Preliminary study on the assessment of radiological effect for radionuclides released through the groundwater pathway after the closure of near-surface disposal facility

Ki Nam Kwon [a*], Min Su Ju [a], Jin Young Chung [a], Tae Hoon Jeon [b], Jung Ho Song [a], Jae Hak Cheong [c]
[a]*BRNC Inc., 24, Gasan digital 1-ro, Geumcheon-gu, Seoul, Republic of Korea*
[b]*ORBITECH, 1130, Beoman-ro, Geumcheon-gu, Seoul, Republic of Korea*
[c]*Kyung Hee University, 1732 Deogyeong-daero, Giheung-gu, Yongin-si, Gyeonggi-do, 17104, Republic of Korea*
[*]*Corresponding author: konakwon@brncinc.co.kr*

1. Introduction

A near-surface disposal facility should be institutionally controlled for a period of time after closure, and management of disposal facility is no longer required after the institutional control period [1]. Radioactive waste which is disposed at disposal facility is isolated from the external environment through package, concrete barrier, and so on. However, since the lifetime of package and concrete barrier is only about a hundred years approximately, those will be degraded and be lost containment function after hundreds of years. As a result, the radionuclides in radioactive waste can be released out of repository along with infiltrated water by precipitation. Released radionuclides can spread out the off-site along the groundwater. At this time, if contaminated groundwater released from disposal facility is used by the public, they may be affected by radionuclides contained in the groundwater.

In Korea, the Low-and Intermediate-Level radioactive Waste (LILW) classification standards specify the limits of activity for eleven radionuclides (i.e. ^{3}H, ^{14}C, ^{59}Ni, ^{60}Co, ^{63}Ni, ^{90}Sr, ^{94}Nb, ^{99}Tc,^{129}I, ^{137}Cs, and Gross alpha). Likewise, the WAC (Waste Acceptance Criteria) for Korean LILW near-surface disposal facilities (i.e. Gyeongju Phase I and Phase II) are applied the same limits as the LILW classification standards. In addition, the safety assessment of after the closure of the disposal facility is evaluated in consideration of the same radionuclides [2].

Through the previous studies, the author established the six stylized human intrusion scenarios and proposed the assessment framework of near-surface disposal facility by using GENII Version 2 which was developed from PNNL (Pacific Northwest National Laboratory) and performed a preliminary safety assessment for the Gyeongju Phase II disposal facility [3]. However, in the previous studies, only the human intrusion scenarios, one of the safety assessments items, were evaluated and the safety assessment for the groundwater pathway scenarios were not performed.

Therefore, this study establishes a preliminary assessment framework to confirm the radiological effects of radionuclides released into groundwater pathway from near-surface disposal facility, and GENII Version 2 is used for safety assessment. In addition, the effects of representative radionuclides expected to be disposed at near-surface disposal facility are compared and reviewed.

2. Methods and Results

2.1 Source-Term

The eleven radionuclides specified in the general waste acceptance criteria (WAC) for LILW in Korea were considered as the representative radionuclides in this study. And the gross alpha was assumed to be ^{239}Pu. In additionally, the concentration of each radionuclide was assumed to be 1 Bq/mL to compare the radiological effect of the eleven radionuclides.

2.2 Assessment model for Representative Scenario

For the preliminary assessment, the Resident-Farmer scenario, which is expected to have the highest radiation dose among the scenarios considered as groundwater pathway scenarios in related studies, was selected as the representative scenario. In the Resident-Farmer scenario, it is assumed that the public drinks contaminated groundwater as drinking water. In addition, the contaminated groundwater is used as irrigation water to grow plants and raise livestock. The exposure pathways of the public are shown in Figure 1.

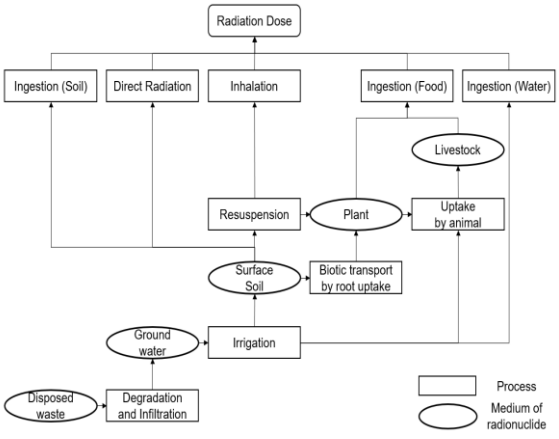

Fig. 1. Schematic diagram of the assessment model for the Resident-Farmer scenario.

2.3 Assessment Framework and Input Parameters

For assessment considering the above exposure pathways, the modules of GENII code were arranged as Figure 2. And the details of each module are as follows.

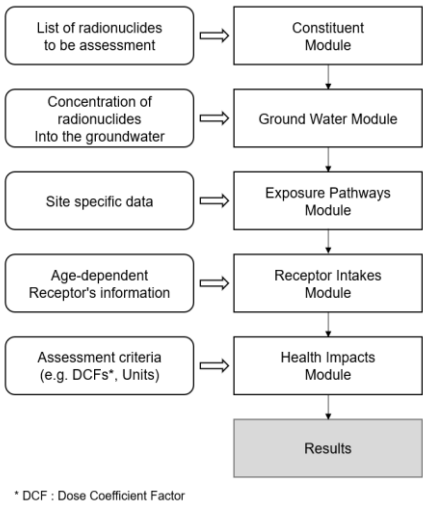

Fig. 2. Assessment process of the Resident-Farmer scenario using GENII Version 2.

As summarized in Table I below, the input parameters refer to values used in related studies.

Table I: Input parameters which is used for assessment the Resident-Farmer scenario and the references

Parameter	Unit	Value	Reference
Soil density	g/cm^3	1.5	[3], [4]
Soil ingestion rate	g/h	4.0×10^{-3}	[4]
Average rain rate	mm/y	1.2×10^{3}	[5]
Irrigation rate	m/y	4.0×10^{-1}	[6]
External exposure time	h/y	Outdoor : 2,190 Indoor : 4,380	[5]
Shielding Factor	-	Outdoor : 1.0 Indoor : 0.7	[4]

In the case of the Dose Coefficient Factor, the values were used according to the recommendation of ICRP (International Commission on Radiological Protection) Publication 60 adopted by the Nuclear Safety Act of Korea as the standard for evaluating exposure radiation dose. And the several parameters (e.g. Food ingestion rate, drinking water ingestion rate, breathing rate, etc.) were used for the age-dependent assessment of the six age groups with reference to the values presented in the related studies [6].

2.4 Results and Discussions

The results of evaluating annual effective dose per unit concentration of the eleven nuclides for six age groups for the Resident-Farmer scenario are shown in Figure 3. In the age group of 1, 5, 10, and 15, the ^{129}I was shown the highest annual effective dose. In other age groups, the annual effective dose of gross alpha was the highest. Additionally, the annual effective dose of the 3 months or 1 year age group tended to be higher than that of the adults, which is to be due to the milk intake rate (except ^{137}Cs). The milk intake rates of these age groups were approximately more than 3 times the intake rate of adults.

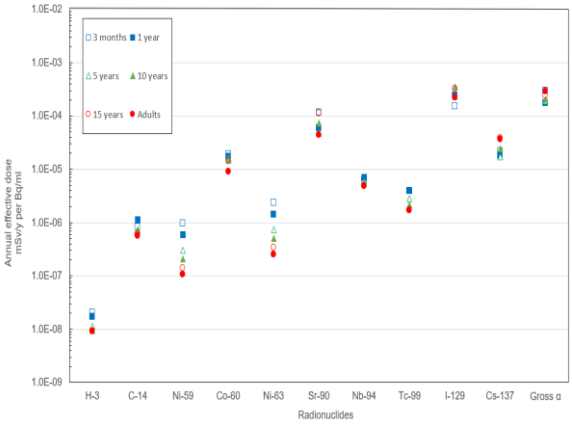

Fig. 3. Results of the Resident-Farmer scenario for six age groups.

3. Conclusions

This study established a preliminary assessment framework that can evaluate the radiological effects of radionuclides that may be released through the groundwater pathway after the closure of a near-surface disposal facility.

And the radiological effects of the eleven radionuclides expected to be released from a near-surface repository were evaluated and compared. This assessment framework will continue to be updated and it is expected that used as the part of a safety case for safety assessment after the closure of near-surface disposal facilities in domestic.

ACKNOWLEDGEMENT

This work was supported by the technology development program (S2712505) funded by the Ministry of SMEs and Startups (MSS, KOREA)

REFERENCES

[1] IAEA, Near surface disposal facilities for radioactive waste, IAEA Safety Standards Series No. SSG-29, IAEA, Vienna, 2014.
[2] S.W. Hong, S.H. Park, J.B. Park, Safety Assessment on the Human Intrusion Scenarios of Near Surface Disposal Facility for Low and Very Low Level Radioactive Waste, JNFCWT. 14(1) (2016) 79-90.
[3] K.N. Kwon, J.H. Cheong, Development of a reference framework to assess stylized human intrusion scenarios using GENII Version 2 considering design features of planned near-surface disposal facility in Korea, Nuclear Engineering and Technology. Vol 51. Issue 6. (2019) 1561-1574.
[4] Yu, Charley, Kamboj, Sunita, Wang, Cheng, Cheng, Jing-Jy, Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil and Building Structures, ANL/EVS/TM-14/4, Argonne National Lab., United States, 2015.
[5] Korean Statistical Information Service, Precipitation trend, http://kosis.kr/statHtml/statHtml.do?orgId=101&tblId=DT_1YL9901&conn_path=I2.
[6] Korea Institute of Nuclear Safety, User's Manual for INDAC, Guideline for Exposure Dose Assessment in Korea, KINS/GR-199, 2000.