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Detailed Compartment Modeling of Nuclide Release from the Near-field of a HLW Repository

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1. Introduction

Spent fuels (SFs) encapsulated in corrosion resistant canisters are to be disposed of in deposition holes surrounded by a high density bentonite clay, drilled into the bottom of tunnels at a depth of about 500 m in a crystalline rock according to the basic repository design currently being developed and named the Korea Repository System (KRS) [1]. It could be the only type of HLW in Korea.

In order to quantify the nuclide release from the canisters damaged initially or due to whatever reason after a disposal, as similarly done for the KBS3 study [2], an in depth modeling for the nuclide transport through the near-field has been carried out by utilizing AMBER [3].

After a leakage from the canister, nuclides will spread out through the buffer material surrounding the canister before migrating farther into the flowing groundwater in the fractures possibly embedded at various locations of the host rock medium through which a preferential nuclide transfer into the far-field seems to take place.

The objective of this paper is to briefly introduce the feature and applicability of this newly developed AMBER case file ACGEO2 to calculate a nuclide release from the near-field of the HLW repository. Unlike previous works [4,5], newly introduced compartments such as the tunnel crown and the excavation disturbed zone (EDZ) as well as the nuclide pathways newly incorporated will provide an in-depth capability of the near-field analysis. Fracture planes associated with seven possible sensitive exit points, each of which provides escape pathway for nuclides initially released from the canister hole are illustrated in Fig. 1. For a demonstrative purpose, some calculation results for a nuclide release are illustrated.

2. Modeling

ACGEO2 is developed based on the compartment modeling method. Accounting for the geometry and material that could control the transport, the near-field concepts of KRS have to be discretized into many compartments as shown in Fig. 2, each of which has a different geometry and characteristics.

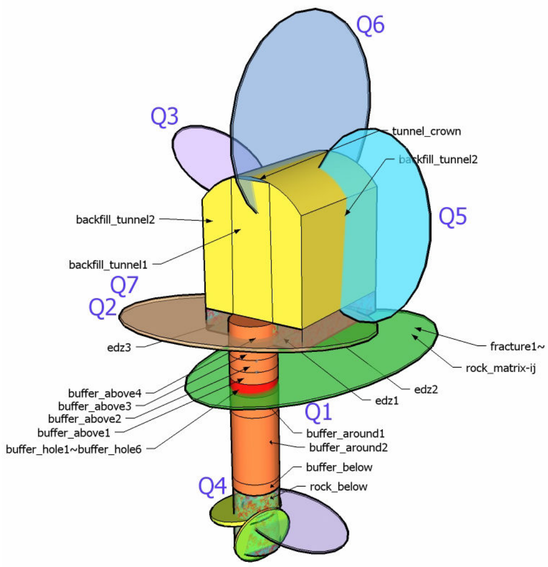


Fig. 1. Near-field of the repository embedded by fractures.

To calculate the nuclide flux or flow rate from the near-field, such important parameters involved in a nuclide transport between compartments such as a transport resistance which is determined by the volume and distribution coefficient, interfacing area and diffusion length associated with each compartment should be prepared.

Nuclides released from canisters with small holes due to an initial intrinsic defect (~0.1% of total number of canisters) are assumed. Once nuclides in the spent fuel matrix as well as in such a gap portion as grain boundaries and cladding, where nuclides are immediately available to a release, are contacted with groundwater, and their transfer and transport begins to take place. After this, the nuclides continue to transport to the surrounding buffer and tunnel backfill where a diffusive transport is assumed to be dominantly governed due to their low permeability. However in the case where the nuclides meet groundwater bearing fractures in the surrounding host rock an advective transport could also occur. Matrix diffusion into the stagnant groundwater in the rock matrix pores as well as sorptions onto both the fracture wall and matrix surfaces are also accounted for.

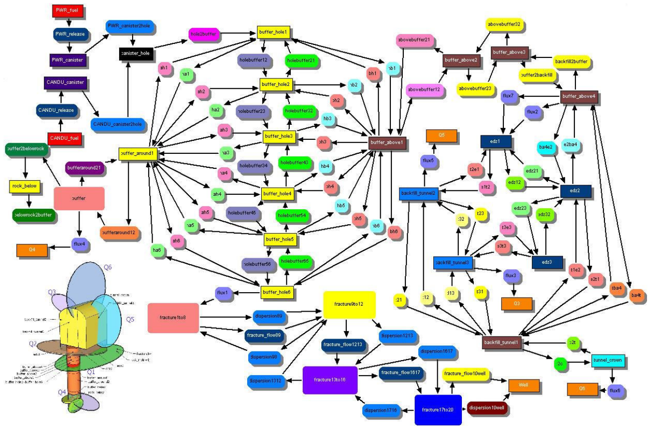
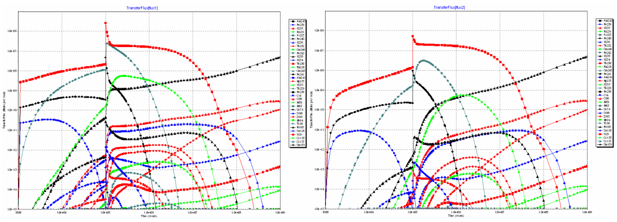


Fig. 2. Compartment scheme for nuclide flux calculation.

3. Illustration

Fig. 3 shows the nuclides release from two special different release exits of the near-field: buffer near a canister hole–fracture interface (Q1) and a buffer–fracture zone embedded in the EDZ (Q2), respectively, among the possible others, to the far-field as a function of time for the case that the canister hole area abruptly grows larger at 10^5 years. In both figures ^{129}I, which is assumed to be nonsorbing for the whole media in the near-field shows its peak at around 10^5 years. The earlier reach to its peak for ^{129}I can be explained by a rather fast IRF release behavior.

Also ^{129}I releases from all 7 exit points are compared with each other in Fig. 4. It is noticeable that release Q1 is the earliest and highest from any of the other release points during a constant canister hole size, whereas Q2+Q7, which represent a total flux to a single fracture and a fracture zone together into the EDZ from the upper part of the buffer zone in a deposition hole, become higher than any of the other fluxes immediately after a change of the canister hole size.



(a) (b)

Fig. 3. Nuclide release from the deposition hole buffer: (a) to the fracture (Q1); and (b) to the fracture zone embedded in the EDZ (Q2).

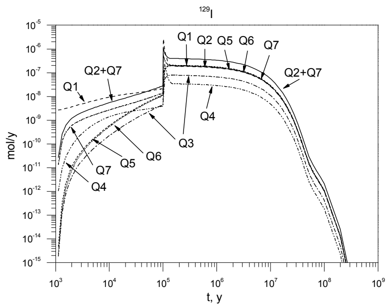


Fig. 5. Release of ^{129}I from seven exit points to the single fractures or fracture zones in the near-field of the repository.

4. Concluding Remarks

Radiological consequences for a nuclide release from the near-field is very important not only to show the final safety of the repository but also to investigate the functionality of the near-field barriers and compartments of the repository. Since many fractures are already be there or could occur through which a nuclide a release could take place around the deposition hole and tunnel, this kind of detailed modeling is necessary. Compartment model developed through this work is so flexible and adaptable in view of the various and complex shapes which are expected to be used for a safety assessment as well as design feedback of the KRS repository.

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