ENGINEERING CALCULATION

Area Factors for Soil – Industrial Use Scenario

ENG-OCS-009

Revision: 0

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1.0 PURPOSE

The purpose of this calculation is to develop area factors (AFs) for use with derived concentration guideline levels (DCGL) values for assessing soil at the Oyster Creek Station (OCS) site.

2.0 APPLICABILITY

This calculation addresses only the development of AF values for use with DCGLs for surface soils at the OCS site.

3.0 REFERENCES

3.1 BHI Energy Engineering Procedure ENG-AP-02, *Verification of Software Operability*

3.2 ANL/EVS/TM-18/1, RESRAD-Onsite 7.2 User's Guide, April 2018

3.3 ENG-OCS-008, *Derived Concentration Guideline Levels for Soil-Industrial Use Scenario*

3.4 NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*, August 2000

3.5 *Radionuclide Selection for DCGL Development-Oyster Creek Station Site Characterization Project*, January 2022

3.6 NUREG/CR-5512, Volume 1, *Residual Radioactive Contamination from Decommissioning: Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent*, Final Report, U.S. Nuclear Regulatory Commission, October 1992.

4.0 DISCUSSION

The operability of the RESRAD-Onsite 7.2 computer code was verified on each computer used for code executions in accordance with BHI Energy Engineering procedure ENG-AP-02, *Verification of Software Operability* [3.1]. The *RESRAD-Onsite 7.2 User's Guide* [3.2] provided instructions for code use.

The method applied in the calculation of AFs is the same as that applied in BHI Energy Engineering calculation ENG-OCS-003, *Derived Concentration Guideline Levels for Soil-Industrial Use Scenario* [3.3], in the development of OCS's soil DCGL values. However, the input values for the following RESRAD-Onsite input parameters were adjusted to account for the reduced areas of the contaminated zone (CZ):

- the size of the CZ
- the length of parallel to aquifer flow

The base case for AFs was an assumed CZ equal to 2,000 m^2 because that is the maximum size for a MARSSIM Class 1 land survey unit [3.4]. AF values are calculated from the peak of the mean (POM) doses generated by RESRAD-Onsite. The following equation was used:

$$AF = (POM_{2000}/POM_i)$$

Where

AF = the area factor (unitless)

POM_{2000} = peak of the mean dose for the base case (mrem/y), and

POM_i = peak of the mean dose for the reduced area i (mrem/y), where "i" is set at various sized areas

5.0 INPUT

5.1 Source input consisted of the radionuclides-of-concern (ROCs) identified for the OCS site [3.5]. Table 1 provides the ROCs for the OC site.

Table 1: Radionuclides-of-Concern for input to RESRAD-Onsite

ROC[a]	Progeny[b]	ROC[a]	Progeny[b]
Am-241	Np-237, Th-229, U-233	Nb-94	---
C-14	---	Ni-63	---
Cm-243	Ac-227, Am-243, Pa-231, Pu-239, U-235	Np-237	Th-229, U-233
Cm-244	Pu-240, Ra-228, Th-228, Th-232, U-236	Pu-238	Pb-210, Po-210, Ra-226, Th-230, U-234
Cs-137	---	Pu-239	Ac-227, Pa-231, U-235
Co-60	---	Pu-240	Ra-228, Th-228, Th-232, U-236
Eu-152	Gd-152	Pu-241	Am-241, Np-237, Th-229, U-233
Eu-154	---	Sb-125	Te-125m
Fe-55	---	Sr-90	---
H-3	---	Tc-99	---
Mn-54	---		

[a] ROC = radionuclide-of-concern identified for the OCS site.
[b] Included automatically with input of parent ROC.

5.2 The Industrial Use Scenario was modeled in the development of the OCS soil DCGL values. The pathways used to estimate human radiation exposure resulting from residual radioactivity in the soil under that scenario include the following:

- Direct external radiation exposure pathway
- Inhalation exposure pathway
- Aquatic food ingestion exposure pathway
- Inadvertent ingestion of contaminated soil

These 4 pathways are active exposure pathways in the development of AFs.

5.3 Eight sizes for the CZ were assumed: 2000 m^2 (base case), 1000 m^2, 500 m^2, 100 m^2, 50 m^2, 10 m^2, 5 m^2, and 1m^2.

5.3.1 As the area of the CZ decreases, the value for the length parallel to aquifer flow (LCZPAQ) also decreases. The CZ is assumed to be circular, so the value for LCZPAQ is equal to the diameter of the circle:

$$\text{LCZPAQ (m)} = 2\sqrt{(A/\pi)}$$

Table 2 shows the input values for the CZ and LCZPAQ.

Table 2: RESRAD-Onsite Input Parameters for Assumed CZ Sizes

RESRAD Parameter	Input Value							
CZ (m^2)	2,000	1,000	500	100	50	10	5	1
LCZPAQ (m)	50	36	25	11	8.0	3.6	2.5	1.1

5.4 Except for the parameter values shown in Table 2, input parameter values used in AF calculations were the same values as those used to calculate DCGLs.

6.0 RESULTS

6.1 The POM doses for reduced CZ sizes are presented by ROC in Table 3. The AF values for each ROC are presented in Table 4.

6.2 AF values were generated from the POM doses using the following equation:

$$AF = (POM_{2000}/POM_i)$$

Where:

AF = the area factor (unitless)

POM_{2000} = peak of the mean dose for the base case (mrem/y), and

POM_i = peak of the mean dose for the reduced area i (mrem/y), where "i" is set at various sized areas

Table 3: RESRAD-Onsite Dose Results by CZ Size

	POM Dose (mrem/y) for CZ Size (m^2):							
ROC	2000	1000	500	100	50	10	5	1
Am-241	3.19E-02	3.16E-02	2.12E-02	1.20E-02	1.02E-02	6.79E-03	5.02E-03	2.62E-03
C-14	3.64E-04	2.13E-04	1.30E-04	2.96E-05	1.42E-05	3.48E-06	2.01E-06	6.22E-07
Cm-243	1.29E-01	1.27E-01	1.19E-01	1.03E-01	9.39E-02	6.13E-02	4.13E-02	1.45E-02
Cm-244	1.28E-02	1.26E-02	7.05E-03	2.43E-03	1.79E-03	1.15E-03	1.01E-03	8.10E-04
Co-60	2.91E+00	2.88E+00	2.82E+00	2.53E+00	2.30E+00	1.47E+00	9.74E-01	3.16E-01
Cs-137	6.42E-01	6.34E-01	6.22E-01	5.61E-01	5.12E-01	3.30E-01	2.19E-01	7.23E-02
Eu-152	1.31E+00	1.30E+00	1.27E+00	1.14E+00	1.04E+00	6.66E-01	4.43E-01	1.44E-01
Eu-154	1.42E+00	1.40E+00	1.37E+00	1.23E+00	1.12E+00	7.16E-01	4.75E-01	1.55E-01
Fe-55	2.97E-06	2.97E-06	1.49E-06	3.08E-07	1.60E-07	3.95E-08	2.40E-08	1.07E-08
H-3	6.33E-05	4.48E-05	3.17E-05	1.41E-05	1.00E-05	4.47E-06	3.16E-06	1.41E-06
Mn-54	6.77E-01	6.69E-01	6.55E-01	5.88E-01	5.37E-01	3.44E-01	2.29E-01	7.50E-02
Nb-94	1.85E+00	1.83E+00	1.79E+00	1.61E+00	1.47E+00	9.44E-01	6.28E-01	2.06E-01
Ni63	3.21E-06	3.21E-06	1.62E-06	3.42E-07	1.82E-07	5.11E-08	3.38E-08	1.82E-08
Np-237	4.05E-01	4.01E-01	3.67E-01	3.11E-01	2.83E-01	1.84E-01	1.23E-01	4.31E-02
Pu-238	2.05E-02	2.03E-02	1.13E-02	3.89E-03	2.86E-03	1.84E-03	1.62E-03	1.30E-03
Pu-239	2.19E-02	2.18E-02	1.18E-02	3.70E-03	2.60E-03	1.55E-03	1.35E-03	1.06E-03
Pu-240	2.19E-02	2.17E-02	1.18E-02	3.68E-03	2.58E-03	1.54E-03	1.34E-03	1.05E-03
Pu241	9.39E-04	6.87E-04	6.18E-04	1.20E-04	8.85E-05	5.49E-05	4.83E-05	3.86E-05
Sb-125	4.13E-01	4.08E-01	4.01E-01	3.62E-01	3.30E-01	2.13E-01	1.42E-01	4.70E-02
Sr-90	5.50E-03	5.44E-03	4.93E-03	4.14E-03	3.75E-03	2.38E-03	1.59E-03	5.21E-04
Tc-99	4.86E-05	2.83E-05	1.90E-05	1.40E-05	1.24E-05	7.93E-06	5.30E-06	1.81E-06

Table 4: Area Factors for Soil DCGLs

ROC	Area Factor for Area CZ (m^2):							
	2000	1000	500	100	50	10	5	1
Am-241	1	1	2	3	3	5	6	12
C-14	1	2	3	12	26	104	181	585
Cm-243	1	1	1	1	1	2	3	9
Cm-244	1	1	2	5	7	11	13	16
Co-60	1	1	1	1	1	2	3	9
Cs-137	1	1	1	1	1	2	3	9
Eu-152	1	1	1	1	1	2	3	9
Eu-154	1	1	1	1	1	2	3	9
Fe-55	1	1	2	10	19	75	124	278
H-3	1	1	2	4	6	14	20	45
Mn-54	1	1	1	1	1	2	3	9
Nb-94	1	1	1	1	1	2	3	9
Ni63	1	1	2	9	18	63	95	176
Np-237	1	1	1	1	1	2	3	9
Pu-238	1	1	2	5	7	11	13	16
Pu-239	1	1	2	6	8	14	16	21
Pu-240	1	1	2	6	8	14	16	21
Pu241	1	1	2	8	11	17	19	24
Sb-125	1	1	1	1	1	2	3	9
Sr-90	1	1	1	1	1	2	3	11
Tc-99	1	2	3	3	4	6	9	27