A Conservative Approach to Estimate the Gaseous Radionuclide Migration in LILW Repository

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1. Introduction

The second-phase geological disposal of low- and intermediated-level radioactive waste (LILW) in Korea has been designed as a trench-type near surface disposal facility [1]. In the safety assessment of the LILW repository, the gaseous phase should additionally be considered in the radionuclide migration pathway along with the liquid phase. In fact, Hwang et al. [2] pointed out that the gaseous H_2 and CH_4 due to corrosion of concrete or iron drums and the radioactive gases due to the radiolysis are one of the main factors affecting the safety of LILW repository. In this study, the modeling studies related to the generation and migration of gaseous radionuclides in the LILW repository have been reviewed. Based on a stepwise approach which was recommended by the US NRC [3], in addition, a conservative approach using a puff release model was conducted as the first-step safety assessment of the gaseous radionuclide migration.

2. Literature Review

2.1 Modeling of Gas Generation

In 1996, Cho et al. [4] reviewed a mathematical model to predict the incidence of gas generated by metal corrosion and microbial degradation in LILW repositories. In the study, the corrosion of the metal material considered as the main factor of H_2 gas generation was classified into three stages; 1) oxidation of iron, 2) reduction of oxide film after depletion of oxygen, and 3) anaerobic corrosion of iron. And, in the gasification by microbial degradation, the gas generation rates, such as H_2, CO_2, and CH_4, were calculated according to the pH and the chemical species. The model used for the calculation was GAMMON developed by AEA Technology, UK. As a result of calculation, it was confirmed that the gas generated in LILW disposal system has the greatest amount of H_2.

In 2008, Kang et al. [5] reviewed the main mechanisms of gas generation from LILW, and evaluated the gas generation rate and the amount using SMOGG developed by Radioactive Waste Management Ltd., UK. The main mechanisms of gas generation considered in SMOGG are metal corrosion, radiolysis, biological degradation of organics, and radioactive decay.

In a LILW repository in Finland, a field-scale experiment of gas generation was conducted, and the experimental data, such as gas generation rate, gas species, geochemical characteristics, bacteria, etc., were collected for more than 9 years [6]. The experiments were simulated by using a biogeochemical reactive transport model (Generalized Repository Model; GRM) developed by British Nuclear Fuels Ltd., UK.

2.2 Stepwise Approach

The PA Working Group of the US NRC proposed a stepwise approach to evaluate the release of gaseous radionuclides (e.g., ^{14}C, ^{85}Kr, ^{222}Rn, ^{3}H, ^{129}I) in the safety assessment of LILW repositories, taking into account the accuracy or complexity of the conceptual model as follows [3]:

- 1st-step (selective method): As the most conservative method, it is assumed that all disposal facilities are failed at the same time and all radionuclides are released to the ground surface (= puff release) in gas phase over a short period of time. Here, for the main radionuclides contributing to the final dose, the gas phase fraction in the actual inventory is considered selectively.
- 2nd-step: Considering the distribution of the gas-liquid phases of the radionuclides reasonably, the amount of the radionuclide migrating into the gas or liquid phase is distinguished.
- 3rd-step: The gas-liquid phases radionuclide distribution is implicitly calculated taking into account the changes of the geochemical characteristics, rather than being explicitly considered like 2nd-step.
- 4th-step: As the most complex and realistic method, it considers the types and forms of various wastes, the failure mechanism of complex disposal facilities, and various mechanisms that affect gas migration.

3. A Conservative Approach

3.1 Layout of the Repository

The layout of the disposal vaults in the second-phase geological repository of LILW in Korea is depicted in Fig. 1.

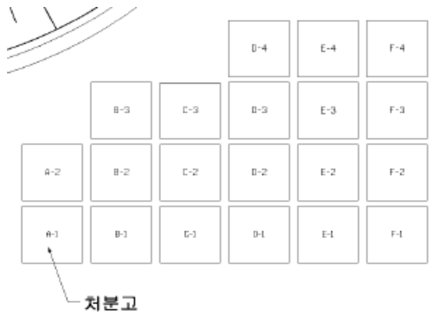

Fig. 1. Layout of the repository.

3.2 Puff Model

As the 1st-step safety assessment of the gaseous radionuclide migration in the repository, the most conservative approach was developed using a puff model. The puff model is generally based on the multivariate normal distribution function as follows:

$$f(\mathrm{x})=\frac{1}{(2\pi)^{d/2}|\Sigma|^{1/2}}\exp\left\{-\frac{1}{2}(\mathrm{x}-\mu)^{T}\Sigma^{-1}(\mathrm{x}-\mu)\right\} \quad (1)$$

where x is the location vector, $f(\ )$ is the density function, d is the dimension of the coordinate, μ is the mean vector, and Σ is the covariance matrix.

3.3 Conservative Assumption

• All disposal facilities are failed at a certain time after the repository is closed.

• All radionuclides are available to migrate to the ground surface in gas phase following the puff model as soon as the repository is failed.

3.4 Radionuclide Distribution at the Ground Surface

From an example result (Fig. 2), the radionuclide distribution at the ground surface could be estimated based on the arbitrarily-defined inventory distribution for each disposal vaults using the puff model (= trivariate normal distribution).

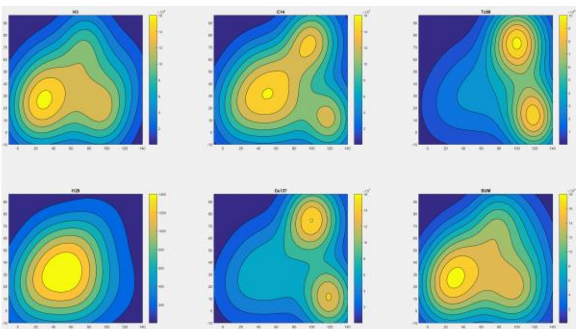

Fig. 2. Radionuclide distribution at the ground surface.

4. Conclusion

The 1st-step safety assessment conducted in this study needs to be deepened by considering the movement of the puff, the various failure time, the selection of gas phase radionuclides, and the gas phase fraction in the actual inventory. From this, the conservatives will be decreased.

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