500m depth, believed to be the reducing condition for nuclides with a rather higher radioactivity and heat generation rate. This program is ready for a probabilistic total system performance assessment (TSPA) which is able to evaluate nuclide release from the repository and farther transport into the geosphere and biosphere under various normal, disruptive natural and manmade events, and scenarios that can occur after a failure of a waste package and canister with associated uncertainty. To quantify the nuclide release and transport through the various possible pathways in the near- and far-fields of the A-KRS repository system under a normal groundwater flow scenario, some illustrative evaluations have been made through this study. Even though all parameter values associated with the A-KRS were assumed for the time being, the illustrative results should be informative since the evaluation of such releases is very important not only in view of the safety assessment of the repository, but also for design feedback of its performance.

2. Model

The storage can for metal wastes are to be disposed of and then buffered by sodium bentonite blocks in a total of two disposal tunnels at the depth of 200m which will be backfilled later by a mixture of bentonite and crushed rock. Similarly to a previous work [2-5], in GoldSim modeling, these tunnels are discretized into several compartments ready for diffusive transport in and among them, modeled as shown in Fig. 1 (left). Two principal release pathways from the tunnels are set in place, as shown in the figure: These are the upper crown pathway and the base and side pathway, both of which reach to the near-field transport. Diffusional transport only was considered between the upper and lower parts of the silo. All releases from the tunnels are collected at the outlet of the near-field, where they are later transported farther into the natural far-field area.

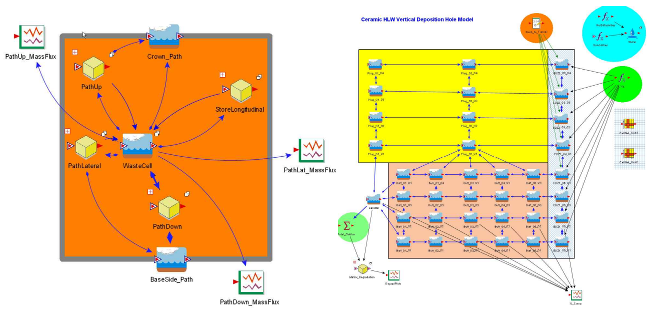

Fig. 1. Source term and near-field modeling (left: metal waste; right: ceramic waste)

The ceramic wastes, modeled as shown in Fig. 1 (right), which are regarded as high-level wastes, are disposed of in tunnels constructed at a depth of 500m which look quite similar to those shown in Swedish KBS-3 vertical concept with the same buffering and backfilling process. Each overpack that has 14 canisters is to be displaced in the deposition hole under the bottom of the tunnel. For both types of repositories at each different depth, normally and commonly, once leakage from a damaged radioactive waste package of a metal storage can and a canister and through tiny holes happens, nuclides will spread out to the buffer material surrounding the can and canister, as well as the backfill or crushed rock region in the tunnel before farther transporting into the flowing groundwater in the internal fractures and the major water conducting features (MWCFs) of the far-field area of the repository. Then the nuclides will finally reach the human environment by passing over the geosphere-biosphere interface for an exposure to human bodies.

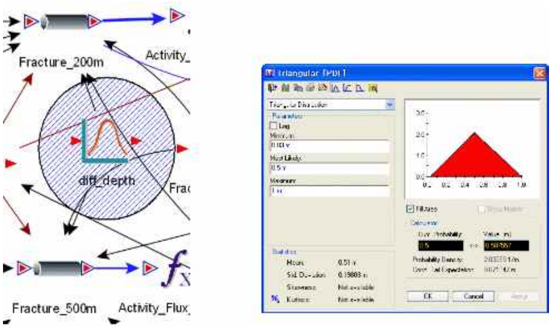

Fig. 2. Probabilistic Modeling for the matrix diffusion depth

3. Illustrations

The scenario considered here is a normal case, under which nuclides are released by groundwater that normally flows along their own preferential pathways after release from each repository. Through this study, a probabilistic behavior of nuclide releases from a pyroprocessed waste repository has been investigated with varying parameters which are selected among many others in view of their possible consequences (e.g., Fig. 2); 1) the diffusion depth in the rock matrix, 2) the solubility in the repository for 4 selected elements (Cs, Sn, Tc, and Pa) under a reducing condition, 3) the distribution coefficients in all the geological media for these 4 elements, 4) the hydraulic conductivity in the fracture, the travel distance between the outlet of the engineered barrier and the inlet of the MWCF, 5) the plume width of groundwater at the outlet of the fracture, and 6) the groundwater flow rate in the MWCF. In Fig. 3, the calculated breakthrough curves for dose exposure rates to farming and freshwater fishing exposure groups are shown for varying cases of the above-mentioned parameters. Even though the peak points are shown to be very stable, the range of peak values seems to change greatly in accordance with varying the parameter values.

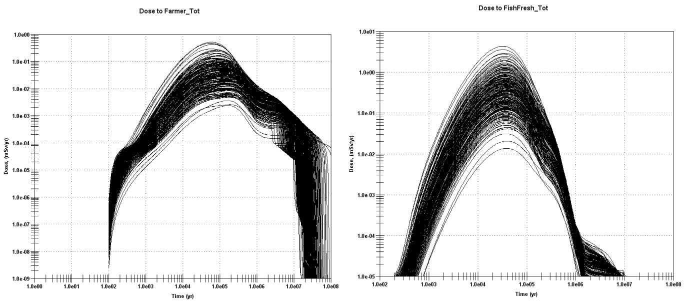

Fig. 3. Breakthrough curves for dose exposure rates

It was also found that the hydraulic conductivity, the distribution coefficient in the buffer, and the travel length in the fracture are particularly more sensitive than any other parameters, giving a major contribution to the change of the breakthrough curves in Fig. 3.

References

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