Model Development for the Post-Closure Safety Assessment of LILW Complex Disposal Facilities

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1. Introduction

Low- and Intermediate-Level radioactive Waste (LILW) disposal facilities in Korea are planned to accommodate about 800,000 drums in total [1]. For the first phase, underground silo-type disposal facility which can accommodate up to 130,000 drums had been constructed in 2014, and it has been currently being operated since 2015 [1]. Recently, near-surface trench-type disposal facility which can accommodate up to 125,000 drums has been proposed as the second phase [1]. The distance between two disposal facilities at phase 1 and 2 is supposed to be about 500 to 1,000 m [2]. Therefore, it is possible that two disposal facilities share the same groundwater system which is the potential pathway of radionuclides. In this case, the interconnection effects should be considered in their post-closure safety assessment. Especially for the human intrusion scenario, the complex impacts of two disposal facilities should carefully be considered since the surface area around the facilities would be the single human life zone in the future. In this study, therefore, a post-closure safety assessment model was newly developed for LILW complex disposal facilities considering the coupled effects of underground silo- and near-surface trench-type disposal facilities.

2. Disposal Concepts

In order to develop the post-closure safety assessment model, conceptual models for each disposal facility were independently developed for a start. Each conceptual models are depicted as follows.

2.1 Underground Silo-Type Disposal Facility (1st Phase)

The schematic of radionuclide migration pathway in the underground silo-type disposal facility is depicted in Fig. 1. The underground silo, which can be called engineered barrier system (EBS), consists of radioactive waste, backfill, and concrete wall. Due to the geometrical locations, backfills were divided into top- and side-backfill, and concrete walls were divided into top-, side-, and bottom-concrete. Diffusion was supposed to occur over all components in the silo considering their geometrical locations. In fact, the diffusion direction in Fig. 1 is meaningless since diffusion occurs just owing to the concentration difference. From a conservative point of view, advection was additionally considered in the direction of groundwater flow through the silo. Groundwater flow direction was assumed to be horizontal. Advection was supposed to be dominant from the silo concrete walls to the neighboring host rock, so that diffusion between them was neglected. During the radionuclide migration through the disposal system in Fig. 1, radioactive decay, solubility, and sorption were also considered by reflecting the intrinsic properties of radionuclides and media (such as groundwater and solid materials). Finally, it was assumed that all radionuclides transported through the host rock would be captured by well discharge which is located in a certain distance. Then, the mass rate to the terminal receptor was converted to dose using radionuclides' specific activities and dose conversion factors.

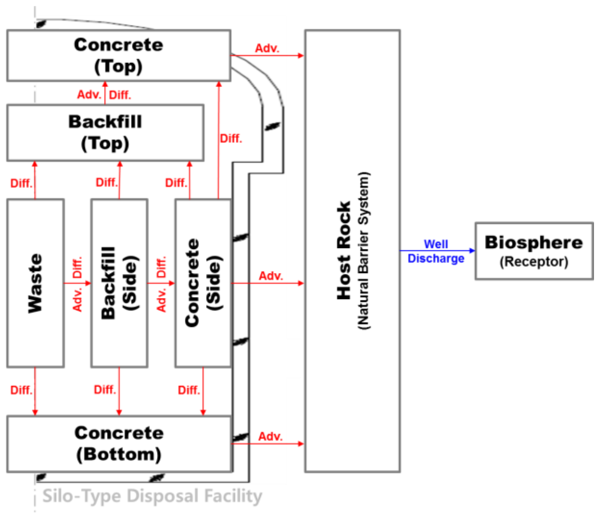

Fig. 1. Schematic of radionuclide migration pathway in the underground silo-type disposal facility.

2.2 Near-Surface Trench-Type Disposal Facility (2nd Phase)

The schematic of radionuclide migration pathway in the near-surface trench-type disposal facility is depicted in Fig. 2. The near-surface trench, which can be called

EBS, consists of radioactive waste, vault concrete, backfill, and cover. Vault concretes were divided into top-, side-, and bottom-concrete. Unlike underground silo-type disposal facility which is located in a certain depth of ground (saturated condition), near-surface trench-type disposal facility is located on the ground surface so that the unsaturated aquifer was necessarily considered in addition. Diffusion was supposed to occur over all components in the trench considering their geometrical locations. Since cover is supposed to drain the infiltrated water to the unsaturated aquifer and to inhibit the groundwater flow through the vaults, advection through the EBS was not considered except the flow bypass from cover to unsaturated aquifer. Advection was supposed to be dominant from the unsaturated aquifer to the underlying saturated aquifer, so that diffusion between them was neglected. Groundwater flow direction was assumed to be vertical. Since the unsaturated hydrology at the trench and unsaturated aquifer is not defined well, the flowrates from cover to unsaturated aquifer and from unsaturated aquifer to saturated aquifer were preliminarily defined with the conservative aspects. Like underground silo-type disposal facility, radioactive decay, solubility, and sorption were also considered in the overall disposal system (Fig. 2). Finally, it was assumed that all radionuclides transported through the saturated aquifer would be captured by well discharge which is located in a certain distance. In order to couple the impacts of both disposal facilities, dose from near-surface trench-type disposal facility was simply added to that from underground silo-type disposal facility.

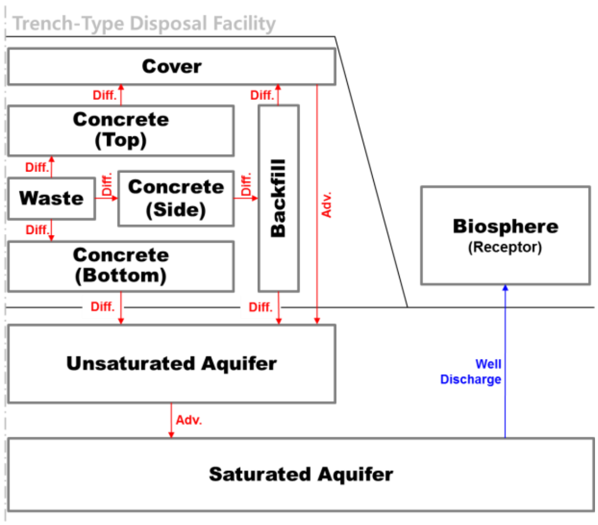

Fig. 2. Schematic of radionuclide migration pathway in the near-surface trench-type disposal facility.

3. Safety Assessment Model

Based on the conceptual model developed above, a post-closure safety assessment model for the LILW complex disposal facilities was newly developed using GoldSim's *Contaminant Transport Module* [3]. Wastes were represented by *Source Element* dealing with inventory and waste degradation. All of the EBS components and unsaturated aquifer in the near-surface trench-type disposal facility were represented by *Cell Pathway Element* dealing with radioactive decay, solubility, and sorption in liquid and solid media. Host rock in the underground silo-type disposal facility and saturated aquifer in the near-surface trench-type disposal facility were represented by *Aquifer Pathway* dealing with advection through the media. The final dose in the biosphere was computed by *Receptor Element* dealing with radionuclides' specific activities and dose conversion factors.

Table 1. Input data used in the post-closure safety assessment model for the LILW complex disposal facilities.

Category	**Input Parameter**
Simulation condition	Scenario type
	Concrete life time
	Human intrusion-related properties
	Precipitation-related properties (2nd phase only)
	Flowrate from cover to unsaturated aquifer (2nd phase only)
	Flowrate from unsaturated aquifer to saturated aquifer (2nd phase only)
	Plume area (2nd phase only)
Geometrical dimension	Length
	Area
	Volume
Waste inventories and package properties	Waste type
	Inventory
	Waste properties (e.g. volume, bulk density, porosity, degradation rate, etc.)
Media properties	Solubility
	Sorption coefficient
	Bulk density
	Porosity
	Diffusion coefficient
Hydrologic properties	Darcy velocity (scenario dependent)
	Travel length (scenario dependent)

Input data including simulation condition, and geometrical dimensions, waste inventories and package properties, media properties, and hydrologic properties of each disposal facility were organized in an EXCEL file which is associated with the GoldSim model (Table 1). The values of input parameters in Table 1 were mostly imported from some relevant literatures such as [1], [2], etc. if possible, or defined by the experts' judgements with the conservative aspects.

4. Model Simulation

Using the post-closure safety assessment model developed above, a well intrusion scenario was illustrated as follows.

Well intrusion scenario explains that a representative person in the future utilizes the discharged groundwater from a well or more which is/are in a certain distance from the disposal facilities, and the groundwater would be contaminated by the disposal facilities. As an example illustration, model simulation results for each disposal facility are depicted in Fig. 3. Although the simulation results are highly dependent on the numerous input data mentioned above, it could be confirmed that the doses from each disposal facility showed obviously different tendencies and either of them could not be significantly neglected. As shown in the example illustration of coupled disposal facilities (Fig. 4), in the other words, the dose from one disposal facility was not always dominant during the safety assessment time span, but the dose from the other could overwhelm during a certain period. From the results, it could be confirmed that the two different concepts of LILW disposal were well reflected in a single post-closure safety assessment model developed in this study.

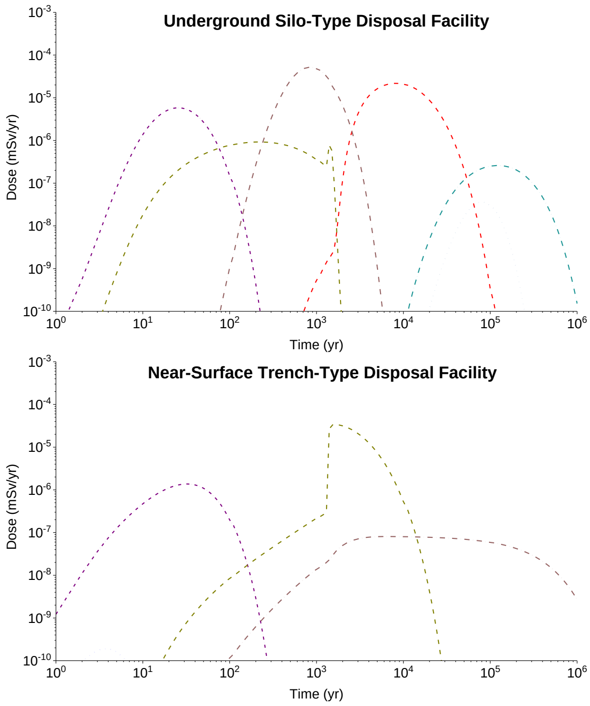

Fig. 3. Example illustration: Doses exposed from each disposal facility (radionuclide names are not shown).

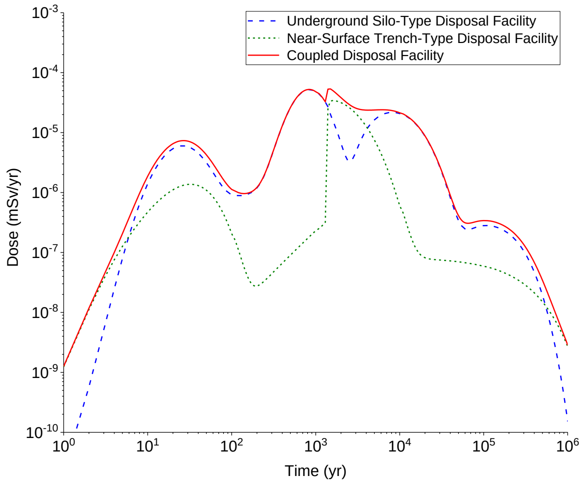

Fig. 4. Example illustration: Overall doses exposed from each disposal facility and the coupled effects.

5. Conclusions

A post-closure safety assessment model for LILW complex disposal facilities was newly developed considering the coupled effects of underground silo- and near-surface trench-type disposal facilities. Thanks to its capability to couple two different concepts of LILW disposal, it is expected that the coupled radiological impacts from those disposal facilities can be more efficiently estimated, especially for the human intrusion scenario which includes various alternative scenarios within the overall LILW disposal sites.

ACKNOWLEDGEMENT

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