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Earthquake Scenario Derivation and Impact Assessment of High-Level Radioactive Waste Disposal Repository Using GoldSim

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1. Introduction

High-level radioactive waste, such as spent nuclear fuel, must effectively isolate or at least delay the migration of radionuclides for a long time after disposal, tens to hundreds of thousands of years, to protect humans and the environment. Therefore, it is imperative that a repository ensure long-term safety. It is also necessary to establish systematic and practical preparedness measures to minimize the damage caused by future natural disasters that are difficult to predict. In this study, we derived earthquake scenarios based on FEP (Feature, Evnet, Process). These scenarios will be modeled and evaluated using the GoldSim program, which is capable of complex flow and impact assessment, to analyze nuclide release..

2. materials and methods

2.1 Scenario selection and assumptions

Deep disposal is a disposal concept that disposes of radioactive waste by constructing a repository deep in bedrock to prevent the release of harmful radioactive materials into the ecosystem. This disposal concept utilizes a multi-barrier system that combines engineered and natural barriers to effectively isolate radionuclides. In particular, the natural barrier serves to delay the migration of radionuclides into the ecosystem in the event of a leak from the engineered barrier. However, if a natural disaster, such as an earthquake, causes cracks in the natural barrier or modifies groundwater flow, the risk of radionuclide release can increase. Therefore, it is necessary to assess and prepare for these risks in advance to ensure long-term safety.

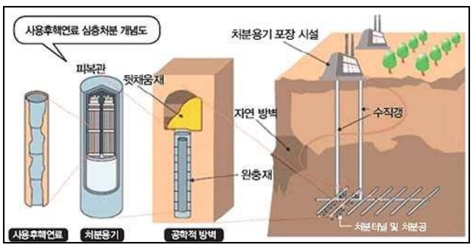

Fig. 1. Multi-Barrier System Concept

According to a table (Table 1) organizing the historical earthquakes on the Korean Peninsula by magnitude published by the Korea Meteorological Administration (KMA), out of a total of 2,161 earthquakes, earthquakes with magnitudes of 2 to 4, which are relatively weak, occurred most frequently (62%). The number of occurrences decreased sharply as the magnitude increased, with only 15 (0.7%) occurrences of magnitude 8-10. Magnitude 4.75 and above accounted for about 5.5% of all earthquakes, making up a very low percentage of the total.

Intensity	Number	Ratio(%)	Magnitude
2~4	1,340	62.0	<3.75
4	381	17.6	3.75
5	321	14.9	4.25
6	59	2.7	4.75
7	25	1.2	5.25
8	20	0.9	5.75
8~10	15	0.7	>5.75
TOTAL	2,161	-	-

Table 1 : Number of historical earthquakes depending on the earthquake intensity and magnitude

Although the overall proportion of low-intensity earthquakes is high and high-intensity earthquakes are rare, the design and safety assessment of facilities such as high-level radioactive waste repositories should consider the possibility of rare but destructive high-intensity earthquakes in the long-term safety assessment.

Therefore, this paper conservatively evaluates nuclide releases by assuming a situation where multiple earthquakes of magnitude 4.5 or greater occur within a short period of time.

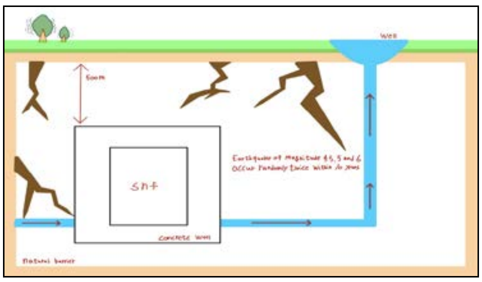

Fig. 2. Sketch of an earthquake scenario

2.2 Input data

The earthquake intensities were set as two 4.5 magnitude, two 5 magnitude, and two 6 magnitude earthquakes, and it was assumed that six earthquakes occurred randomly over a 10-year period.

In addition, we assumed the release of 14 nuclides that are subject to the concentration requirements of the Korean Radioactive Waste Handover Regulations.

Nuclide
H-3
C-14
Fe-55
Co-58
Co-60
Ni-59
Ni-63
Sr-90
Nb-94
Tc-99
I-129
Cs-137
Ce-144
Total Alpha

Table 2 : 14 nuclides subject to concentration determination under the Radioactive Waste Handover Regulations

2.3 GoldSim Modeling

The sketched earthquake scenario was modeled as follows. The modeling was done by setting the intensity and duration of the earthquake and incorporating nuclides.

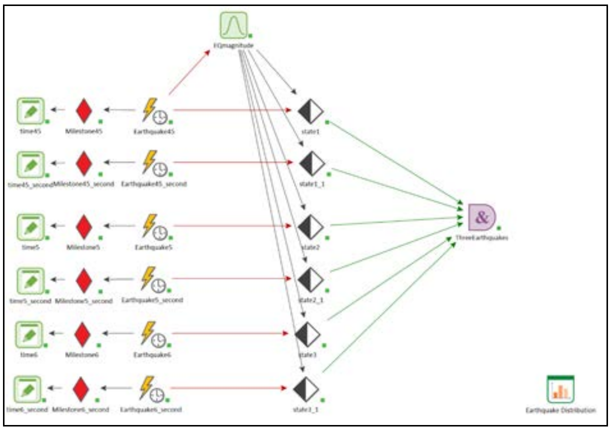

Fig. 3. Modeling an earthquake scenario

The modeling was performed using GoldSim, a program optimized for simulating mass and volume transfer in complex disposal systems, including nuclide migration in various media and across artificial and natural barriers, and groundwater flow.

3. Conclusions

According to the modeling results, the release of the 14 radionuclides subject to concentration identification under the domestic radioactive waste acceptance criteria begins after 100 years following repository closure, even under an extreme scenario involving six large-scale earthquakes. This indicates that, despite repeated seismic events causing damage to the natural barrier, no release of radionuclides occurs within the first 100 years, thereby confirming the safety of the repository during the short-and medium0term period.

Therefore, while the repository can be considered stable in the short- and medium- term, the potential for radionuclide release due to damage to the natural barrier after 100 years necessitates the establishment of long-term countermeasures. Future research will focus on refining the pathways of radionuclide migration and conducting safety assessments based on post-disaster habitation scenarios, with the goal of establishing long-term protection and management strategies.

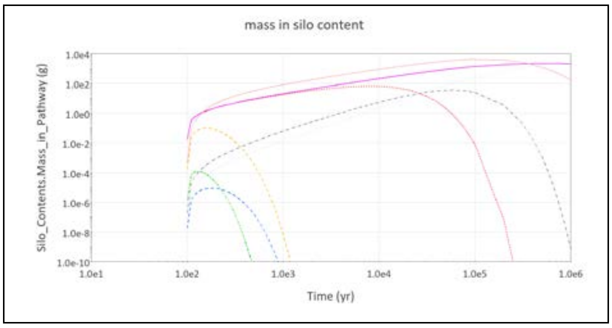

Fig. 4. Graph of modeling results

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