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Development of Soil Derived Concentration Guidance Levels for Decommissioning at Overseas Nuclear Power Plants

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1. Introduction

The ultimate goal of decommissioning of a nuclear power plant is to release the site from the regulatory control for future use thereby terminating its license. This License Termination can be achieved by reducing the risk of residual radioactivity below the site release criteria. In Korea, the criteria are expected to be given in terms of dose as in US and Spain. However, since dose cannot be measured, corresponding measurable concentration limits, so-called Derived Concentration Guidance Levels (DCGLs), should be developed for each radionuclide which is expected to be present in the site. Also, as they serve as a goal of decommissioning and direct dismantling and decontamination methods applicable to the site, DCGLs should be developed in the early phase of decommissioning.

This paper describes how each overseas nuclear power plant developed its site-specific Soil DCGLs[1]: what kind of post closure use of the site (scenario) was assumed and how the site-specific Soil DCGLs were calculated based on the scenario assumed for each plant. Through this, it is intended to derive lessons learned which will be instructive for future decommissioning of domestic nuclear power plants including Kori Unit 1.

2. Examples of Site-Specific Soil DCGLs Developments at Overseas NPPs

2.1 Connecticut Yankee

To derive a site-specific Soil DCGLs, Connecticut Yankee assumed the Resident Farmer Scenario with the site release criterion of 19 mrem/yr as required by the State of Connecticut, which is stricter than that required by NRC (25 mrem/yr). Because onsite groundwater was contaminated and there was contaminated subsurface concrete, their effects had to be accounted for in order to calculate the site-specific Soil DCGLs. For this, dose from contamination which was present in groundwater (Dose $_{\text{Existing GW}}$), and from contamination which was expected to be present in groundwater due to leach of radionuclides from subsurface concrete (Dose $_{\text{Future GW}}$) needed to be subtracted from the total allowable dose of 19 mrem/yr (Dose $_{\text{Total}}$) by applying the following a "compliance equation":

$$\text{Dose}_{\text{Soil}} = \text{Dose}_{\text{Total}} - (\text{Dose}_{\text{Existing GW}} + \text{Dose}_{\text{Future GW}}) \quad (1)$$

The Dose $_{\text{Existing GW}}$ was set at 2 mrem/yr based on the groundwater monitoring sample results and Dose $_{\text{Future GW}}$ was also set at 2 mrem/yr based on the calculation results for leach of radionuclides from the subsurface concrete, respectively. As a result, the dose allotted for the site-specific Soil DCGLs was determined to be 15 mrem/yr [19 – (2 + 2)]. The Soil DCGLs calculated for each of radionuclides using RESRAD code are shown in Table I [1]. The similar method was applied at Yankee Rowe and Maine Yankee, which had contamination groundwater and subsurface concrete as Connecticut Yankee [2, 3].

Table I: Soil DCGLs at Connecticut Yankee (15 mrem/yr)

Nuclide	DCGL (Bq/g)	Nuclide	DCGL (Bq/g)
H-3	9.12	Cs-134	0.1
C-14	0.13	Cs-137	0.17
Mn-54	0.38	Eu-152	0.22
Fe-55	608.4	Eu-154	0.2
Co-60	0.08	Pu-238	0.66
Ni-63	16.08	Pu-239	0.59
Sr-90	0.04	Pu-241	19.32
Nb-94	0.16	Am-241	0.57
Tc-99	0.28	Cm-243	0.64

2.2 Rancho Seco

The situation of Rancho Seco was different from those of earlier plants such as Connecticut Yankee because the site was planned to be reused for the Industrial purpose (a natural gas fired power plant) and continue to be owned by the utility after license termination, thereby enabling enforcement of institute-onnal control over the site. Furthermore, Rancho Seco site showed only low levels of soil contamination with only 6 radio-nuclides being detected. This situation allowed Rancho Seco to apply the Industrial Worker Scenario with NRC's site release criterion (25 mrem/yr). As Rancho Seco site had no groundwater contamination, they did not need to use the compliance equation as Connecticut Yankee did.

The utility could have higher Soil DCGLs than the earlier plants due to the following reasons: First, it could use the Industrial Worker Scenario which is more practical and less conservative than the Resident Farmer

[1] The Soil DCGL represents the concentration of a residual radionuclide in soil distinguishable from back-ground which, if distributed uniformly throughout the site, would result in dose corresponding to the site release criteria.

Scenario because the former assumes that a member of the critical group (an industrial worker) receives dose through fewer exposure pathways and shorter exposure time than the latter. Second, the site release criteria applied to Rancho Seco was higher than those of the earlier plants. The Soil DCGLs specific for Rancho Seco site which were calculated using the RESRAD code are given in Table II [2].

Table II: Soil DCGLs at Rancho Seco (25 mrem/yr)

Nuclide	DCGL (Bq/g)	Nuclide	DCGL (Bq/g)
C-14	30,800	Sr-90	240
Co-60	0.47	Cs-134	0.83
Ni-63	562,000	Cs-137	1.95

2.3 Jose Cabrera

Jose Cabrera implemented a unique approach for the derivation of its Soil DCGLs. They calculated two kinds of Soil DCGLs using the RESRAD code: one based on the assumption of the Industrial Worker Scenario and the site release criterion of 10 mrem/yr, and the other on the assumption of the Resident Farmer Scenario and the site release criterion of 100 mrem/yr. The former site release criterion should be met for unrestricted release of site in Spain and the latter criterion is allowed for the case where institutional controls needed for the unrestricted release is lost. Jose Cabrera decided its site-specific Soil DCGL by selecting a more limiting value from these two kinds of DCDLs calculated for each radionuclide (Table III) [2].

Table III: Comparison of Soil DCGLs at Jose Cabrera

Key Radio-nuclide	DCGL (Bq/g) for 10 mrem/yr		
	Industrial Worker	Resident Farmer	Limiting
Am-241	45.6	60.5	45.6
Co-60	0.234	0.654	0.234
Cs-134	0.417	1.03	0.417
Cs-137	0.987	2.22	0.987
Ni-63	237,710	95,900	95,900
Pu-239	105	67.5	67.5
Pu-240	105	67.7	67.7

As can be seen from Table III, for Am-241, Co-60, Cs-134 and Cs-137, the DCGLs derived based on the assumption of the Industrial Worker Scenario and the site release criterion of 10 mrem/yr were applied while for Ni-63, Pu-239 and Pu-340, the DCGLs based on the assumption of the Resident Farmer Scenario and the site release criterion of 100 mrem/yr were applied, respectively.

3. Discussions and Conclusions

From the experiences at the overseas plants above, it can be seen that, if a site has contamination in ground water and/or subsurface component, it is necessary to estimate dose resulting from these contamination and to subtract it from the total allowable dose of the site release criteria, which will reduce values of the Soil DCGLs accordingly.

Table IV shows the Soil DCGLs of the three plants mentioned earlier, which have been recalculated with the same site release criterion (25 mrem/yr) in order to investigate the impact of the selection of scenario. As can be seen from Table IV, the selection of scenario has a considerable impact on the resultant Soil DCGLs: the DCGLs derived based on the Industrial Worker Scenario have always higher values than those derived based on the Resident Farmer Scenario. Also the table shows that, the Soil DCGLs for the Industrial Worker Scenario can vary depending on site-specific conditions of the site of concern.

Therefore, it is very important to have as good understanding as possible of characteristics of the site by collection of relevant information and data in order to apply a scenario which is most foreseeable and plausible for a site to be decommissioned and to provide site-specific inputs to the calculation of the Soil DCGLs. These efforts will help to have not-overly conservative values for the Soil DCGLs, thus thereby reducing the costs and time needed for performing the decommissioning.

Table IV: Comparison of Soil DCGLs recalculated with the same site release criterion of 25 mrem/yr

Key Radio-nuclide	DCGL (Bq/g) for 25 mrem/yr		
	Connecticut Yankee (Resident Farmer Scenario)	Rancho Seco (Industrial Worker Scenario)	Jose Cabrera (Industrial Worker Scenario)
C-14	0.21	30,800	-
Co-60	0.14	0.47	0.585
Ni-63	26.8	562,000	594,275
Sr-90	0.06	240	-
Cs-134	0.17	0.83	1.04
Cs-137	0.29	1.95	2.47
Pu-239	0.99	-	262.5

REFERENCES

[1] Connecticut Yankee, Haddam Neck Plant License Termination Plan, Revision 4, 2006.
[2] EPRI, Technical Bases for the Development and Application of Derived Concentration Guidance Levels for Decommissioning and License Termination of Nuclear Power Plants, 1025315, 2012.
[3] Maine Yankee, Maine Yankee License Termination Plan, Revision 3, 2002.
[4] Rancho Seco, Rancho Seco License Termination Plan, Revision 0, 2006.