Calculation of Dose Fractions for Discounted Radionuclides in Selecting Potential Radionuclides

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1. Introduction

The first commercial nuclear power plant in Korea, Kori Unit 1, is currently in a transition phase for decommissioning, and it is also the period when preparations for decommissioning are actively in progress. Once the Dismantling and Decontamination (D&D) activities of nuclear power plant is completed, site remediation process will be carried out. In this regard, DCGLs (Derived Concentration Guideline Levels) calculated from soil contamination will have to comply with site release criteria. To do this, the selection of potential radionuclides should be appropriate, and it is necessary to select important radionuclides rather than considering all nuclides. Therefore, the purpose of this study is to assess the dose fraction to eliminate less important radionuclides for making a list of potential radionuclides, and to present its basis.

2. Methods and Results

This section reviews the list of potential radionuclides used in decommissioning of nuclear power plant in the U.S., and then lists the initial radionuclides which is expected to present in the site for assessing dose fractions for discounted radionuclides.

2.1 Literature review

From overseas experiences such as Rancho Seco Nuclear Power Station (RSNPS), Zion Station, and Humboldt Bay Power Plant (HBPP), typically, they adopt several U.S. NRC document for selecting initial radionuclides including NUREG/CR-3474 [1], NUREG/ CR-4289, and NUREG/CR-0130 [2]. With these regulatory reference documents, they also performed additional technical reviews referring ORIGEN computer code, historical site assessment, and several sampling campaigns, so finally made a list of potential radionuclides.

The list of initial radionuclides derived by the above references includes minor radionuclides which need to be eliminated. To do this, their importance was assessed by the comparison of the total radioactivity, because the radionuclides supported from NUREG/CR-3474 and those derived from the ORIGEN code provide information on the radioactivity of radionuclides. Based on this information, the fraction of radioactivity was possibly calculated. The criteria for discounting radionuclides from the NUREG/CR-3473 or ORIGEN code, the fractions less than 0.1 % of the total radioactivity concentration were considered to be excluded. Next, the dose was assessed by using DandD code which confirmed to be insignificant when the dose fractions are less than 10 % of the total dose.

There are some radionuclides among the discounted radionuclides not supported by the DandD code. In this case, they used the weighted Dose Conversion Factor (DCF) comparing with Co-60 and Ni-63 which have high radioactivity ratio. Additionally, naturally occurring radionuclides and noble gases are also discounted because they are less likely to be found when the site is remediated.

2.2 Discounted radionuclides

This study used radionuclides of NUREG/CR-3474 document which can utilize the radioactivity information for the target in order to obtain the fraction of minor radionuclides. Radionuclides presented in the tables' No. 5.1 to 5.6, 5.13, and 5.15, cited in reference plants (RSNPS, Zion, and HBPP). Therefore, in this study, a total of 40 nuclides are listed, and those with a half-life of less than 2 years are excluded from the target because it takes at least 15 years to complete the decommissioning of nuclear power plant. As a result, a total of 38 radionuclides are listed for the initial radionuclides as shown in Table I.

Table I : Initial Radionuclides of NUREG/CR-3474

H-3	C-14	Cl-36	Ar-39
Ca-41	Mn-53	Fe-55	Ni-59
Co-60	Ni-63	Nb-92m	Zr-93
Mo-93	Nb-94	Tc-99	Ag-108m
Sn-121m	I-129	Ba-133	Cs-134
Cs-135	Cs-137	Pm-145	Sm-146
Sm-151	Eu-152	Eu-154	Eu-155
Tb-158	Ho-166m	Hf-178m	Pb-205
U-233	Pu-239	Sr-90	Se-79
Kr-81	Kr-85		

From the information of radioactivity which consists of shroud, core barrel, thermal pads, vessel cladding, and vessel walls, we re-calculated the radioactivity after 15 years by applying each radionuclides half-life, then 3 types of comparison (radioactivity of total, Ni-63, and Co-63) are performed. As a result, we found that the

major radionuclides, more than 0.1 % of each comparison, are C-14, Fe-55, Ni-59, Co-60, and Ni-63, and the ratio of the rest of minor radionuclides assumed to be discounted accounts for 0.045 %.

2.3 RESRAD settings

For our dose assessment by using the RESRAD, we used the values of the parameters reflecting the geological survey and environmental characteristics of the site. For this purpose, we referred to the historical site assessment (HSA), the evaluation data on the radioactive transport in groundwater, the data developed by the regulatory, guidelines of development of regulatory requirements for radioactive waste, and development of technology in radiation safety regulations. The RESRAD manual and the RESRAD Data Collection Handbook were also used to define parameter values.

For the selectin of proper site reuse scenario, this study is not for the purpose of calculating exact dose values but for relative comparison. Therefore, farmer scenario which considering all exposure pathways is applied. In addition, there are two analysis methods in the RESRAD, deterministic and probability analysis. Similar to the above reason, this study used deterministic analysis. In case of input parameter of radioactivity for 38 radionuclides, the fractions of radioactivity derived were used.

2.4 Dose Results

The dose fractions of each radionuclides are calculated by using RESRAD evaluation results as shown in Table II. The radioactivity input value of each radionuclide represents the fraction of the radioactivity in consideration of the period of decommissioning completion (15 years) for the information of radioactivity provided by NUREG/CR-3474 as described above. Therefore, the dose value represents doses for the relative radioactivity of each radionuclides.

Table II : Dose Results for Initial Radionuclides

Nuclides	Radioactivity	Dose	Fraction
Co-60	4.53E-01	8.70E-01	9.99E-01
C-14	6.36E-04	7.73E-04	8.88E-04
Ni-63	4.24E-01	3.47E-04	3.98E-04
Fe-55	1.19E-01	2.88E-05	3.31E-05
Sr-90	2.89E-05	2.07E-05	2.38E-05
Cs-137	3.12E-05	1.60E-05	1.83E-05
Eu-154	1.15E-05	1.09E-05	1.25E-05
Ba-133	2.75E-05	6.91E-06	7.93E-06
Ho-166m	3.85E-06	5.21E-06	5.98E-06
Cl-36	1.31E-05	4.69E-06	5.39E-06
Eu-152	4.70E-06	4.09E-06	4.70E-06
Hf-178m	1.45E-06	2.52E-06	2.89E-06
Cs-134	1.20E-06	1.36E-06	1.56E-06
Nb-94	9.39E-06	1.08E-06	1.23E-06
Ni-59	3.04E-03	1.05E-06	1.20E-06
Mo-93	2.13E-05	6.53E-07	7.50E-07
Ag-108m	2.25E-06	5.22E-07	5.99E-07
H-3	2.79E-04	2.15E-07	2.46E-07
Tc-99	3.10E-06	7.90E-08	9.07E-08
Eu-155	1.70E-06	4.06E-08	4.66E-08
Tb-158	4.52E-08	2.72E-08	3.12E-08
Sn-121m	9.25E-08	2.08E-08	2.38E-08
Pu-239	2.36E-07	1.01E-08	1.15E-08
Se-79	1.45E-08	5.50E-09	6.31E-09
Ca-41	1.19E-07	8.50E-10	9.75E-10
U-233	1.14E-08	1.43E-10	1.65E-10
Mn-53	7.57E-08	5.07E-11	5.82E-11
I-129	1.39E-11	5.00E-11	5.74E-11
Pm-145	1.31E-08	4.81E-11	5.52E-11
Cs-135	9.22E-10	9.87E-12	1.13E-11
Sm-151	2.92E-07	8.24E-12	9.46E-12
Zr-93	2.38E-09	4.17E-12	4.79E-12
Pb-205	4.68E-11	1.06E-14	1.22E-14
Sm-146	2.57E-15	4.02E-17	4.61E-17
Ar-39	3.30E-06	0.00E+00	0.00E+00
Kr-81	1.59E-08	0.00E+00	0.00E+00
Kr-85	6.98E-06	0.00E+00	0.00E+00
Nb-92m	9.94E-174	0.00E+00	0.00E+00
Total	1.00E+00	8.71E-01	1.00E+00

3. Conclusions

Through analysis using radionuclides and their radioactivity fractions provided by NUREG/CR-3474, major radionuclides and minor radionuclides could be selected by using the 0.1 % criteria for the radioactivity fraction. Radioactivity fraction exceeding 0.1 % were 5 radionuclides (Co-60, C-14, Ni-63, Fe-55, and Ni-59), and the remaining nuclides were screened as insignificant radionuclides. As shown in Table II, the total dose fraction of these minor radionuclides was 8.61E-05 (0.00861 %), indicating that dose contributions are also insignificant, which shows the minor radionuclides can be discounted. Additionally, as shown in the dose results, Co-60 account for 99.9 % of the total dose, representing that most of the dose is caused by Co-60. From this sense, it is noted that Co-60 is the most important radionuclide in terms of exposure in the decommissioning.

REFERENCES

[1] NRC, Long-Lived Activation Products in Reactor Materials, U.S. Nuclear Regulatory Commission, NUREG/CR-3474, 1984.
[2] NRC, Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station, U.S. Nuclear Regulatory Commission, NUREG/CR-0130, 1978.