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Site-specific Probabilistic Analysis of DCGLs Using RESRAD Code

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1. Introduction

Issues related to license termination and site release are essential to the decommissioning of nuclear power plant. This process must demonstrate that any remaining radioactivity does not pose an unacceptable risk to members of the public following release of the site [1].

Site release regulations state that a site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a Total Effective Dose Equivalent (TEDE) to an average member of the critical group of less than the site release criteria, for example 0.25 mSv per year in U.S. [2].

Utilities use computer dose modeling codes to establish an acceptable level of contamination, the derived concentration guideline level (DCGL) that will meet this regulatory limit. Since the DCGL value is the principal measure of residual radioactivity, it is critical to understand the technical basis of these dose-modeling codes.

In general, DCGLs can be conservative (screening DCGL) if they do not take into account site specific factors. Use of such conservative DCGLs can lead to additional remediation that would not be required if the effort was made to develop site-specific DCGLs.

Therefore, the objective of this work is to provide an example on the use of the RESRAD 6.0 probabilistic (site-specific) dose analysis to compare with the screening DCGL

2. Screening probabilistic analysis[1] [3]

To provide example on the use of screening probabilistic analysis, computer analyses using a typical source term(s) for a nuclear power station was performed. The source term nuclides in the example analyses were determined according to the sampling efforts at decommissioning power plant sites as follows: ^{3}H, ^{14}C, ^{55}Fe, ^{60}Co, ^{63}Ni, ^{99}Tc, ^{129}I, ^{134}Cs, ^{137}Cs, ^{144}Ce, ^{238}Pu, ^{239}Pu, ^{241}Pu, ^{241}Am, ^{242}Cm, and ^{243}Cm/^{244}Cm. ^{242}Cm was not included in the RESRAD 6.0 data library thus was dropped in the subsequent analyses.

In the example analyses, the distribution of annual dose to a member of a critical group was calculated for a unit soil contamination level (1 pCi/g) for each respective nuclide. Summary of these results as the calculated DCGLs are presented in Table 1. The results confirm the conservatism of the NRC screening values and indicate that probabilistic dose analysis can be very effective in reducing the conservatism in DCGL derivation.

Table 1: Comparisons of DCGL (NRC Screening Approach versus the Values Using RESRAD Probabilistic Dose Analysis)

Nuclide	NRC's surface soil screening values (pCi/g)	DCGL (Using Probabilistic RESRAD 6.0)	DCGL from deterministic analysis (RESRAD 6.0)
	From NRC	Based on the mean of peak	Deterministic
H-3	1.1e+2	1.55E+03	1.75e+3
C-14	1.2e+1	3.64E+01	2.19e+1
Fe-55	1.0e+4	5.73E+04	9.73e+4
Co-60	3.8e+0	4.40E-00	2.82e+0
Ni-63	2.1e+3	2.83E+03	5.45e+3
Sr-90	1.7e+0	2.11E-00	5.01e+0
Tc-99	1.9e+1	2.12E+01	5.36e+1
I-129	5.0e-1	8.93E-00	3.85e+1
Cs-134	5.7e+0	6.63E-00	5.01e+0
Cs-137	1.1e+1	1.24E+01	1.10e+1
Ce-144	N/A*	3.19E+02	2.03e+2
Pu-238	2.5e+0	4.73E+01	6.31e+1
Pu-239	2.3e+0	3.68E+01	5.69e+1
Pu-241	7.2e+1	2.19E+03	3.01e+3
Am-241	2.1e+0	3.82E+01	5.30e+1
Cm- 243	3.2e+0	3.91E+01	3.95e+1
Cm- 244	-	7.02E+01	1.03e+2

3. Site-specific probabilistic analysis [3]

To provide example on the use of site-specific probabilistic dose analysis, the following was performed

1) Key parameters of importance were identified
2) Sources of information to provide site-specific data for key parameters were examined
3) Example computer analyses using key site-

[1] The existing default inputs of the RESRAD 6.0 code are used except for the user-provided site-specific source term information.

specific parameters were conducted

Key parameters were identified from the probabilistic sensitivity analysis. The results of these analyses showed that potential site-specific key parameters are the soil-to-plant transfer factor, thickness of unsaturated zone; k_d (distribution coefficient) in the contaminated zone; density of the unsaturated zone, and; contaminated zone total porosity. Among these, the soil-to-plant transfer factor was most significant for site-specific investigations.

Example site-specific probabilistic dose analysis were performed with two key nuclides of concern in nuclear power plant decommissioning, i.e., ^{137}Cs and ^{90}Sr. The input distributions for site-specific soil-to-plant transfer factors of ^{137}Cs and ^{90}Sr were derived based on the soil conditions for a site selected as the test case and the default input distributions using the Bayesian technique. The resulting difference in DCGL between the screening probabilistic analysis and site-specific analysis are summarized in Table 2.

Table 2: Comparison of the DCGL (pCi/g) calculated between the Screening and Site-specific Probabilistic Dose Analysis

	Cs-137		Sr-90	
	Screening	Site-specific	Screening	Site-specific
Based on the mean of the peak	12.5	16.3	2.62	8.71
NRC screening value	11		1.7	

The results showed that use of site-specific data led to a higher DCGL for a given site in comparison to the DCGL from the screening methodology. Based on the use of the mean of the peak dose, the DCGL changed from 12.5 and 2.62 pCi/g to 16.3 and 8.7 pCi/g, for ^{137}Cs and ^{90}Sr, respectively, for the given site. This indicates a significant benefit of using site-specific soil-to-plant transfer factors especially for ^{90}Sr.

4. Conclusions

The objective this work was to provide example on nuclear power plant decommissioning dose analysis in a probabilistic analysis framework. The focus was on the demonstration of regulatory compliance for surface soil contamination using the RESRAD 6.0 code. Both the screening and site-specific probabilistic dose analysis methodologies were examined. Example analyses performed with the screening probabilistic dose analysis confirmed the conservatism of the NRC screening values and indicated the effectiveness of probabilistic dose analysis in reducing the conservatism in DCGL derivation. For a site-specific probabilistic dose analysis, this study found the nuclides' soil-to-plant transfer factor as the most important parameter. Example analyses using the site-specific soil-to-plant transfer factor for ^{137}Cs and ^{90}Sr showed a significant benefit of site-specific approach.

REFERENCES

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