Derivation of Surface Soil Area Factor for Kori-1 NPP by Using RESRAD-ONSITE

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1. Introduction

Currently, decommissioning procedure and related preparations for Kori Unit 1 are being prepared based on MARSSIM, U.S. standard decommissioning procedure guidance manual. MARSSIM recommends derivation of DCGLs to establish safety assessment methods for site de-regulation in preliminary survey and final status survey. DCGLs are derived differently from $DCGL_w$, which is calculated by applying the uniformly distributed residual radioactivity over a wide area, and $DCGL_{EMC}$, which is applied when there is elevated residual radioactivity in small areas. In this study, a suite of potential radionuclides of Kori Unit 1 was selected in the same way as the preceding $DCGL_w$ derivation, and area factor for $DCGL_{EMC}$ of surface soil exposure was derived by referring to the decommissioning technical documents of U.S. nuclear power plants.

2. Potential Radionuclides of Concern

A suite of potential radionuclides of Kori Unit 1 was selected by combining the methodologies of Rancho Seco and Zion NPPs. Table 1 lists the theoretical potential radionuclides.

Table 1. Theoretical Radionuclides of Concern

NPP	Rancho Seco (PWR, Babcocks&Wilcox)		Zion 1,2 (PWR, Westinghouse)	
Document	NUREG/CR-3474 [1]			
Common	^{108m}Ag	^{39}Ar	^{133}Ba	^{14}C
	^{41}Ca	^{36}Cl	^{60}Co	^{134}Cs
	^{137}Cs	^{152}Eu	^{154}Eu	^{155}Eu
	^{178m}Hf	^{3}H	^{129}I	^{81}Kr
	^{166m}Ho	^{85}Kr	^{53}Mn	^{93}Mo
	^{121m}Sn	^{94}Nb	^{59}Ni	^{63}Ni
	^{205}Pb	^{145}Pm	^{239}Pu	^{79}Se
	^{146}Sm	^{151}Sm	^{90}Sr	^{158}Tb
	^{99}Tc	^{233}U	^{93}Zr	^{55}Fe
Difference	^{93m}Nb	^{135}Cs	^{240}Pu	^{92m}Nb
Document	NUREG/CR-4289 [2]			
Common	^{238}Pu	^{241}Am		^{244}Cm
	^{125}Sb		^{237}Np	
Difference	^{240}Pu		^{243}Am	
Document	NUREG/CR-0130, Vol. 1 [3]		WINCO-1191 [4]	
Difference	–		^{147}Pm	^{241}Pu
	ORIGEN code		19 samples [5]	
	^{147}Pm	^{241}Pu	^{243}Cm	
	^{243}Am	^{243}Cm		
	NCRP Report No.58 [6]			
	^{234}U	^{235}U		
	^{236}U	^{238}U		

Referring NUREG/CR-3474, NUREG/CR-4289, NUREG/ CR-0130, vol. 1, WINCO-1191, radionuclides with a half-life of more than 2 years were initially selected. Remaining radionuclides were supplemented with reference to the results of the ORIGEN code execution and NCRP Report No. 58 in Rancho Seco NPP and Zion NPP added radionuclides through 19 sample analyzes, including waste stream analysis actually collected at the site. As a result, theoretical radionuclides of concern for Rancho Seco and Zion NPP were 54 and 47, respectively.

However, in order to select the site-specific radionuclides, a process of summarizing the nuclides of Table 1 is necessary. In the case of Rancho Seco NPP, site-specific suite of radionuclides was established by using the results of the NUREG/CR-3474 radioactive fraction and ORIGEN code results, radionuclides with less than 0.1% concentration of total radioactivity were excluded and added via 10 CFR Part 61 waste stream analysis [7]. Zion NPP excluded radionuclides with an active concentration of less than 0.0001 (0.01%) compared to the active concentration calculated from the sum of ^{60}Co and ^{63}Ni, the main radionuclides identified in 19 representative samples. Although it does not appear in the documentation, ^{92m}Nb of Zion NPP has been excluded with a half-life of 10.13 days. In common, inert gases and naturally occurring radionuclides were also excluded. Finally, 26 site-specific radionuclides were determined for both NPPs. (Common radionuclides: ^{108m}Ag, ^{14}C, ^{60}Co, ^{134}Cs, ^{137}Cs, ^{152}Eu, ^{154}Eu, ^{155}Eu, ^{55}Fe, ^{3}H, ^{59}Nb, ^{59}Ni, ^{63}Ni, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{90}Sr, ^{99}Tc, ^{241}Am, ^{244}Cm, ^{237}Np, ^{125}Sb, ^{147}Pm, ; Radionuclides specific to Rancho Seco NPP: ^{22}Na, ^{242}Pu, ; Radionuclides specific to Zion NPP: ^{243}Am, ^{243}Cm).

Rancho Seco NPP selected site-specific radionuclides for soil by positively detected radionuclides through pool cooler pad soil sample, which was the most contaminated during characterization, and found that the contribution dose was less than 10% through nuclide fraction (*nf*). Radionuclides applied to soil for Zion NPP were selected which accounted for more than 99.5% of the total dose in the auxiliary building [8]. The concerned radionuclides selected for the two NPPs were the same, with the exception of ^{14}C for Rancho Seco NPP. Since the characterization survey of Kori Unit 1 has just started, there is not enough information about radionuclides that can be directly applied to soil of the site. Referring to methodologies for selecting concerned radionuclides in soil of two U.S. NPPs cases, the remaining radionuclides were assumed to be same as Rancho Seco NPP. Concerned radionuclides of Kori Unit 1 were preliminarily selected as listed in Table 2**.**

Table 2. A preliminary suite of concerned radionuclides for soil at Kori Unit 1 reuse scenario

Radionuclides of concern	
Radionuclide	Half-life (years)
^{14}C	5.73×10^{3}
^{60}Co	5.27×10^{0}
^{134}Cs	2.06×10^{0}
^{137}Cs	3.02×10^{1}
^{90}Sr	2.86×10^{1}
^{63}Ni	1.00×10^{2}

3. Area factor for $DCGL_{EMC}$

$DCGL_w$ is the average concentration of a wide area calculated as a result of an average member of a critical group receiving a dose at the appropriate dose limit, assuming that the concentration of radionuclide is homogeneous. Given the potential for elevated residual radioactivity of small areas, an assessment should be performed to assess the likelihood of missing such areas during a scan outside of a fixed measurement range. As shown in Fig. 1, $DCGL_{EMC}$ is a site release standard concentration applicable to the hot spot area, Class 1, which is applied to a region where there is locally elevated residual radioactivity to be measured. The use of elevated measurement comparisons (EMC) represents a conservative approach in that all measurements must be below the action level. The level of investigation for this comparison is called $DCGL_{EMC}$ [9].

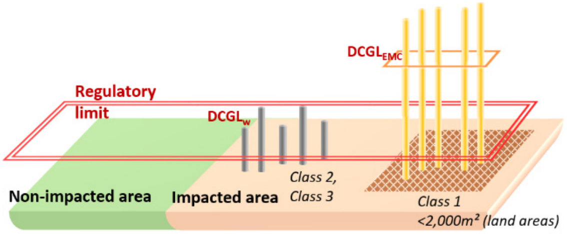

Fig. 1. Conceptual figure of area classification related to DCGLs.

In order to determine $DCGL_{EMC}$, modified $DCGL_w$ using an area factor that takes into account the difference in area and hence the dose change. Area factor is influenced by how the smaller area affects the dose to average member of critical group, for example, a smaller area may mean that the external dose is more limited because it is not reasonable to expect it to be exposed at the same time as when the individual is in a larger area. Area factor is derived by calculating Equation (1).

$$AF_i = DSR_{base}/DSR_i \qquad (1)$$

Where AF_i is area factor of EMC area i, DSR_{base} is the Dose to Source Ratio (DSR) of the baseline area, and DSR_i is DSR of the EMC area i. DSRs were calculated through RESRAD-ONSITE probabilistic analysis.

4. Results & Discussion

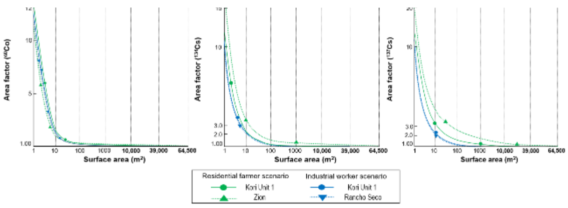

Fig. 2. Surface soil area factors for gamma emitters.

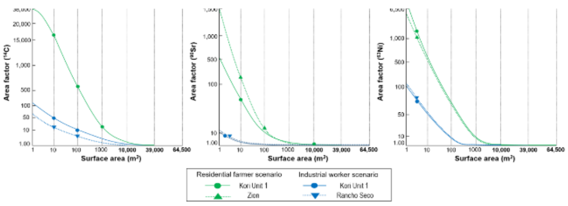

Fig. 3. Surface soil area factors for beta emitters.

Fig. 2 and Fig. 3 show gamma emitters and beta emitters in order to confirm the trend of area factor according to scenarios rather than direct comparison. Baseline areas for each Rancho seco, Kori Unit 1, Zion NPP were specified by 10,000 m^2, 39,000 m^2, 64,500 m^2 [7, 10]. Of the gamma emitters, ^{60}Co had a maximum difference of about 8% based on 1 m^2, regardless of scenarios. As area factors were derived with the same values as Zion NPP in same residential farmer scenario, there was also no effect of increasing exposure pathways. Similarly, for ^{134}Cs and ^{137}Cs, there was little difference in area factors applying industrial worker scenario. The difference between area factors of Zion NPP in the same residential farmer scenario was greater than the difference between the area factors of residential farmer scenario and industrial worker scenario. In the case of beta emitters, differences in area factors by scenario were much larger than gamma emitters. ^{90}Sr showed the greatest difference in area factor from Zion NPP in the same residential farmer scenario, while ^{63}Ni showed maximum difference according to the scenario. Area factors in both gamma and beta emitters were derived to a value higher than industrial worker scenario when residential farmer scenario was applied.

5. Conclusion

Preliminary area factors for class 1 soil surface were derived in consideration of the presence of elevated residual radioactivity in impact area for further FSS of Kori Unit 1. Classification of impact area via area factors is essential during the decommissioning process, and the level of survey effort is determined by the classified area. Survey designs will be developed that provide coverage by selecting appropriate instrumentation and techniques through a combination of scans, instrument measurements, and sampling. It is expected that appropriate sensitivity of scanning technique and additional sampling points could be adjusted through the area factors and applied to elevated residual radioactivity evaluation during the FSS.

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