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Area Factor Determinations for an Industrial Worker Exposed to a Concrete Slab End-State

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INTRODUCTION

The U.S. Department of Energy's (DOE) Savannah River Site (SRS) is decommissioning many of its excess facilities through removal of the facility structures leaving only the concrete-slab foundations in place. Site-specific, risk-based derived concentration guideline levels (DCGLs) for radionuclides have been determined for a future industrial worker potentially exposed to residual contamination on these concrete slabs as described in Jannik [1]. These risk-based DCGLs were estimated for an exposure area of 100 m^2. During deactivation and decommissioning (D&D) operations at SRS, the need for area factors for larger and smaller contaminated areas arose. This paper compares the area factors determined for an industrial worker exposed to a concrete slab end-state for several radionuclides of concern at SRS with 1) the illustrative area factors provided in MARSSIM [2], 2) the area correction factors provided in the U.S. Environmental Protection Agency's (EPA) Soil Screening Guidance [3], and 3) the hot spot criterion for field application provided in the RESRAD User's Manual [4].

WORK DESCRIPTION

Based on current and projected land use plans for SRS, the reasonable future use of most of the areas where facility decommissioning will take place is as an industrial area. Therefore, the reasonable maximum exposure scenario is likely to be an industrial worker potentially exposed to contaminated concrete slabs following facility decommissioning. The potential exposure pathways include dust inhalation, incidental concrete ingestion, and external gamma. The

industrial worker is assumed to be a typical adult employee who works a standard work year outside on the contaminated area either performing light industrial work or guarding the area. It is assumed this person will not consume onsite groundwater or work in an office built on the site. As described in Jannik et al. (2005), site-specific industrial worker DCGLs were determined in accordance with the RESRAD (Version 6.3) dosimetry code methods [4]. An area of 100 m^2 was used for the area of the contaminated zone. This area is cited in 1) MARSSIM as the recommended area for Class 1 structures [2], 2) DOE Order 5400.5 as the appropriate area to determine average residual concentrations of radioactive material in soil, and 3) the RESRAD User's Guide as the appropriate area for daily activity [3].

In facility D&D field applications, small areas of elevated contaminate concentrations, such as sumps, trenches, and spill locations, are often encountered and must be assessed in real-time. The guidance provided in MARSSIM [2] allows elevated measurement concentration (EMC) areas to remain as is - if they stay within reasonable multiples of the release criteria. Ideally, known hot spots should be assessed individually and subsequent risk values compared to the established release criteria risk value. However, for real-time consideration, generic area factors or "hot spot" multiplication factors (in lieu of multiple, area-specific tables of DCGLs) should be provided as guidance for field applications.

MARSSIM [2], EPA's Soil Screening Guidance [3], and RESRAD [4] all provide guidance and examples of area factors. However, the illustrative examples provided in these references are based on specific exposure pathways that are different than the SRS conceptual site model for D&D projects [1]. In MARSSIM, the full resident farmer scenario and associated exposure pathways are used; in the Soil Screening Guidance, only external exposures are considered; in RESRAD the resident farmer is referenced but the area factors are determined using the following equation:

$$\text{Area Factor} = \sqrt{100/\text{Area}}$$

where 100 m^2 is the reference area considered.

Table 1 shows the exposure scenarios considered in the referenced guidance documents as well as the SRS D&D industrial worker scenario.

Table 2 shows the area factors that were determined for an SRS industrial worker exposed to concrete slab end-states for the common radionuclides provided in the referenced guidance documents. The RESRAD dosimetry code was used for this assessment. All input parameters remained constant except for the area of contamination.

RESULTS

The purpose of this site-specific area factor assessment was to determine if any of the recommended area factors provided in the guidance documents could be utilized at SRS for field applications of the industrial worker DCGLs.

In Table 2, in addition to the SRS site-specific area factors, the following area factors are provided for comparison:

- Illustrative examples of outdoor area dose factors (MARSSIM) [2]
- Area correction factors as a function of source area (Soil Screening Guidance) [3]. Note: the area correction factors provided in [3] were inverted to correspond to a DCGL area factor.
- Recommended area correction factors as a function of source area (Soil Screening Guidance) [3]
- Ranges for hot spot multiplication factors (RESRAD) [4].

As can be seen in Table 2, because the MARSSIM area factors are highly affected by ingestion and inhalation pathways, they do not compare well with the SRS area factors. The Soil

Screening Guidance area factors are in general more conservative than the SRS area factors because they are based exclusively on external exposures. The RESRAD multiplication factors (though limited to area less than 25 m^2), are in general more conservative than the SRS area factors but compare well with them. These are the factors that were recommended for use in SRS D&D projects field applications [5].

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Table 1. Exposure Pathways used for Area Factor Determinations				
	SRS Industrial Worker	**MARSSIM**	**Soil Screening Guidance**	**RESRAD**
Soil/Dust Inhalation	X	X		X
Soil/Dust Ingestion	X	X		X
External	X	X	X	X
Food Ingestion		X		X
Water Ingestion		X		X

Table 2. Area Factor Comparison

Area Factors for an Industrial Worker Exposed to Concrete Slab End-States at SRS

	10000 m^2	1000 m^2	500 m^2	100 m^2	50 m^2	10 m^2	1 m^2
Am-241	1.0	1.0	1.1	1.3	1.5	2.2	9.1
Co-60	1.0	1.1	1.1	1.4	1.7	3.2	16.8
Cs-137	1.0	1.1	1.1	1.4	1.7	3.2	16.3
Ni-63	1.0	1.0	2.0	9.8	19.2	83.1	382.1
Pu-239	1.0	1.2	2.0	5.0	6.5	9.8	14.5
Ra-226	1.0	1.1	1.1	1.5	1.7	3.3	16.8
Th-232	1.0	1.1	1.1	1.5	1.7	3.3	17.0
U-238	1.0	1.1	1.1	1.5	1.7	3.1	15.7

Table 5.6 from MARSSIM [2] "Illustrative Examples of Outdoor Area Dose Factors"

	10000 m^2	1000 m^2	300 m^2	100 m^2	30 m^2	10 m^2	1 m^2
Am-241	1.0	1.3	4.4	13.4	44.2	96.3	208.7
Co-60	1.0	1.1	1.1	1.2	1.5	2.1	9.8
Cs-137	1.0	1.1	1.3	1.4	1.7	2.4	11.0
Ni-63	1.0	1.7	5.6	16.6	54.2	154.8	1175.2
Pu-239	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ra-226	1.0	1.0	1.1	1.1	3.2	7.8	54.8
Th-232	1.0	1.1	1.5	1.8	2.3	3.2	12.5
U-238	1.0	1.3	1.4	6.7	8.4	11.1	30.6

Table 5.2* from EPA SSG [3] "Area Correction Factors as a Function of Source Area"

	10000 m^2	1000 m^2	500 m^2	100 m^2	50 m^2	10 m^2	1 m^2
Am-241	1.0	1.1	1.2	1.3	1.4	2.3	n/a
Co-60	1.0	1.1	1.1	1.3	1.5	2.6	n/a
Cs-137	1.0	1.1	1.1	1.3	1.5	2.6	n/a
Ni-63	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Pu-239	1.0	1.1	1.2	1.3	1.4	2.2	n/a
Ra-226	1.0	1.1	1.1	1.3	1.5	2.6	n/a
Th-232	1.0	1.1	1.2	1.3	1.4	2.3	n/a
U-238	1.0	1.1	1.2	1.3	1.5	2.4	n/a

*the values shown are the reciprocals of the area correction factor values found in Table 5.2 of [3]

Table 5.1* from EPA [3] " Recommended Area Correction Factors as Function of Source Area "

	10000 m^2	1000 m^2	500 m^2	100 m^2	50 m^2	10 m^2	1 m^2
	1.0	1.1	1.2	1.3	1.5	2.5	n/a

*the values shown are the reciprocals of the area correction factor values found in Table 5.1 of [3]

Table 3.3 from RESRAD [4] " Ranges for Hot Spot Multiplication Factors"

					25 m^2	10 m^2	<1 m^2
				Multiplication Factor	2	3	10