Derivation of DCGLs for the Surface Soil of Kori-1 NPP by Using RESRAD Probabilistic Analysis

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1. Introduction

The decommissioning related preparations of Kori Nuclear Power Plant (NPP) Unit 1 are ongoing. Safe decommissioning of nuclear power plants requires a procedure to provide guidelines for the planning, implementation and evaluation of radiological surveys being carried out to ensure compliance with the site release standards. The 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. In the case of decommissioning of Kori-1 NPP, the derivation of DCGLs following MARSSIM guidelines are necessary. Based on less conservative but realistic 'industrial worker scenario' for the surface soil exposure, $DCGL_w$, the concentration of a single radionuclide that would provide 0.25 mSv/y (Domestic: 0.1mSv/yr) total effective dose equivalent (TEDE), were derived. After selecting a suite of potential radionuclides in Kori-1 NPP, Probabilistic analysis of RESRAD-ONSITE was performed to derive $DCGL_{w,}$ with reference to the decommissioning experiences of Rancho Seco NPP and Zion NPP in the U.S.

2. Potential Radionuclides of Concern

Due to the limited source information of Kori-1 NPP, the method used at Rancho Seco NPP for determining radionuclides of concern (ROC) which include DandD and ORIGEN codes implementation is not appropriate so the method used at Zion NPP was used to derive ROC for Kori-1 NPP case. In conclusion, nevertheless in different ways of approach, ROCs from both Rancho Seco and Zion NPPs are very similar.

The list of ROC can be listed based on NUREG/CR-3474, NUREG/CR-4289 and WINCO-1191 as shown in Table 1 [1, 2, 3].

Table 1. Theoretical Radionuclides of Concern [1]

Radionuclides			
NUREG/CR-3474			
^{3}H	^{79}Se	^{99}Tc	^{63}Ni
^{14}C	^{81}Kr	^{108m}Ag	^{205}Pb
^{36}CI	^{85}Kr	^{121m}Sn	^{166m}Ho
^{39}Ar	^{90}Sr	^{129}I	^{233}U
^{41}Ca	^{92m}Nb	^{133}Ba	^{178m}Hf
^{53}Mn	^{93}Zr	^{134}Cs	^{158}Tb
^{55}Fe	^{93}Mo	^{137}Cs	^{151}Sm
^{59}Ni	^{94}Nb	^{145}Pm	^{152}Eu
^{60}Co	$^{239/240}$Pu	^{146}Sm	^{154}Eu
^{63}Ni	^{233}U	^{151}Sm	^{155}Eu
WINCO-1191		**NUREG/CR-4289**	
^{147}Pm		^{238}Pu	
^{241}Pu		^{237}Np	
^{125}Sb		^{241}Am	
		^{244}Cm	

There are no sample analysis yet performed at Kori-1 NPP so the method used at Zion Station TSD-11-001 was used to exclude radionuclides which contributes a relative fraction of 0.0001 (0.01%) or less [4]. As a result, except for the inert gas Ar-39, the remained ROCs are shown in Table 2.

Table 2. Radionuclides Relative Fractions Equal To, or Greater than, 0.0001

Radionuclides			
^{3}H	^{59}Ni	^{60}Co	^{125}Sb
^{14}C	^{63}Ni	^{94}Nb	^{134}Cs
^{55}Fe	^{90}Sr	^{99}Tc	^{137}Cs
^{241}Am	^{238}Pu	^{239}Pu	^{240}Pu
^{241}Pu	$^{233/244}$Cm		

By integrating Tables 1 and 2, the radionuclides with active concentrations of less than 0.0001 (0.01%) compared to the activity concentrations of Co-60 and Ni-63 which are dominant in activity contribution are excluded. The excluded radionuclides were ^{36}Cl, ^{41}Ca, ^{53}Mn, ^{79}Se, ^{92m}Nb, ^{93}Zr, ^{93}Mo, ^{108m}Ag, ^{121m}Sn, ^{129}I, ^{133}Ba, ^{145}Pm, ^{146}Sm, ^{151}Sm, ^{155}Eu, ^{158}Tb, ^{166m}Ho, ^{187m}Hf, ^{205}Pb and ^{233}U. As a result of calculating dose contribution of standardized radionuclides by multiplying dose factor from Zion TSD-14-019 by source term [5], Five radionuclides were selected as the main radionuclides to determine the soil DCGLs. ^{60}Co, ^{63}Ni, ^{90}Sr, ^{134}Cs and ^{137}Cs accounted for more than 99.5% of the dose.

3. Derivation of $DCGL_w$

Site-specific $DCGL_w$ values can be derived as follow: [6]

$$DCGL_w = \frac{Regulatory\ dose\ limit - Potential\ dose}{Peak\ of\ the\ mean\ dose} \quad (1)$$

Probabilistic dose modeling should use the "Peak of the mean" to demonstrate compliance with 10 CFR Part 20, Sub E [7]. To perform the parameter sensitivity analysis, various site-specific parameter values with 0.037 Bq/g (1 pCi/g) of each detectable radionuclide with a simplified hydrologic and geologic model of Kori-1 were used as deterministic and probabilistic inputs. The results are shown in Table 3. Part Rank Correlation Coefficient (PRCC) was used to estimate a nonlinear and monotonic relationship which provides a unique contribution of the input parameters to the resulting dose as recommended in NUREG/CR-6692. If the absolute value of the PRCC is greater than 0.25, then the parameters were classified as sensitive, the parameter value at either the 75% quartile or the 25% quartile was assigned to calculate total effective dose equivalent (TEDE) [8].

Table 3. Assigned values of RESRAD-ONSITE from parameter sensitivity analysis

Parameter	PRCC	Quartile	Assigned value
External gamma shielding factor	0.89	75%	0.397
Density of contaminated zone	0.64	75%	1.673
Kd of ^{60}Co in contaminated zone	0.45	75%	1283.31

4. Results & Discussion

Table 4. Single radionuclide $DCGL_w$ values for Industrial Worker Scenario

Radionuclide	*Rancho Seco $DCGL_w$ [Bq/g] (0.25mSv/yr)*	KORI $DCGL_w$ [Bq/g] *(0.25mSv/yr)*	KORI $DCGL_w$ [Bq/g] *(0.1mSv/yr)*
^{134}Cs	*0.829*	0.888	0.355
^{137}Cs	*1.954*	2.108	0.843
^{60}Co	*0.466*	0.497	0.199
^{90}Sr	*240*	160.32	64.13
^{63}Ni	*562400*	591935	236774

5. Conclusion

As recommended in MARSSIM, the DCGLs were derived by using RESRAD-ONSITE with probabilistic analysis. The derived DCGL can then be used as an evaluation criterion of the MARSSIM survey unit and FSS design for Kori-1 NPP. The methodology based on MARSSIM but differently applied to Rancho Seco NPP and Zion NPP were analyzed and applied to Kori-1 NPP case. The DCGL results are very similar to the Rancho Seco case which used similar 'industrial worker scenario" of Kori-1 NPP case.

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