System-Level Test of MOSAIC: ISAM Vault Safety Case

Ji-Hoon Lee, Joo-Wan Park, Jin-Beak Park, Chang-Lak Kim

Korea Hydro & Nuclear Power Co., Ltd, NETEC, 150 Duck-Jin Dong, Yusung-Ku, Daejeon

jihoon@khnp.co.kr

A computer code, called MOSAIC (MOdular Safety Assessment code with Integrated Concrete analysis) has been developed by KHNP for evaluation of the concept for low-level waste disposal. A significant feature of MOSAIC is to evaluate explicitly the degradation of a concrete vault as a function of time. Intercomparison with those results from other codes has been undertaken, in which includes a system-level test with the IAEA ISAM Vault Safety Case. Characteristics of the test are

- Multiple layers of differing materials in the unsaturated zone,
- Sorption in the vault (K_d values) change with time,
- Flow through the disposal system begins at 10 percent of its full value, then increases linearly between 100 and 500 years.

Documentation of benchmarks carried out between Amber and Ecolego for the vault safety case is presented in Maul et al. (2004). The description of the conceptual model presented by Maul et al. does not precisely match the ISAM Vault Safety Case Description (IAEA, 2004), in that diffusion and dispersion in the vault and unsaturated zone was not included. However, Maul et al. provide results for a complete set of radionuclides, demonstrating excellent agreement between Ecolego and Amber for their benchmark exercise.

As expected from the results of Maul et al., a number of the radionuclides peak after 10^5 years; the more mobile fission product radionuclides and uranium isotopes peak before 10^5 years. A comparison is presented in Table 1 of the arrival time and peak flux between those calculated by Maul et al. and those using MOSAIC. As noted by Maul et al., comparing the peak is a stringent criterion for such a comparison. Excellent agreement is achieved between the two analyses for all sets of radionuclides, particularly since the models are implemented in different ways, and there was no possibility to check input files or the Ecolego and Amber model implementations to ensure consistency between the approaches. The largest observed difference between the analyses is for H-3; this difference is attributable to minor differences in the approach to represent the linear increase in flow during the period 100 – 500 years specified in the problem specification.

The release profiles from the near field were used with the MOSAIC far field to calculate concentrations at the well for the ISAM Vault Safety Case as specified by Maul et al. It is necessary to use the total well pumping rate (8300 m^3/y) deduced from irrigation and non-irrigation uses specified by Maul et al. to convert the geosphere flux to concentration.

Table 1. Comparison of the results of Maul et al. (2004) with MOSAIC for releases from the unsaturated zone. Dispersivities were set to zero in the vault and unsaturated zone in this benchmark of Ecolego and Amber.

Nuclide	Maul et al.		MOSAIC	
	Time (y)	Peak (Bq/y)	Time (y)	Peak (Bq/y)
C-14	2.9E4	7.9E5	2.8E4	7.6E5
H-3	5.0E2	7.8E-4	5.0E2	5.5E-4
Ni-59	1.0E6	1.4E-2	1.0E6	1.5E-2
Tc-99	2.5E3	1.9E7	2.8E3	1.8E7
I-129	7.4E3	1.4E6	7.4E3	1.4E6
Th-229	1.9E5	3.5E-2	1.9E5	3.5E-2
Th-230	1.2E5	2.0E2	1.2E5	2.0E2
Ra-226	1.2E5	1.2E3	1.2E5	1.2E3
Pb-210	1.2E5	2.0E3	1.2E5	2.0E3
Pu-239	5.1E5	4.7E-12	5.0E5	4.4E-12
U-233	1.7E5	3.3E1	1.7E5	3.3E1
U-234	3.5E4	5.1E5	3.4E4	5.1E5
U-235	7.2E4	7.0E0	6.7E4	6.9E0
U-238	3.5E4	5.1E5	3.4E4	5.1E5

The resulting comparison between the Ecolego and Amber analyses of Maul et al. and MOSAIC results is presented in Table 2. Good to excellent agreement is observed for all radionuclides.

Table 2. Concentrations for the ISAM vault safety case test problem as specified by Maul et al. (2004) compared to output from MOSAIC.

Nuclide	Maul et al.		MOSAIC	
	Time (y)	Peak (Bq/m^3)	Time (y)	Peak (Bq/m^3)
C-14	2.9E4	9.5E1	2.4E4	9.2E1
H-3	5.0E2	9.3E-8	5.0E2	6.6E-8
Tc-99	2.5E3	2.2E3	2.5E3	2.2E3
I-129	7.4E3	1.7E2	7.4E3	1.7E2
Th-229	1.9E5	4.2E-6	1.9E5	4.1E-6
Th-230	1.2E5	2.4E-2	1.2E5	2.4E-2
Ra-226	1.2E5	1.4E-1	1.2E5	1.4E-1
Pb-210	1.2E5	2.4E-1	1.2E5	2.4E-1
U-233	1.7E5	4.0E-3	1.7E5	4.0E-3
U-234	3.5E4	6.2E1	3.4E4	6.1E1
U-235	7.2E4	8.4E-4	6.7E4	8.4E-4
U-238	3.5E4	6.2E1	3.4E4	6.1E1

References

1. IAEA, Safety Assessment Methodologies for Near Surface Disposal Facilities, Results of a Coordinated Research Project, Volume 2: Test Cases, IAEA-ISAM, International Atomic Energy Agency, 2004.

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