Derived DCGL for Site Release of Kori Unit 1

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1. Introduction

As Kori Unit1 is permanently shut down in June, 2017, permanent suspension and decommissioning of domestic old aging nuclear power plants are anticipated.

The final purpose of decommissioning is to release the site, and it should be ensured that the concentration in the soil of radionuclides remaining on the site where decontamination has been completed satisfies Derived Concentration Guideline Levels (DCGL). DCGL is the limit of radioactive concentration of nuclear species applied for reuse of site after decommissioning. If it is proved that the concentrations of radioactive materials in nuclear facilities and sites are below the specified site release criteria, site opening is possible.

In this paper, radionuclide were selected from the decommissioned nuclear power plants in the United States (U.S.), and DCGL values of the nuclear species of Kori Unit 1 are derived.

2. Methodology

2.1 Regulation for Site Release

In U.S., the Federal Regulations (10 CFR Part 20) allow unrestricted use of premises if the Total Effective Dose Equivalent (TEDE) of the average individual by residual radiation does not exceed 0.25 mSv/yr. Most nuclear power plants use these numbers, but some states (Maine Yankee 0.1mSv/yr, Connecticut Yankee 0.19 mSv/yr) have adopted more conservative standards. Based on these criteria, a total of 8 commercial nuclear power plants were re-used as greenfields or thermal power plant sites after completion of decommissioning and summarized in Table I.

Table I : Case for Site Reuse after NPP Decommissioning

NPP	Site Reuse	Criteria
Maine Yankee	Green Field	0.1mSv/yr
Haddam Neck	Green Field	0.19mSv/yr
Shoreham	Thermal Power Plant	0.25mSv/yr
Fort St. Vrain	Thermal Power Plant	0.25mSv/yr
Trojan	Green Field	0.25mSv/yr
Big Rock Point	Green Field	0.25mSv/yr
Yankee Rowe	Green Field	0.25mSv/yr
Rancho Seco	Thermal Power Plant	0.25mSv/yr

In Korea, the criteria for reuse of the site after decommissioning the domestic nuclear power plant is specified in Nuclear Safety and Security Commission (NSSC) Notice No. 2016-33 “Criteria for Reuse of Site and Remaining Buildings after Completion of Decommissioning of Nuclear Facilities”. In order to unlimited reuse of site after decommissioning, the annual radiation exposure for individuals due to residual radiation shall not exceed 0.1 mSv/yr per year. The Korea Atomic Energy Research Institute (KAERI) led the completion of decontamination and decommissioning of the second research reactor (TRIGA MARK-II, III). In this process, the value of 0.1 mSv/y considering the unrestricted use of the site was applied.

2.2 Concept of DCGL

DCGL are radionuclide-specific concentration limits used to guide clean-up of a decommissioning site to meet radiological criteria for license termination. Cleanup and release from regulatory control of a site is one of the sources of exposure. The International Atomic Energy Agency (IAEA) recommends that site release criteria be optimized within the range of 10-300 μSv/yr. But the reason why the regulatory agency presents only site opening criteria for the dose (DCGL is not suggested) is that the DCGL value changes depending on the site characteristics.

2.3 Nuclide Selection for DCGL Calculation

To calculate the DCGL, the nuclide must first be selected. According to the EPRI document "Lessons Learned from EPRI Decommissioning Program Site Characterization", the following points should be considered when selecting nuclides.

- Decay half-life
- Quantities projected compared to release limits
- Dose significance based on abundance and human radiosensitivity

In NUREG-1757, nuclides to be considered in the derivation of Soil nuclides are specified, and EPRI document provides typically nuclides that should be considered in decommissioning nuclear power plants (Table II). In order to refer to the decommissioning cases of overseas nuclear power plants, it reviewed the nuclides of the four U.S. nuclear power plants (Yankee Rowe, Connecticut Yankee, San Onofre Unit 1, Rancho Seco) that were decommissioned (Table III).

Table II : Typical Radionuclides of Concern at Power Plant Decommissioning

Radionuclide	Half-life(yr)	Radionuclide	Half-life(yr)
H-3	$1.23*10^{1}$	Cs-134	$2.06*10^{0}$
C-14	$5.73*10^{3}$	Cs-137	$3.02*10^{1}$
Mn-54	$8.56*10^{-1}$	Eu-152	$1.33*10^{1}$
Fe-55	$2.68*10^{0}$	Eu-154	$8.50*10^{0}$
Co-60	$5.27*10^{0}$	Eu-155	$4.96*10^{0}$
Ni-63	$1.00*10^{2}$	Pu-238	$8.77*10^{1}$
Sr-90	$2.88*10^{1}$	Pu-239/ Pu-240	$2.41*10^{4}$
Nb-94	$2.00*10^{4}$	Pu-241	$1.44*10^{1}$
Tc-99	$2.14*10^{5}$	Am-241	$4.32*10^{2}$
Ag-108m	$1.27*10^{2}$	Cm-243/244	$2.85*10^{1}$

Table III : DCGL (derived nuclides) by each Nuclear Plant

Radio nuclide	Yankee Rowe	Connecticut Yankee	San Onofre Unit1	Rancho Seco
H-3	O	O	O	-
C-14	O	O	O	O
Mn-54	-	O	O	-
Fe-55	O	O	O	-
Co-60	O	O	O	O
Ni-63	O	O	O	O
Sr-90	O	O	O	O
Nb-94	O	O	-	-
Tc-99	O	O	O	-
Ag-108m	O	O	-	-
Cs-134	O	O	-	O
Cs-137	O	O	O	O
Eu-152	O	O	O	-
Eu-154	O	O	-	-
Pu-238	O	O	O	-
Pu-239	O	O	O	-
Pu-241	O	O	O	-
Am-241	O	O	O	-
Cm-243	O	O	-	-

In order to calculate conservatively, the nuclides derived from three or more nuclear power plants among four nuclear power plants were selected as the DCGL derived nuclides of Kori Unit 1. Site characteristics data of Kori Unit 1 for using RESRAD-Onsite were referenced by the KINS/GR-297.

3. Results

3.1 U.S. Site Release Criteria (0.25 mSv/yr)

To compare the results of Kori Unit 1 with the results of U.S. nuclear power plants, 0.25mSv/yr was applied which is site release criteria in U.S. Table IV shows the result of Kori Unit 1.

Table IV : Results of U.S. NPPs and Kori Unit 1 (Bq/g)

Radio nuclide	Yankee Rowe	Connecticut Yankee	San Onofre Unit 1	Kori Unit 1
H-3	1.30E+01	1.52E+01	4.07E+00	3.94E+01
C-14	1.92E-01	2.09E-01	4.44E-01	1.01E-02
Fe-55	1.04+03	1.01E+03	5.18E+02	5.88E+02
Co-60	1.41E-01	1.41E-01	1.41E-01	9.45E-02
Ni-63	2.85E+01	2.68E+01	7.77E+01	4.59E+01
Sr-90	5.92E-02	5.74E-02	6.29E-02	4.59E-02
Tc-99	4.81E-01	4.66E-01	7.03E-01	5.87E-01
Cs-134	1.74E-01	1.73E-01	N/S*	1.88E-01
Cs-137	3.03E-01	2.93E-01	4.07E-01	2.73E-01
Eu-152	3.52E-01	4.07E-01	3.22E-01	2.06E-01
Pu-238	1.15E+00	1.10E+00	9.25E-02	1.47E+00
Pu-239	1.04E+00	9.88E-01	8.51E-02	1.33E+00
Pu-241	3.44E+01	3.22E+01	2.66E+00	6.99E+01
Am-241	1.04E+00	9.55E-01	7.77E-02	1.64E+00

*Not Detected in Characterization Samples

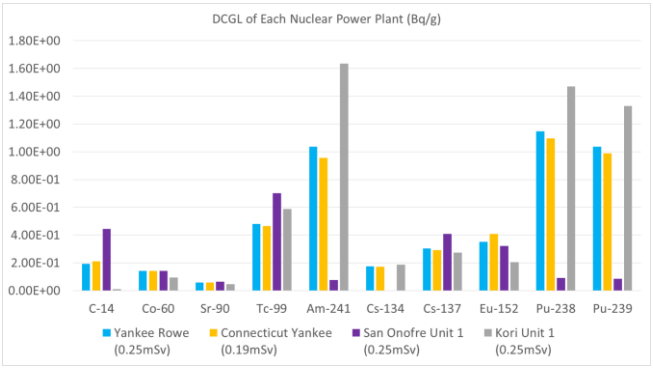

Fig. 1 Calculation Results (C-14, Co-60, Sr-90, Tc-99, Am-241, Cs-134, Cs-137, Eu-152, Pu-238, Pu-239)

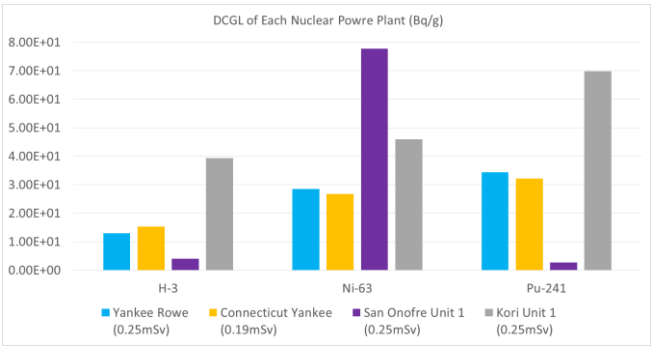

Fig. 2 Calculation Results (H-3, Ni-63, Pu-241)

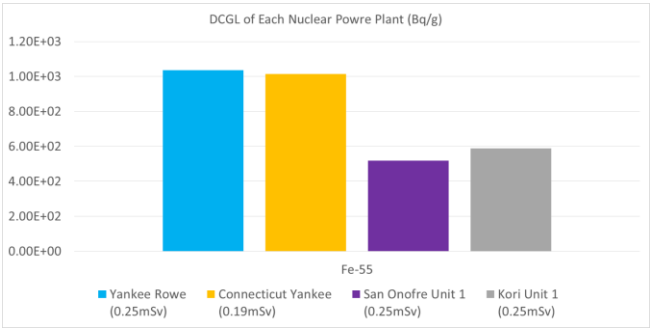

Fig. 3 Calculation Results (Fe-55)

The values of H-3 and Pu-241 of Kori Unit 1 tended to be slightly higher than those of U.S. nuclear power plants, but there was no significant difference in overall.

3.2 Domestic Site Release Criteria (0.1 mSv/yr)

The DCGL value of Kori Unit 1 was calculated by applying 0.1mSv/yr, which is the site release criteria in Korea (Table V).

Table V : Result of Kori Unit 1 (Bq/g)

Radionuclide	Kori Unit 1
H-3	1.58E+01
C-14	4.05E-03
Fe-55	2.35E+02
Co-60	3.78E-02
Ni-63	1.83E+01
Sr-90	1.84E-02
Tc-99	2.35E-01
Cs-134	6.55E-01
Cs-137	7.53E-02
Eu-152	1.09E-01
Pu-238	8.23E-02
Pu-239	5.89E-01
Pu-241	5.31E-01
Am-241	2.80E+01

4. Conclusions

In order to release the site of the dismantling nuclear power plant, it can be judged by confirming whether DCGL is satisfied or not. In this study, the DCGL value of Kori Unit 1 was calculated using RESRAD-Onsite.

The DCGL of Kori Unit 1 using RESRAD-Onsite in this paper is preliminary, Compared with the U.S. nuclear power plants that were decommissioned, there was no significant difference (when 0.25mSv/yr applied). In addition, when applying the domestic standard of 0.1mSv/yr and comparing it with the results of the U.S. nuclear power plant, all nuclear species were within the range of the U.S. cases.

5. Acknowledgement

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REFERENCES

[1] EPRI, “Lessons Learned from EPRI Decommissioning Program Site Characterization,” March 2015.
[2] IAEA Safety Standards, “Release of Sites from Regulatory Control on Termination of Practices,” No. WS-G-5.1, 2006.
[3] W. Son, G.B. Lee, S. H. Son, “Technical review of residual radioactivity induced concentration standards,” Korean Radioactive Waste Society, 2015.
[4] T. B. Yun, S. H. Kim, J. Y. Kim, “Application of Reuse Standard for Dismantling Site of Nuclear Power Plant in Korea,” Korean Radioactive Waste Society, 2016.
[5] KINS/GR-297, “Development of Technology in Radiation Safety Regulations,” February 2005.