

DETERMINATION OF DERIVED CONCENTRATION GUIDELINE LEVEL (DCGL) FOR R-14 RANGE SOILS

1.0 INTRODUCTION

This appendix presents the results of derived concentration guideline level (DCGL) calculations for depleted uranium (DU) present in soil at the R-14 Range of the U.S. Army Research Laboratory (ARL) located at Aberdeen Proving Ground (APG) in Aberdeen, Maryland. In determining the DCGLs presented in this report, several receptor scenarios (such as resident farmer and resident gardener) were evaluated. The modeling results were compared to the DCGLs derived for the Transonic Range and Bomb Throwing Device (BTD) Sites to determine the applicable soils DCGL for DU at this site.

The DCGLs presented in this document are based on the *Radiological Criteria for Unrestricted Use* requirements set forth by the U.S. Nuclear Regulatory Commission (NRC) in 10 CFR Part 20.1402. In accordance with these requirements, a site is 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 that does not exceed 25 mrem (0.25 mSv) per year, and the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA).

2.0 BACKGROUND

The *Transonic Range Decommissioning Plan* (DP; ATG, 2000) utilized the DCGL report developed by Argonne National Laboratory (ANL) for DU-contaminated soils at the Transonic Range of APG (ANL, 1999). The DP was approved by the NRC, and the site was remediated and released in accordance with the specified DCGLs. The DCGLs for the DU Study Area of the Transonic Range were based on site-specific uranium guidelines derived for a 50-year TEDE to a hypothetical individual not exceeding 25 mrem in any one year, and evaluated over a 1,000 year time interval. The *Residual Radioactivity* (RESRAD) computer code, Version 5.82, was used to develop DCGLs for the Transonic Range (ANL, 1999). The RESRAD code parameters/pathways used in the Transonic Range evaluation were set up to consider nine exposure pathways:

- 1) Direct exposure from contaminated soil,
- 2) Internal dose from inhalation of contaminated dust,
- 3) Internal radiation from the inhalation of emanating radon-222,
- 4) Internal radiation from the ingestion of plant foodstuffs grown in contaminated soil and irrigated with groundwater drawn from a well located within the decontaminated area,
- 5) Internal radiation from the ingestion of meat from livestock fed fodder grown in the decontaminated area and irrigated with groundwater from the decontaminated area,
- 6) Ingestion of milk from milk animals raised with fodder and irrigation groundwater drawn from the decontaminated area,
- 7) Internal radiation from ingestion of fish from a pond drawing water from the decontaminated area,

- 8) Internal dose from the ingestion of on-site soil, and
- 9) Internal radiation from drinking water drawn from an on-site well.

Two potential exposure scenarios - the industrial-worker scenario and the resident-farmer scenario - were considered using combinations of the above pathways. Based on uranium-234 (^{234}U), uranium-235 (^{235}U), and uranium-238 (^{238}U) activity fractions of 0.190, 0.021, and 0.790, a DCGL of 230 picocuries per gram (pCi/g) was determined for DU under the resident-farmer scenario.

An additional evaluation was also performed to develop the DCGL for DU at the Aberdeen Test Center (ATC) BTM site by utilizing the same procedure as that for the Transonic Site (CABRERA, 2003). The results of the BTM evaluation showed that:

The DCGL developed at the Transonic Range is considered applicable to and adequately protective for the BTM Site on the basis of comparable site-specific RESRAD parameter/pathways, the similarity of both locations, and the equivalence of the radiological isotopic DU mixes. Use of the approved Transonic DCGL at the BTM Site will ensure that the potential dose to a hypothetical individual will not exceed 25 mrem in any one year over a 1,000-year period. The DCGL for the BTM Site soil is 230 pCi/g total DU (resident-farmer scenario).

3.0 SCOPE/PURPOSE

The purpose of this evaluation is to contrast and compare the parameters used to develop the DU-contaminated soil DCGL applied at the Transonic Range to the R-14 Range Site. This evaluation will be used to demonstrate that the DCGL used at the Transonic Range may be similarly applied at the R-14 Range Site.

4.0 METHODOLOGY

The following sections of this evaluation summarize the methodology for determining DCGLs for DU under various receptor scenarios at the R-14 Range Site and compare the results with those obtained for Transonic Range Site. The results of the most conservative DCGL derivation will be utilized as the DCGL for the Rang Site.

4.1 Dose Assessment Model

RESRAD, Version 6.3 (ANL, 2005), was used to derive the DCGL for each uranium isotope and for DU. RESRAD is a computer code developed by ANL for the U.S. Department of Energy (DOE) to determine site-specific residual radiation guidelines and dose to a future hypothetical onsite receptor at sites that are contaminated with residual radioactive materials.

4.2 Source Term

Radionuclides of concern (ROCs) known to be present in the R-14 Range area are limited to DU isotopes (i.e., ^{234}U , ^{235}U , and ^{238}U) and their short-lived decay progeny. The activity fractions are calculated from the weight ratios and specific activities of each uranium isotope. The resulting composition consists of ^{234}U , ^{235}U , and ^{238}U activity fractions of 0.084, 0.012, and 0.904, respectively. Table 1 shows the how the concentrations of each of the three uranium isotopes are calculated, based on a unit gram of depleted uranium.

Table 4-1: Concentrations for Depleted Uranium Isotopes

Name of Radionuclides	% Activity Fraction	Specific Activity (Ci/g)	Source Concentration ² (pCi/g)
U-234	8.4	6.2E-3	5.21E-13
U-235 ¹	1.2	2.1E-6	2.52E-17
U-238 ¹	90.4	3.3E-7	2.98E-16

¹ The concentrations of Th-231 and Th-234, daughters of U-235 and U-238 respectively, were included within the concentrations of U-235 and U-238, due to their very short half-life (25.52 hours and 24.1 days, respectively).

² Source Concentration = (Activity Fraction x Specific Activity [Ci/g]) x 10⁻⁹ [pCi/Ci] /100

4.3 Site Physical Parameters

The assigned values for site physical parameters used in the Transonic Range Site DCGL derivation were used in selecting values for RESRAD input parameters for the R-14 Range Site. RESRAD default values were used when assigned values were not available. Table 4-2 presents the assigned value for each of the non-default site physical parameters related to the RESRAD model.

Table 4-2: Assigned Values for Non-default RESRAD Input Site Physical Parameters

Category	Parameter	Values	Reference
Physical Parameters	Thickness of the Contaminated Zone (m)	0.15	ANL, 1999
Cover Parameters	Cover Depth (m)	0	ANL, 1999
	Density of the Cover Material (g/cm ³)	NA	
	Cover Erosion Rate (m/yr)	NA	
Hydrological Data for Contaminated Zone	Contaminated Zone Erosion Rate (m/yr)	0.0006	Assuming, 2% slope and significant farming and gardening activities at the site (ANL, 1993)

NA = Not Applicable

4.4 Receptor Scenarios

The following receptor scenarios were evaluated during the determination of the DU DCGL for the R-14 Range Site: resident farmer and resident gardener. Each of the receptors was assumed to be exposed to radioactive contamination in soil through various pathways. Unlike the Transonic and BTD Sites, the radon pathway was suppressed during this evaluation due to its inapplicability. As radium-226 is not an ROC for this site, neither is its daughter radon an ROC for the site. In addition, in a Federal Register Notice (NRC, 1994), issued as a result of comments received from a radon workshop, the NRC noted that “radon would not be evaluated when developing release criteria due to: the ubiquitous nature of radon in the general environment, the large uncertainties in the models used to predict radon concentrations; and the

inability to distinguish between naturally occurring radon and that which occurs due to licensed activities.” Both the receptor and exposure scenarios are summarized in the following sections.

4.4.1 RESRAD Default Resident Farmer

The RESRAD model defines a resident farmer scenario, under which a family is assumed to move onto the site after it has been released for use without radiological restrictions, builds a home, and raises crops and livestock for family consumption. Members of the family can incur a radiation dose by:

- 1) Direct radiation from radionuclides in the soil,
- 2) Inhalation of re-suspended contaminated dust,
- 3) Ingestion of food from crops grown in the contaminated soil,
- 4) Ingestion of milk from livestock raised on contaminated soil,
- 5) Ingestion of meat from livestock raised on contaminated soil,
- 6) Ingestion of fish from a nearby pond contaminated by water percolating through the contaminated zone,
- 7) Ingestion of water from a contaminated well or pond, and
- 8) Ingestion of contaminated soil.

RESRAD default values were assigned for the exposure parameters under this receptor scenario, as presented in Table 4-3. The following document was used for selection of RESRAD default values: *Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil, Environmental Assessment and Information Sciences Division, Argonne National Laboratory (ANL, 1993).*

4.4.2 NRC's Resident Farmer Scenario

The resident farmer scenario is also defined in *Residual Radioactive Contamination From Decommissioning - Parameter Analysis* (NRC, 1999a). Under the NRC scenario, the resident farmer may be exposed to radioactive contamination through several exposure pathways relative to site soils. The resident farmer was assumed to be exposed through the same exposure pathways as defined for the RESRAD default resident farmer scenario. Table 4-3 presents the assigned values for each of the exposure parameters associated this scenario. The following NRC documents were used to select the assigned values for the exposure parameters associated with NRC resident farmer scenario.

- *Residual Radioactive Contamination From Decommissioning - Parameter Analysis, Draft Report for Comments*; NUREG/CR-5512, Volume 3 (NRC, 1999a)
- *Comparison of the Models and Assumptions used in DandD 1.0, RESRAD 5.61, and RESRAD-Build 1.50 Computer Codes with Respect to the Residual Farmer and Industrial Occupant Scenarios*; NUREG/CR-5512, Volume 4 (NRC, 1999b)

4.4.3 Resident Gardener Scenario

The following EPA guidance documents define the resident gardener scenario.

- *Soil Screening Guidance Document for Radionuclides: User's Guide* (EPA, 2000))
- *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Model* (EPA, 1991b)

Under the resident gardener scenario, receptors live on or adjacent to the site and are expected to be in frequent, repeated contact with contaminated media. Complete exposure pathways applicable to this scenario include:

- 1) Direct radiation from radionuclides in the soil,
- 2) Inhalation of re-suspended contaminated dust,
- 3) Ingestion of home grown produce in the contaminated soil,
- 4) Ingestion of fish from a nearby pond contaminated by water percolating through the contaminated zone,
- 5) Ingestion of water from a contaminated well or pond, and
- 6) Ingestion of contaminated soil.

The animal pathway is not evaluated for areas zoned residential, because such regulations generally prohibit the keeping of livestock. Due to the absence of surface water on or adjacent to the site, the ingestion of fish exposure pathway was also not evaluated under this scenario. Table 4-3 presents the assigned values for the exposure parameters. The assigned values were based on various EPA guidance documents. In general, the order of precedence was to use the most recent guidance document first. For exposure parameters with no EPA recommended value, RESRAD default values were used during the determination of the DCGL. The following EPA documents were used for selection of values for exposure parameters.

- *Soil Screening Guidance Document for Radionuclides: User's Guide* (EPA, 2000)
- *Exposure Factors Handbook* (EPA, 1997a).

Table 4-3: Assigned Values for Exposure Parameters under Different Scenarios

RESRAD Parameter	RESRAD Default Resident Farmer	NRC Resident Farmer Scenario	Resident Gardener	Units
Inhalation rate	8,400	8,600 ¹	7300 ³ (20 m ³ /d)	m ³ /yr
Mass loading for inhalation	0.0001	5.9E-06 ¹	0.0001 ²	g/m ³
Exposure duration	30	30 ¹	30 ³	yr
Indoor Dust Filtration Factor	0.4	0.4 ¹	0.4 ²	unitless
External gamma shielding factor	0.7	0.5512 ¹	0.4 ³	unitless
Fraction of time spent indoors	0.5	0.6571 ¹	0.683 ³	unitless
Fraction of time spent outdoors (on site)	0.25	0.1181 ¹	0.073 ³	unitless
Fruits, vegetables and grain consumption	160	112 ¹	(42.7) ³	kg/yr
Leafy vegetable consumption	14	21.4 ¹	4.66 ³	kg/yr
Milk consumption	92	233 ¹	NA	L/yr
Meat and poultry consumption	63	65.1 ¹	NA	kg/yr
Fish consumption	5.4	20.6 ¹	7.34 ⁴ (20.1 gm/d)	kg/yr
Other seafood consumption	0.9	0.9 ²	0.9 ²	kg/yr
Soil ingestion rate	36.5	18.25 ¹	43.8 ³ (120 mg/d)	g/yr
Drinking water intake	510	478.5 ¹	730 ³ (2 L/d)	L/yr
Contamination fraction of drinking water	1.0	1 ²	1 ²	unitless
Contamination fraction of household water	NA	NA	NA	unitless
Contamination fraction of livestock water	1.0	1 ²	1 ²	unitless
Contamination fraction of irrigation water	1.0	1 ²	1 ²	unitless
Contamination fraction of aquatic food	0.5	1 ²	0.5 ²	unitless
Contamination fraction of plant food	-1 **	-1 **	0.5 ²	unitless
Contamination fraction of meat	-1 **	1 ²	NA	unitless
Contamination fraction of milk	-1**	1 ²	NA	unitless
Livestock fodder intake for meat	68	26.85 ²	NA	kg/day
Livestock fodder intake for milk	55	63.25 ²	NA	kg/day

¹ Ref: *Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes* (NRC, 2000)

² Ref: *Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil* (ANL, 1993)

³ Ref: *Soil Screening Guidance for Radionuclides: User's Guide* (EPA, 2000)

⁴ Ref: *Exposure Factors Handbook* (EPA, 1997a)

** Adjusted automatically by RESRAD based on the contaminated surface area.

NA Not Applicable for this scenario

5.0 SOIL DCGL RESULTS FOR URANIUM ISOTOPES AND DU

RESRAD, Version 6.3 (ANL, 2005), was used to perform the dose assessments for contaminated soil present at the R-14 Range Site. The concentrations for DU isotopes presented in Table 4-1 were input into the model along with the site physical parameters presented in Table 4-2, and the assigned values for exposure parameters for each receptor scenario presented in Table 4-3 during the dose assessments. The maximum dose-to-source ratio (DSR) (in units mrem/yr per pCi/g) over the 1000-year evaluation period for each uranium isotope was then divided into the dose limits to determine soil DCGLs for different receptors. The DCGL for DU was then calculated by summing the products of DCGL of individual isotope with their corresponding source term. Table 5 presents the results of DU DCGL for different receptor scenarios.

Table 5. Results of Individual Uranium Isotope and Depleted Uranium DCGLs (pCi/g)

Radionuclide	Resident Farmer (RESRAD Default)	NRC's Resident Farmer Scenario	Resident Gardener
U-234	307	319	231
U-235+D	56	70	55
U-238+D	233	294	247
DU ¹	237	294	243

¹ DU = DCGL of U-234 x 0.084 + DCGL of U-235 x 0.012 + DCGL of U-238 x 0.904

The DCGL results for DU indicated that the RESRAD default resident farmer scenario is the most limiting scenario, with a DCGL for DU of 237 pCi/g. The same default resident farmer scenario was used for both Transonic and BTM Sites, and the DCGL for DU was determined to be 230 pCi/g. The DCGL results for R-14 Range Site and the other two sites at APG are comparable. Thus, as a conservative approach, a DCGL of 230 pCi/g will be used for DU at the R-14 Range Site.

6.0 CONCLUSION

Surface soil DCGLs were derived for DU present at the R-14 Range Site using several receptor scenarios. The NRC dose limit of 25 mrem in any year in excess of natural background radiation was used as the basis for each derivation. Table 5 presents the DCGL results for each uranium isotope and DU. Similar to the Transonic and BTM Sites, the RESRAD default resident farmer scenario was the most conservative receptor scenario. The DCGL result for DU derived for the R-14 Range Site is comparable to that used for Transonic and BTM Sites. Thus, the DCGL used at the Transonic Range is demonstrated to be applicable and protective at the R-14 Range Site. The DCGL value of 230 pCi/g will be used as the soil action level for remediation at the R-14 Range Site, and as the concentration limit for evaluating the final status survey results with respect to the NRC criteria for unrestricted release.

7.0 REFERENCES

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