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Derivation of Guidelines for Uranium Residual Radioactive Material in Soil at the B&T Metals Company Site, Columbus, Ohio

Environmental Assessment Division
Argonne National Laboratory

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CONTENTS

FIGURES

TABLES

actual uranium guidelines for the B&T Metals site, DOE will apply the as-low-as-reasonably-achievable (ALARA) policy to the decision-making process, along with such other factors as whether a particular scenario is reasonable and appropriate.

1 INTRODUCTION AND BRIEF HISTORY

The B&T Metals Company site is located in Columbus, Ohio. The site has been designated for remedial action by the U.S. Department of Energy (DOE) under its Formerly Utilized Sites Remedial Action Program (FUSRAP). This designation was made after a preliminary inspection by Oak Ridge National Laboratory (ORNL) in 1988 and 1989 indicated that uranium contamination was present both inside and outside of the main office building at the B&T Metals site (Cottrell et al. 1990). The B&T Metals Company property was included in FUSRAP in 1991 (DOE 1991). FUSRAP was established in 1974 by the U.S. Atomic Energy Commission (AEC), a predecessor of DOE. The mandate of the program is to identify, evaluate, and (if necessary) decontaminate sites previously used by the AEC or its predecessor, the Manhattan Engineer District (MED).

Remedial action activities at the B&T Metals site will follow the guidelines established in DOE Order 5400.5 (DOE 1990). The DOE *res*idual *rad*ioactive material computer code, RESRAD (Yu et al. 1993a), is used to derive residual radionuclide guidelines on a site-specific basis. This report presents the uranium guidelines derived for the B&T Metals site on the basis of a dose constraint of 30 mrem/yr for the current use and likely future use scenarios and a dose limit of 100 mrem/yr for less likely but plausible future use scenarios (Yu et al. 1993a). The dose constraint of 30 mrem/yr is not currently required under DOE Order 5400.5, but it is included in the proposed 10 CFR Part 834 rule-making (DOE 1993) to account for additional dose contributions from other potential sources of radiation exposure.

1.1 SITE DESCRIPTION AND SETTING

The B&T Metals site is located on the southwestern side of Columbus, Ohio, at 425 West Town Street (Figure 1). Since the 1940s, the site has been continuously owned and operated by the B&T Metals Company. It encompasses approximately 18,700 m^2. Immediately surrounding the site are commercial businesses to the north, east, and west and residences to the south. The exterior ground cover at the site is either asphalt, concrete, or grass (Figure 2). The site consists of three buildings: (1) a main office, (2) a storage building, and (3) an extrusion building that did not exist at the time of the MED-sponsored activities. The work for MED was performed in the northwestern corner of the main office building, the largest of the three structures. Shavings from these activities may have been dumped outside in what is now a parking area, west of the main office building. Machinery used for processing uranium was sold or removed, with no records indicating final disposition.

The town of Columbus is located in Franklin County, Ohio. The average precipitation rate for Columbus is 0.93 m/yr (U.S. Department of Agriculture [USDA] 1980; U.S. Geological Survey [USGS] 1989). The soil at the site is predominantly silty loam (USDA 1980). The site currently

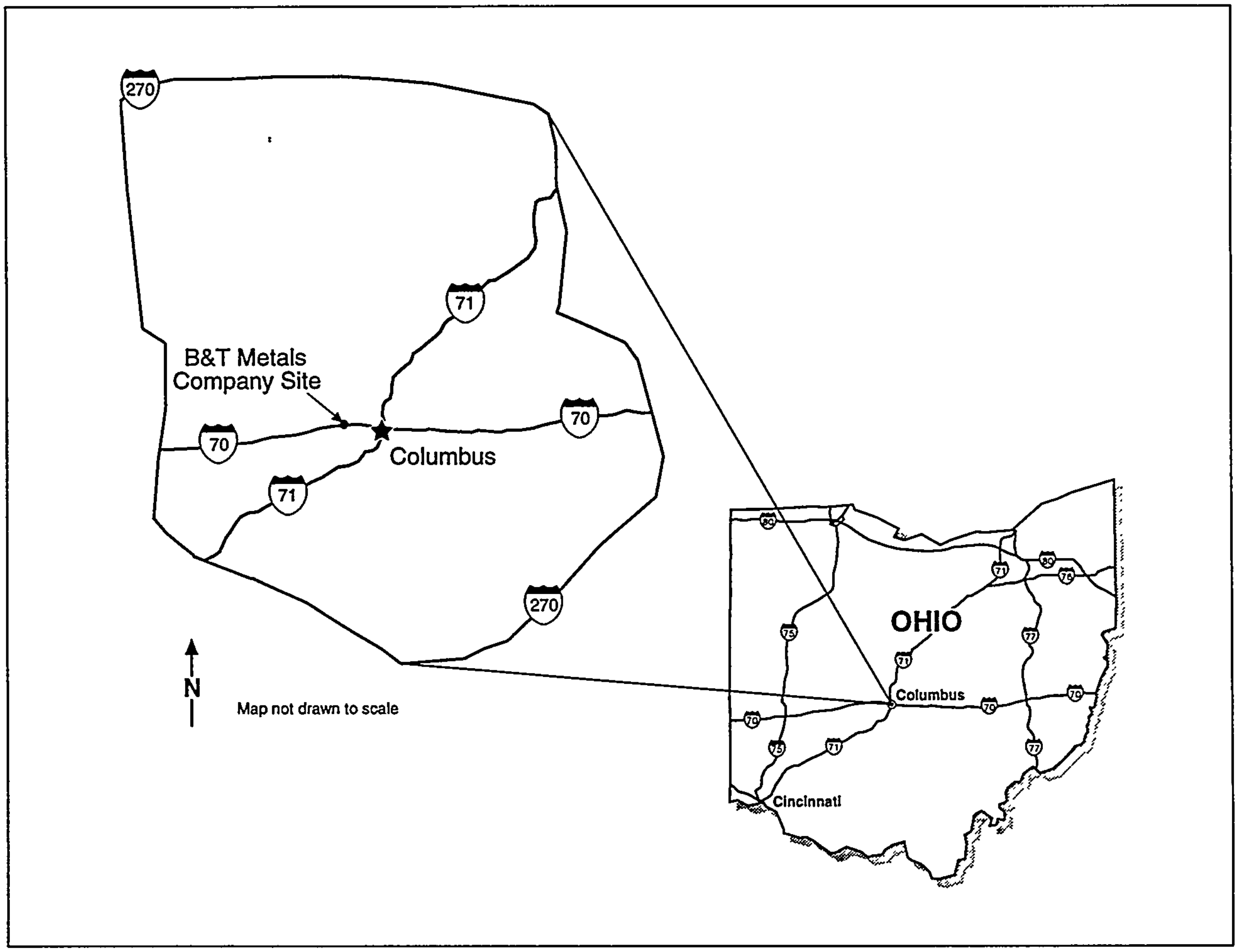

FIGURE 1 Map Showing Columbus, Ohio, Location of the B&T Metals Company Site (SK019601-L)

obtains water from municipal sources; there are no wells on the property. The water table in the area ranges from 4.8 to 6.6 m below the soil surface (Sheets 1995). The distribution coefficient for the uranium in surface soil samples collected from the parking area west of the main office building is 1,410 cm^3/g (Orlandini 1995).

1.2 SITE HISTORY

In February 1943, the DuPont Company, acting as agent of the MED, contracted with B&T Metals to extrude rods from uranium metal billets. The rods were for use at the Hanford reactor. The extrusion and machining activities were on a relatively small scale and occurred over a period of about 10 months. More than 50 tons of uranium was likely extruded. A review of records indicated that part of the extrusion and machining process involved "blowing out" the heating cylinders on the

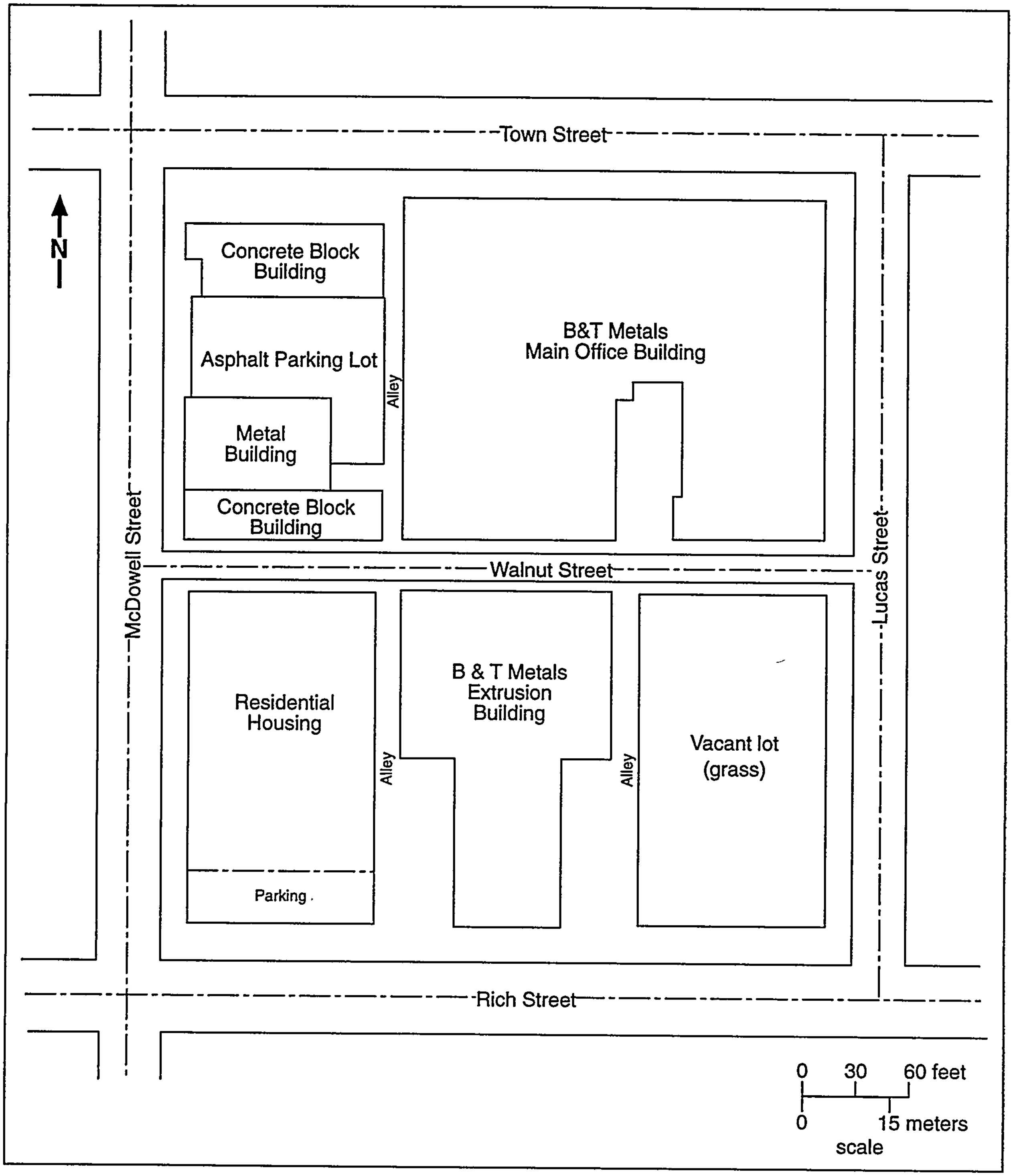

FIGURE 2 Map of the B&T Metals Site Showing Areas of Suspected Contamination (Source: Cottrell 1990) (SK019602-L)

extrusion press. This activity caused large quantities of uranium-bearing material to be blown into the room.

Health and safety protection for the B&T operations was provided by the Metallurgical Laboratories of the University of Chicago. Measurements taken in March and April 1943 indicated that significant amounts of airborne material were present in the plant, so the extrusion process was modified to reduce debris. Upon completion of the project, MED and DuPont representatives visually inspected the site to verify that the facilities and equipment had been cleaned and that all sweepings, turnings, solid scrap, oxides, and wet residue had been shipped off-site. The site was decontaminated in accordance with the standards and survey methods in use at that time. Since that time, more stringent radiological criteria and guidelines have been implemented for the release of such sites for unrestricted use.

In August 1988, the ORNL conducted a preliminary radiological survey to determine the condition of the B&T Metals site. A subsequent visit was made to the site in April 1989 to collect air samples from the main office building. The results of the surveys indicated that three floor locations in the main building, the drain system beneath the building, and the building support beams had radionuclide concentrations in excess of DOE guidelines (DOE 1990). Additionally, outdoor areas where shavings from the former MED operations were reportedly dumped also contained elevated radionuclide concentrations (Cottrell et al. 1990). On the basis of these surveys, the outdoor contamination was estimated to total about 12,000 m^2 (in a few noncontiguous areas).

1.3 DERIVATION OF CLEANUP GUIDELINES

Although most DOE cleanup guidelines applicable to remedial actions at FUSRAP sites are generic (DOE 1990), guidelines for uranium in soil are derived on a site-specific basis. The purpose of this analysis was to derive residual radioactive material guidelines for uranium (i.e., uranium-234, uranium-235, uranium-238, and total uranium) that would be applicable to remedial action at the B&T Metals site. The derived guidelines represent the residual concentration of uranium in soil in a homogeneously contaminated area that must not be exceeded if the site is to be released for use without radiological restrictions. The total uranium guideline is derived by assuming that uranium-238, uranium-234, and uranium-235 are present in their natural activity concentration ratio of 1:1:0.046.

Site-specific uranium guidelines for the B&T Metals site were derived on the basis of a dose constraint of 30 mrem/yr for the current use and likely future use scenarios and a dose limit of 100 mrem/yr for less likely but plausible future use scenarios (Yu et al. 1993a). Uranium was assumed to be the only radionuclide present at a concentration above background levels. Version 5.60 of the RESRAD computer code (Yu et al. 1993a) was used to derive these guidelines.

RESRAD implements the methodology described in the DOE manual for establishing residual radioactive material guidelines (Yu et al. 1993a).

2 SCENARIO DEFINITIONS

Three potential exposure scenarios were considered for this assessment of residual radioactivity guidelines for soil at the B&T Metals site. For all three scenarios, it was assumed that at some time within 1,000 years, the site will be released for use without radiological restrictions following remedial action.

Potential radiation doses resulting from nine exposure pathways were considered in this evaluation: (1) direct exposure to external radiation from decontaminated soil material, (2) internal radiation from inhalation of contaminated dust, (3) internal radiation from inhalation of emanating radon-222, (4) internal radiation from ingestion of plant foods grown in the decontaminated area and irrigated with water drawn from a well located at the downgradient edge of the decontaminated area, (5) internal radiation from ingestion of meat from livestock fed with fodder grown in the decontaminated area and irrigated with water drawn from an on-site well, (6) internal radiation from ingestion of milk obtained from livestock fed with fodder grown in the decontaminated area and irrigated with water drawn from an on-site well, (7) internal radiation from ingestion of fish from a pond downgradient from the decontaminated area, (8) internal radiation from incidental ingestion of on-site soil, and (9) internal radiation from drinking water drawn from an on-site well. The applicability of these exposure pathways to the three scenarios evaluated is summarized in Table 1.

Scenario A (the current use scenario) assumed continued industrial use of the site. Under this scenario, a hypothetical individual was assumed to work 8 hours per day at the site (6 hours working indoors and 2 hours outdoors), 5 days per week, 50 weeks per year. It was also assumed that the worker would not ingest water, plant foods, or fish obtained from the decontaminated area or meat or milk from livestock raised in the decontaminated area. The dose to the worker was assumed to be only from the decontaminated soil.

Scenario B (a likely future use scenario) assumed residential use of the site. The basic premise of this scenario was that at some time in the future, the industrial activities at the site would be discontinued, the existing buildings would be removed, and the whole site would be transformed into a residential area. A hypothetical resident of the site was assumed to ingest plant foods grown in a garden on the site. All water used by the resident for drinking, household purposes, and irrigation would be from municipal sources that are not radioactively contaminated. For this scenario, it was assumed that no livestock would be raised on the site for the production of meat and milk and that no pond would be present to provide fish or other aquatic food.

Scenario C (a plausible but unlikely future use scenario) is similar to Scenario B, in which a resident was assumed to ingest plant foods grown in an on-site garden. However, under Scenario C, in addition to growing vegetables, the resident was also assumed to ingest meat and milk from livestock fed with forage grown on-site and to catch and consume fish and other aquatic organisms

TABLE 1 Summary of Applicable Exposure Pathways for Scenarios A, B, and C at the B&T Metals Site

Pathway	Applicable Pathways		
	Scenario A[a]	Scenario B[b]	Scenario C[c]
External gamma exposure	Yes	Yes	Yes
Inhalation of dust	Yes	Yes	Yes
Inhalation of radon	Yes	Yes	Yes
Ingestion of soil	Yes	Yes	Yes
Ingestion of plant foods	No	Yes	Yes
Ingestion of meat	No	No	Yes
Ingestion of milk	No	No	Yes
Ingestion of fish	No	No	Yes
Ingestion of water	No	No	Yes

[a] Industrial worker: no consumption of water or food obtained on the site.

[b] Resident: water used for drinking, household purposes, and irrigation assumed to be from uncontaminated municipal sources.

[c] Resident: water used for drinking, household purposes, livestock watering, and irrigation assumed to be from an on-site well.

from an on-site pond. For this scenario, the groundwater drawn from a well located on-site would be the only water source for drinking, household use, livestock watering, and irrigation. Currently, no agricultural activity occurs at the site, and production of livestock or construction of a fishing pond in the decontaminated area is considered extremely unlikely. Agricultural use of the property would require removal of the current buildings and paved areas at the site. For the purposes of this analysis, it was assumed that any residual soil contamination would not be removed during the process.

The RESRAD computer code (Yu et al. 1993a) was used to calculate the potential radiation doses for the hypothetical future industrial worker (Scenario A) and resident (Scenarios B and C), on the basis of the following assumptions:

- During one year, the industrial worker spends 1,500 hours (17% of the year) indoors at the decontaminated site, 500 hours (6%) outdoors at the site, and 6,760 hours (77%) away from the site. During one year, the resident (Scenarios B and C) spends 4,380 hours (50%) indoors, 2,190 hours (25%)

outdoors in the decontaminated area, and 2,190 hours (25%) away from the site (Yu et al. 1993a).

- The walls, floor, and foundation of the house (Scenarios B and C) or commercial building (Scenario A) reduce external exposure by 30%. The indoor dust level is 40% of the outdoor dust level (Yu et al. 1993a).

- The outdoor airborne dust loading is 0.1 mg/m^3.

- The depth of the house or building foundation is set to maximize the radon inhalation dose but not to exceed 1 m below ground surface (RESRAD default is -1), with an effective radon diffusion coefficient of 3×10^{-7} m^2/s (Yu et al. 1993a).

- The size of the decontaminated area is sufficiently large (12,000 m^2) for the resident to grow plant foods and forage for the lifestock. Of the plant food diet consumed by the resident (Scenarios B and C), 10% and 50%, respectively, are grown in a garden in the decontaminated area (Yu et al. 1993a). The industrial worker (Scenario A) does not consume these plant foods.

- The size of the decontaminated area is sufficiently large to produce 60% of the forage used to feed livestock for meat and milk consumed by the resident in Scenario C (Yu et al. 1993a). The industrial worker in Scenario A and the resident in Scenario B do not consume these animal products.

- For Scenario C, 50% of the fish and other aquatic foods consumed by the resident are obtained from an on-site pond (Yu et al. 1993a).

- The current water supply for the industrial building is from uncontaminated municipal sources, and such sources would continue to be used for Scenarios A and B. However, for the plausible but unlikely scenario (Scenario C), the source of water for drinking, household uses, livestock watering, and irrigation is assumed to be an on-site well.

- The soil at the site is predominantly silty loam (USDA 1980). Because of the lack of site-specific data, typical values for silty loam soils tabulated in Yu et al. (1993b) are used for the density, total and effective porosities, soil "b" parameter, and hydraulic conductivity in the contaminated, unsaturated, and saturated zones.

- The uranium distribution coefficient was measured at 1,410 cm^3/g for surface soil (Orlandini 1995); this value is used for all uranium isotopes in the contaminated, unsaturated, and saturated zones. The distribution coefficients of the radioactive progeny are those for loam soils, tabulated in Yu et al. (1993b).

- The annual average precipitation rate of 0.93 m/yr for Columbus (USDA 1980; USGS 1989) is used.

- No wells have been dug at the site. The water table in the area ranges from 4.8 to 6.6 m below the soil surface (Sheets 1995); a distance of 5.5 m to the water table is assumed on the basis of the average water table in area wells. The water table drop rate is assumed to be zero.

- After remedial action, no cover material is placed over the decontaminated area. The erosion rate is assumed to be zero.

- The depth of contamination, 0.15 m, is based on values from ORNL measurements (Cottrell et al. 1990).

- The area of the contaminated zone is approximated at 12,000 m^2, on the basis of the size of the outdoor area found contaminated during the 1988 and 1989 ORNL surveys. For modeling purposes, these noncontiguous areas of contamination are conservatively treated as a single homogeneously contaminated area.

- All other parameters are set to the RESRAD defaults.

3 DOSE/SOURCE CONCENTRATION RATIOS

The RESRAD computer code, Version 5.60 (Yu et al. 1993a), was used to calculate the dose/source concentration ratio $DSR_{ip}(t)$ for uranium isotope i and pathway p at time t after remedial action for each of the three scenarios. The time frame considered in this analysis was 1,000 years. Radioactive decay and ingrowth were considered in deriving the dose/source concentration ratios. The various parameters used in the RESRAD code for this analysis are listed in the Appendix. The calculated maximum dose/source concentration ratios for all pathways are presented in Tables 2, 3, and 4 for Scenarios A, B, and C, respectively. For all three scenarios, the maximum dose/source concentration ratios would occur immediately following remedial action. The dose from natural uranium in soil for Scenarios A and B is contributed by external exposure and inhalation of dust. For Scenario C, the dose from natural uranium is contributed almost equally by external exposure, dust inhalation, and plant ingestion pathways.

The summation of $DSR_{ip}(t)$ for all pathways p is the $DSR_i(t)$ for the ith isotope,

$$DSR_i(t) = \sum_p DSR_{ip}(t) \ .$$

The total dose/source concentration ratio for total uranium can be calculated as

$$DSR(t) = \sum_i W_i \ DSR_i(t) \ ,$$

where W_i is the existing activity concentration fraction in soil at the site for uranium-234, uranium-235, and uranium-238.

For this analysis, W_i is assumed to represent the natural activity concentration ratios of 1/2.046, 1/2.046, and 0.046/2.046 for uranium-238, uranium-234, and uranium-235, respectively. The total dose/source concentration ratios for single radionuclides and total uranium are listed in Table 5. These ratios were used to determine the allowable residual radioactivity for uranium in soil at the B&T Metals site.

The dose from radon inhalation is zero because the maximum dose/source concentration ratios would occur immediately after remedial action and, thus, do not allow for the ingrowth of uranium progeny. However, even at 1,000 years following remediation, the radon dose would be low because the contamination is shallow (15 cm). In addition, the leaching of radon-222 parent radionuclides from the source would more than offset any dose contribution from the ingrowth of radon. Therefore, the total dose at 1,000 years would not exceed the total dose at time zero.

TABLE 2 Maximum Dose/Source Concentration Ratios for Scenario A at the B&T Metals Site

Pathway	Maximum Dose/Source Concentration Ratios[a] (mrem/yr)/(pCi/g)		
	Uranium-234	Uranium-235	Uranium-238
External gamma exposure	6.9×10^{-5}	1.2×10^{-1}	2.0×10^{-2}
Inhalation of dust	1.4×10^{-2}	1.3×10^{-2}	1.2×10^{-2}
Inhalation of radon	0	0	0
Ingestion of soil	2.4×10^{-3}	2.2×10^{-3}	2.3×10^{-3}

[a] All values are reported to two significant figures. Maximum dose/source concentration ratios would occur immediately following remedial action.

TABLE 3 Maximum Dose/Source Concentration Ratios for Scenario B at the B&T Metals Site

Pathway	Maximum Dose/Source Concentration Ratios[a] (mrem/yr)/(pCi/g)		
	Uranium-234	Uranium-235	Uranium-238
External gamma exposure	2.3×10^{-4}	4.1×10^{-1}	6.8×10^{-2}
Inhalation of dust	4.9×10^{-2}	4.5×10^{-2}	4.3×10^{-2}
Inhalation of radon	0	0	0
Ingestion of plant foods	2.1×10^{-3}	2.0×10^{-3}	2.0×10^{-3}
Ingestion of soil	7.7×10^{-3}	7.3×10^{-3}	7.4×10^{-3}

[a] All values are reported to two significant figures. Maximum dose/source concentration ratios would occur immediately following remedial action.

TABLE 4 Maximum Dose/Source Concentration Ratios for Scenario C at the B&T Metals Site

	Maximum Dose/Source Concentration Ratios[a] (mrem/yr)/(pCi/g)		
Pathway	Uranium-234	Uranium-235	Uranium-238
External gamma exposure	2.3×10^{-4}	4.1×10^{-1}	6.8×10^{-2}
Inhalation of dust	4.9×10^{-2}	4.5×10^{-2}	4.3×10^{-2}
Inhalation of radon	0	0	0
Ingestion of plant foods	1.0×10^{-2}	9.8×10^{-3}	9.9×10^{-3}
Ingestion of meat	1.9×10^{-3}	1.8×10^{-3}	1.8×10^{-3}
Ingestion of milk	4.9×10^{-3}	4.6×10^{-3}	4.7×10^{-3}
Ingestion of fish	0	0	0
Ingestion of soil	7.7×10^{-3}	7.3×10^{-3}	7.4×10^{-3}
Ingestion of water	0	0	0

[a] All values are reported to two significant figures. Maximum dose/source concentration ratios would occur immediately following remedial action.

Uncertainty in the derivation of dose/source concentration ratios arises from the distribution of possible input parameter values, as well as from the conceptual model used to represent the site. Depending on the scenario, different parameters affect the results in each case. For Scenarios A and B, the external gamma exposure and dust inhalation pathways contribute almost equally to most of the dose. Therefore, uncertainty in parameters affecting these pathways, such as the thickness of the contaminated zone and mass loading of dust in the air, will affect the results more than parameters affecting other pathways. In addition, doses will depend strongly on the choice of occupancy factors selected for these two scenarios. In addition to the external gamma exposure and dust inhalation, the plant ingestion pathway also contributes significantly to the dose calculated for Scenario C. Therefore, the guidelines will be sensitive to parameters that affect this pathway, such as root uptake factors and plant ingestion rates.

Because the maximum dose would occur immediately following the remedial action for all three scenarios, the results are not affected by uncertainties in the parameters for the leaching of radionuclides from the contaminated zone. It should be noted that the breakthrough time (the time it takes the uranium to reach the water table) does not occur within 1,000 years after remediation. Sensitivity analyses were performed on the uranium distribution coefficients in the contaminated zone. The uranium distribution coefficients were changed from 1,410 cm^3/g to 50 cm^3/g (RESRAD default), but the maximum dose/concentration ratios did not change for any of the three scenarios.

TABLE 5 Total Dose/Source Concentration Ratios for Uranium at the B&T Metals Site

	Maximum Dose/Source Concentration Ratios[a] (mrem/yr)/(pCi/g)		
Radionuclide	Scenario A[b]	Scenario B[c]	Scenario C[d]
Uranium-234	1.6×10^{-2}	5.9×10^{-2}	7.4×10^{-2}
Uranium-235	1.4×10^{-1}	4.7×10^{-1}	4.8×10^{-1}
Uranium-238	3.5×10^{-2}	1.2×10^{-1}	1.4×10^{-1}
Total uranium	2.8×10^{-2}	9.8×10^{-2}	1.1×10^{-1}

[a] All values are reported to two significant figures.

[b] Industrial worker: no consumption of water or food obtained on the site (current use scenario).

[c] Resident: water used for drinking, household purposes, and irrigation assumed to be from uncontaminated municipal sources (likely future use scenario).

[d] Resident: water used for drinking, household purposes, livestock watering, and irrigation assumed to be from an on-site well (unlikely but plausible future use scenario).

The area of the contaminated zone used in this analysis was 12,000 m^2, which is equivalent to the estimated size of the outdoor areas found contaminated during the surveys. If the total area of the site (18,700 m^2) was used in the analysis, the dose/source ratio would increase about 0-2%, depending on the scenario considered.

The RESRAD default values were used in the calculations when no site-specific data were available. These default values are based on national average or reasonable maximum values. In addition, the contaminated zone thickness of 0.15 m that was selected to derive the dose/source concentration ratios is based on the assumption that the soil is uniformly contaminated to that depth. In reality, most of the contamination has been detected in the top few centimeters of soil and is not dispersed uniformly throughout the site. In Scenarios B and C, it is likely that large amounts of potentially contaminated soil and demolition debris would be removed in preparing the site for residential or farming use. Additionally, in this analysis, the noncontiguous contaminated areas were treated as a single homogenous area (12,000 m^2). Therefore, the calculated dose/source ratios are considered to be conservative.

4 RESIDUAL RADIOACTIVE MATERIAL GUIDELINES

The residual radioactive material guideline is the concentration of residual radioactive material that can remain in the soil in a decontaminated area and still allow use of the area without radiological restrictions. Given a dose limit, *DL*, for an individual, the residual radioactive material guideline *G* for uranium at the B&T Metals site can be calculated as

$$G = DL/DSR \ ,$$

where *DSR* is the total dose/source concentration ratio listed in Table 5. The dose limit, *DL*, used to derive the residual radioactive material guideline is 30 mrem/yr for the current use and likely future use scenarios (Scenarios A and B in this case) and 100 mrem/yr for all other plausible future use scenarios (Scenario C in this case) (Yu et al. 1993a). The residual radioactive material guidelines for single radionuclides (uranium-234, uranium-235, and uranium-238) and total uranium calculated for the B&T Metals site scenarios are presented in Table 6.

TABLE 6 Residual Radioactive Material Guidelines for the B&T Metals Site

	Guideline (pCi/g)[a]		
Radionuclide	Scenario A[b]	Scenario B[c]	Scenario C[d]
Uranium-234	1,800	510	1,400
Uranium-235	220	64	210
Uranium-238	860	250	740
Total uranium	1,100	300	880

[a] All values are reported to two significant figures.

[b] Industrial worker: no consumption of water or food obtained on the site (current use scenario, dose constraint = 30 mrem/yr).

[c] Resident: water used for drinking, household purposes, and irrigation assumed to be from uncontaminated municipal sources (likely future use scenario, dose constraint = 30 mrem/yr).

[d] Resident: water used for drinking, household purposes, livestock watering, and irrigation assumed to be from an on-site well (unlikely but plausible future use scenario, dose limit = 100 mrem/yr).

For the calculations of the total uranium guidelines, it was assumed that the activity concentration ratio of uranium-238, uranium-234, and uranium-235 is 1:1:0.046. The derived guidelines for total uranium for Scenarios A, B, and C are 1,100, 300, and 880 pCi/g, respectively. If uranium-238 is measured as the indicator radionuclide, the uranium-238 limits for total uranium can be calculated by dividing the total uranium guidelines by 2.046. The resulting uranium-238 limits for Scenarios A, B, and C are 520, 150, and 430 pCi/g, respectively.

The sum-of-fractions rule applies when the derived radionuclide guidelines for decontamination of a site are implemented. The summation of the radionuclide concentrations S_i remaining on-site (averaged over an area of 100 m^2 and a depth of 15 cm) and divided by their guidelines G_i should not be greater than unity, that is,

TABLE 7 Ranges for Hot Spot Multiplication Factors

Hot Spot Area Range (m^2)	Factor (multiple of authorized limit)
<1	10[a]
1 – <3	6
3 – <10	3
10 – 25	2

[a] Areas less than 1 m^2 are averaged over a 1-m^2 area; average shall not exceed 10 times the authorized limit.

Source: Yu et al. (1993a).

$$\sum_i S_i/G_i \leq 1 .$$

The derived guidelines listed in Table 6 are for a large, homogeneously contaminated area. For a small isolated area of contamination (a hot spot), the allowable concentration that can remain on-site may be higher than the homogeneous guideline, depending on the size of the contaminated area, and in accordance with the ranges given in Table 7.

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APPENDIX

SCENARIOS AND PARAMETERS USED FOR THE ANALYSIS OF THE B&T METALS COMPANY SITE, COLUMBUS, OHIO

The following exposure scenarios were analyzed for the B&T Metals site in Columbus, Ohio:

- *Scenario A: Industrial Use of the Site.* A hypothetical person is assumed to work in the area of the site.

- *Scenario B: Residential Use of the Site — Municipal Water Supply.* A hypothetical resident is assumed to live in the decontaminated area and to use an uncontaminated municipal water supply for drinking, household purposes, and irrigation. The resident is assumed to ingest plant foods grown on-site; however, no livestock are raised on-site for the production of meat and milk, and no pond is present on-site to provide fish and other aquatic food.

- *Scenario C: Residential Use of the Site — On-Site Well Water.* A hypothetical resident is assumed to live in the decontaminated area and to use water from an on-site well for drinking, household purposes, livestock watering, and irrigation. The resident is assumed to ingest plant foods grown in the garden and meat and milk from livestock fed with forage grown on-site. The resident is assumed to catch and consume fish and other aquatic organisms from an on-site pond.

The parametric values used in the RESRAD code for the analysis of the B&T Metals site are listed in Table A.1. All parametric values are reported at up to three significant figures. Some values are specific to the B&T Metals site; others are generic.

TABLE A.1 Parameters Used in the RESRAD Computer Code for the Analysis of the B&T Metals Site

Parameter	Unit	Value		
		Scenario A	Scenario B	Scenario C
Area of contaminated zone[a]	m^2	12,000	12,000	12,000
Thickness of contaminated zone[a]	m	0.15	0.15	0.15
Length parallel to aquifer flow[a]	m	110	110	110
Basic radiation dose limit[a,b]	mrem/yr	30	30	100
Cover depth[a]	m	0	0	0
Contaminated zone				
Density[a]	g/cm^3	1.28	1.28	1.28
Erosion rate[a]	m/yr	0	0	0
Total porosity[a]	—[c]	0.45	0.45	0.45
Effective porosity[b]	—[c]	0.2	0.2	0.2
Hydraulic conductivity[a]	m/yr	227	227	227
Soil-specific b parameter[a,b]	—[c]	5.3	5.3	5.3
Evapotranspiration coefficient[b]	—[c]	0.5	0.5	0.5
Precipitation[a]	m/yr	0.93	0.93	0.93
Irrigation[b]	m/yr	0.2	0.2	0.2
Irrigation mode[b]	—[c]	Overhead	Overhead	Overhead
Runoff coefficient[a]	—[c]	0.4	0.4	0.4
Watershed area for nearby pond[b]	m^2	Not used	Not used	1,000,000
Accuracy for water/soil computation[b]	—[c]	Not used	Not used	0.001
Saturated zone				
Density[a]	g/cm^3	Not used	Not used	1.28
Total porosity[a]	—[c]	Not used	Not used	0.45
Effective porosity[a,b]	—[c]	Not used	Not used	0.2
Hydraulic conductivity[a]	m/yr	Not used	Not used	227
Hydraulic gradient[a,b]	—[c]	Not used	Not used	0.02
Soil-specific b parameter[a,b]	—[c]	Not used	Not used	5.3
Water table drop rate[a,b]	m/yr	Not used	Not used	0
Well pump intake depth (below water table)[a,b]	m	Not used	Not used	10
Model: nondispersion (ND) or mass balance (MB)[b]	—[c]	Not used	Not used	ND
Well pumping rate[a,b]	m^3/yr	Not used	Not used	250
Number of unsaturated zone strata[a]	—[c]	Not used	Not used	1
Unsaturated zone				
Thickness[a]	m	Not used	Not used	5.35
Soil density[a]	g/cm^3	Not used	Not used	1.28
Total porosity[a]	—[c]	Not used	Not used	0.45
Effective porosity[a,b]	—[c]	Not used	Not used	0.2
Soil-specific b parameter[a,b]	—[c]	Not used	Not used	5.3
Hydraulic conductivity[a]	m/yr	Not used	Not used	227

TABLE A.1 (Cont.)

Parameter	Unit	Value		
		Scenario A	Scenario B	Scenario C
Distribution coefficient[a] (all zones)	cm^3/g			
Uranium-234		1,410	1,410	1,410
Uranium-235		1,410	1,410	1,410
Uranium-238		1,410	1,410	1,410
Actinium-227		1,500	1,500	1,500
Protactinium-231		1,800	1,800	1,800
Lead-210		16,000	16,000	16,000
Radium-226		36,000	36,000	36,000
Thorium-230		3,300	3,300	3,300
Inhalation rate[b]	m^3/yr	8,400	8,400	8,400
Mass loading for inhalation[a]	g/m^3	0.0001	0.0001	0.0001
Shielding factor, inhalation[b]	—[c]	0.4	0.4	0.4
Shielding factor, external gamma[b]	—[c]	0.7	0.7	0.7
Fraction of time indoors[a,b]	—[c]	0.17	0.5	0.5
Fraction of time outdoors[a,b]	—[c]	0.06	0.25	0.25
Shape factor, external gamma[b]	—[c]	1	1	1
Dilution length for airborne dust, inhalation[b]	m	3	3	3
Food consumption				
Fruits, vegetables, and grain[a,b]	kg/yr	Not used	160	160
Leafy vegetables[a,b]	kg/yr	Not used	14	14
Milk[a,b]	L/yr	Not used	Not used	92
Meat and poultry[a,b]	kg/yr	Not used	Not used	63
Fish[a,b]	kg/yr	Not used	Not used	5.4
Other aquatic food[a,b]	kg/yr	Not used	Not used	0.9
Soil ingestion[a,b]	g/yr	36.5	36.5	36.5
Drinking water intake[a,b]	L/yr	Not used	Not used	510
Contaminated fraction of food and water	—[c]			
Drinking water[a,b]		Not used	0	1
Household water[a,b]		Not used	0	1
Livestock water[a,b]		Not used	Not used	1
Irrigation water[a,b]		Not used	0	1
Aquatic food[a,b]		Not used	Not used	0.5
Plant food[a,b]		Not used	0.1	0.5[d]
Meat[a,b]		Not used	Not used	0.6[d]
Milk[a,b]		Not used	Not used	0.6[d]
Livestock fodder intake for meat[a,b]	kg/d	Not used	Not used	68
Livestock fodder intake for milk[a,b]	kg/d	Not used	Not used	55
Livestock water intake for meat[a,b]	L/d	Not used	Not used	50
Livestock water intake for milk[a,b]	L/d	Not used	Not used	160
Livestock soil intake[a,b]	kg/d	Not used	Not used	0.5

TABLE A.1 (Cont.)

Parameter	Unit	Value: Scenario A	Scenario B	Scenario C
Mass loading for foliar deposition[a,b]	g/m^3	Not used	0.0001	0.0001
Depth of soil mixing layer[b]	m	0.15	0.15	0.15
Depth of roots[a,b]	m	Not used	0.9	0.9
Groundwater fractional usage (balance from surface water)	—[c]			
Drinking water[a,b]		Not used	Not used	1
Household water[a,b]		Not used	Not used	1
Livestock water[a,b]		Not used	Not used	1
Irrigation[a,b]		Not used	Not used	1
Storage times of contaminated foodstuffs	days			
Fruits, nonleafy vegetables, and grain[a,b]		Not used	14	14
Leafy vegetables[a,b]		Not used	1	1
Fish[a,b]		Not used	Not used	7
Crustacea and mollusks[a,b]		Not used	Not used	7
Milk[a,b]		Not used	Not used	1
Meat and poultry[a,b]		Not used	Not used	20
Well water[a,b]		Not used	Not used	1
Livestock fodder[a,b]		Not used	Not used	45
Total porosity of the house or building foundation[b]	—[c]	0.1	0.1	0.1
Volumetric water content of the foundation[b]	—[c]	0.03	0.03	0.03
Diffusion coefficient for radon gas	m^2/s			
In foundation material[b]		3.0×10^{-7}	3.0×10^{-7}	3.0×10^{-7}
In contaminated zone soil[b]		2.0×10^{-6}	2.0×10^{-6}	2.0×10^{-6}
Emanating power of radon-222[b]	—[c]	0.25	0.25	0.25
Radon vertical dimension of mixing[b]	m	2	2	2
Average annual wind speed[b]	m/s	2	2	2
Average building air exchange rate[b]	1/h	0.5	0.5	0.5
Height of building (room)[b]	m	2.5	2.5	2.5
Building indoor area factor[b]	—[c]	0	0	0

TABLE A.1 (Cont.)

Parameter	Unit	Value		
		Scenario A	Scenario B	Scenario C
Bulk density of house or building foundation[b]	g/cm^3	2.4	2.4	2.4
Thickness of house or building foundation[b]	m	0.15	0.15	0.15
Building depth below ground surface[b]	m	-1	-1	-1

[a] Values based on site specifications, scenario assumptions, or Yu et al. (1993a,b).

[b] RESRAD default values.

[c] Parameter is dimensionless.

[d] Calculated with the RESRAD computer code.

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Environmental Assessment Division
Argonne National Laboratory

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Director, Environmental Assessment Division
Argonne National Laboratory
Argonne, Illinois 60439-4815
Telephone (708) 252-3107

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by S. Kamboj, M. Nimmagadda, and C. Yu

Environmental Assessment Division,
Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439

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