Safety Assessment for Liquid Release Scenario in IAEA Vault Safety Case

Jin Beak Park, Joowan Park, and Chang-Lak Kim
Nuclear Environment Technology Institute, Korea Hydro & Nuclear Power Co., Ltd.
P.O.Box 149, Yuseong Daejeon, 305-600, Korea, jbpark@khnp.co.kr

1. Introduction

As a part of the IAEA coordinated research program on Improvement of Safety Assessment Methodologies for near surface disposal facilities (ISAM), Vault Safety Case(VSC) was developed to test and understand safety assessment approaches and to provide practical experience in their implementation. VSC is based on proposed disposals to hypothetical engineered vaults with a Vaalputs geosphere and biosphere in South Africa. Among the design scenarios which represent disposal system evolution assuming the design functions as planned, the liquid release scenario was evaluated and compared with the reported results. A newly developed system-level assessment tool, SAGE, was used for the analysis. The features and code capabilities are also addressed.

2. System Description

The disposal facility is defined as a set of 20 concrete vaults located above ground level. The waste disposal area contains two lines of 10 vaults. Approximate dimensions of the disposal area are 170 by 210 m giving a surface area of 35,700 m^2. 150,000 m^3 of grouted waste is disposed in standard 200*l* drums and placed into concrete cubes, and grout filled in between the drums. The facility has a total of about 750,000 drums (37,500 per vault). Each vault has internal dimensions of 9m high by 20.5m wide by 83m long allowing concrete cubes to be stacked in an array 4 high x 17 wide x 69 long.

The site, Vaalputs, is situated in a semi-arid region, approximately 90 km from the nearest town. At Vaalputs, the unsaturated zone extends between 50–70m below the surface and consists of the weathered overburden and fractured bedrock. The unsaturated zone(UZ) is made up of a sequence of four lithologies. The UZ is followed by saturated, fractured bedrock.

Table 1 lists the radionuclide inventory at facility closure and decay chains considered in this safety assessment. All of the parameters necessary for the modeling of source-term, geosphere and biosphere are given by IAEA[1].

3. Scenario and Assessment Models

3.1 Liquid Release Scenario

Scenario corresponds to the use of contaminated water in the biosphere compartment at the interface with the geosphere, after migration of the radionuclides through the geosphere. The water and contaminant transport is started from the cover, which is directly exposed to the infiltrating water. Due to the water flow through the engineered structure of vault disposal system, the contaminated water flows downward from the waste matrix and the rest of the vault to the far field (the unsaturated layer and aquifer). The aquifer is assumed as the only source of biosphere contamination. Groundwater is abstracted from a well that is 200 m away from the boundary of the disposal area. The simplified representation of the scenario and conceptual model is shown in Figure 1.

Table 1. Radionuclide inventory and decay chains considered

Nuclides	Inventory (Bq)	Decay Chain
H-3	1E+15	
C-14	1E+13	
Ni-63	1E+10	
Sr-90	1E+15	
Tc-99	1E+14	
I-129	3E+10	
Cs-137	6E+09	
U-234	8E+15	Th-230→Ra-266→Pb-210
U-238	5E+10	U-234→Th-230→Ra-226→ Pb-210→Po-210
Pu-238	2E+10	U-234→Th-230→Ra-226→ Pb-210→Po-210
Pu-239	3E+10	U-235→Pa-231→Ac-227
Pu-241	6E+11	Am-241→Np-237→Pa-233→ U-233→Th-229
Am-241	2E+10	Np-237→Pa-233→ U-233→Th-229
TOTAL	1E+16	

3.2 Assessment Models

SAGE(Safety Assessment Groundwater Evaluation) is used for this assessment. It has been developed to provide functionality in evaluation releases to groundwater as part of a total safety assessment for development and licensing of an engineered concrete vault disposal facility[2]. The compartment approach is implemented in the code for near field, far field, and biosphere modeling.

It has been assumed that the near-field barriers degrade with time. The closure cover is maintained during the 100-year active institutional control period but then starts to degrade so that it allows the 50 % of

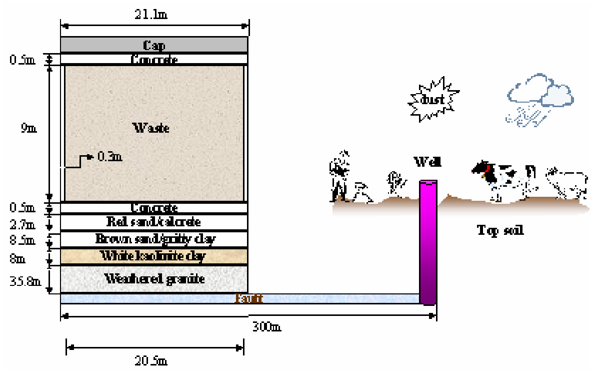

Figure 1. Conceptual drawing for liquid release scenario

total precipitation. After 500 years it no longer limits the rate of water infiltration. Furthermore, the near field would be degraded chemically after 500 years. In order to consider changing the distribution coefficient K_d's in the vault as a function of time, SAGE model assumes that K_d for each element and in each material in the near field is a piecewise step function of time.

For flow in the UZ, it was assumed that there are a series of fractures below the disposal facility and that an equivalent porous medium approximation can be made to represent flow and transport in the zone. In the saturated zone(SZ), it is assumed that the water that has percolated down from the UZ is intercepted by a series of fractures. It was assumed that the series of fractures in the SZ that intercept the percolating water from the disposal facility can be represented by a single streamtube.

4. Results and Discussion

The flux from the UZ to the SZ and the concentration of radionuclides in the well water were calculated by SAGE and compared with those from the published AMBER modeling[3]. As shown in Table 2 for releases into the aquifer, and in Table 3 for well concentrations, there is very good agreement between two analyses in terms of the timing and magnitude of the peak fluxes and concentrations of the key radionuclides. This is because similar conceptual and mathematical models have been used to calculate flow and transport in the saturated zone, although the implementation in the calculational software is different. Key differences in the mathematical models would come from the assumptions on changes in the infiltration of precipitation into the repository and on changes in the physical status of the concrete in the repository from non-degraded to fully degraded. In AMBER, linear relationships were used for infiltration and concrete failure modeling. Nevertheless, it was observed that the results were broadly the same because of the relatively rapid assumed transit time of water along the fracture and the low distribution coefficients for the radionuclides in the geosphere.

Table 2. Comparison of peak flux rates to the aquifer from published values and SAGE

Nuclides	AMBER		SAGE	
	Time (yr)	Peak Flux (Bq/y)	Time (yr)	Peak Flux (Bq/yr)
C-14	30000	3.7E+5	25000	5.9E+5
Tc-99	2500	1.9E+7	2100	1.7E+7
I-129	8000	1.4E+6	6700	1.1E+6
U-234	40000	4.1E+5	41000	4.7E+5
U-238	50000	4.6E+5	41000	4.7E+5

Table 3. Comparison of peak concentrations in the well from published values and SAGE.

Nuclides	AMBER		SAGE	
	Time (yr)	Peak Concentration ($Bq\ m^{-3}$)	Time (yr)	Peak Concentration ($Bq\ m^{-3}$)
C-14	30000	4.4E+1	28000	6.0E+1
Tc-99	2500	2.2E+3	2300	2.0E+3
I-129	8000	1.7E+2	6700	1.3E+2
U-234	50000	5.5E+1	43000	5.6E+1
U-238	50000	5.5E+1	43000	5.6E+1
Ra-226	100000	1.4E-1	100000	1.4E-1
Pb-210	100000	2.3E-1	100000	2.3E-1
Po-210	100000	4.6E-1	100000	4.6E-1

5. Conclusions

A discussion of a system-level safety assessment for liquid release scenario in IAEA VSC has been provided. The SAGE results have been compared against those from the other computer codes to ensure that the implementation is correct. The functionality of SAGE has also been tested. SAGE compared extremely well with the benchmark analysis, and is anticipated to give reliable results when applied for the assessment of near-surface disposal facilities.

REFERENCES

[1] IAEA, Vault Safety Case Data for the Liquid Release Calculations for the Design Scenario, ISAM Vault Safety Working Group, International Atomic Energy Agency, Vienna, 2001.

[2] Park, J.W., C.L. Kim, E.Y. Lee, Y.M. Lee, C.H. Kang, W. Zhou, and M.W. Kozak, "Development of a Computer Code for Low- and Intermediate-Level Radioactive Waste Disposal Safety Assessment," The First Asian and Oceanic Congress for Radiation Protection (AOCRP-1), Seoul, Oct. 2002.

[3] Kelly E., C. L. Kim, P. Lietava, R. Little, and I. Simon, "Safety Assessment of a Vault-based Disposal Facility Using the ISAM Methodology", International Conference on Issues and Trends in RW Management, IAEA, Vienna, Dec. 2002.