Development of Preliminary Remediation Goals for Indoor Dust at the Colonie FUSRAP Site - 12273

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ABSTRACT

The Colonie FUSRAP Site is located in the Town of Colonie, Albany County, New York. The U.S. Army Corps of Engineers is currently addressing environmental contamination associated with the Site under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) process as part of the Formerly Utilized Sites Remedial Action Program (FUSRAP). Soil remediation activities have been substantially completed at the Colonie FUSRAP Site and its vicinity properties under the FUSRAP. A study unrelated to FUSRAP was recently performed by an independent party to establish the distribution of DU contamination in various media in the environs of the Site. As part of this study, dust samples were collected in residencies and businesses in the immediate vicinity of the Site. These samples were collected in non-living areas such as basement window sills and garages. Many of these samples tested positive for DU. An assessment was performed to establish preliminary remediation goals (PRGs) for indoor dust in non-living areas of residential homes and businesses in the vicinity of the Site. The results of this assessment provide estimates of dose-based, carcinogenic risk-based, and noncarcinogenic-based PRGs derived from a hypothetical exposure scenario with reasonable levels of conservatism. Ultimately, the PRGs will be compared to results of dust sampling and analyses in residences and businesses in proximity of the Site to determine whether a response action is appropriate.

INTRODUCTION

The Colonie FUSRAP Site is located at 1130 Central Avenue (New York State Route 5) in the Town of Colonie, Albany County, New York. The Site consists of 11.2 acres. The surrounding area consists of residential and commercial properties. These properties are known as vicinity properties.

Industrial operations at the Site began in 1923, when a facility was built for manufacturing wood products and toys. In 1937, National Lead purchased the facility for conducting electroplating operations. In 1958, the nuclear division of National Lead began producing items manufactured from uranium and thorium under a license issued by the Atomic Energy Commission and New York State.

The New York State Supreme Court shut down the National Lead plant in 1984 due to environmental concerns, and ownership of the Site was transferred to the US Department of Energy (DOE). DOE surveyed the vicinity properties surrounding the

National Lead plant for radioactivity in 1980 and determined that uranium released into the air had deposited on residential and commercial properties and structures. DOE's findings also showed that the majority of the deposited uranium was in the direction of the area's prevailing winds.

In October 1983, DOE performed more detailed radiological surveys of the individual Vicinity Properties. These surveys were designed to locate those properties on which uranium concentrations exceeded the remedial action guidelines agreed upon by the State of New York and DOE. These surveys identified 56 properties that required remedial actions. DOE conducted remediation activities at 53 of the 56 vicinity properties in 1984, 1985 and 1988 and stored the contaminated materials on the Colonie Interim Storage Site awaiting final deposition.

As of this writing, soil remediation activities have been substantially completed at the Colonie FUSRAP Site and its vicinity under the FUSRAP. A study unrelated to FUSRAP was recently performed by an independent party to establish the distribution of DU contamination in various media in the environs of the Site (Lloyd et al, 2009) (Parish et al, 2008). As part of this study, dust samples were collected in residencies and businesses in the immediate vicinity of the Site. These samples were collected in non-living areas such as basement window sills and garages. Many of these samples tested positive for depleted uranium, with concentrations ranging from non-detect to 1,065 mg/kg (426 pCi/g). The two highest measured uranium concentrations were from samples collected in the inner portion of an outdoor porch lamp at a residence (Parrish, 2008).

It should be noted that the recent study that identified DU in residential dwellings did not include collection and analysis of samples from general living areas. Samples were collected, and dust contamination was identified, in limited use areas such as garages, basement window sills, and in an outdoor light fixture (Parrish, 2008). Data has not been located that describes the uranium concentration in dusts within general living areas of residences in the vicinity of the Site from that study or any other study. The US Army Corps of Engineers is currently conducting a Site Investigation to better quantify dust DU concentrations in the non-living areas within vicinity residences. It is anticipated that the results of the Site Investigation will be used in conjunction with the results of this assessment, and/or subsequent assessments, to establish whether or not a response action is appropriate.

METHOD

This assessment is performed using methods consistent with industry-accepted guidance developed by the US Environmental Protection Agency (EPA), US Nuclear Regulatory Commission (NRC), and DOE to estimate dose and risk from radionuclides and uranium. The dose assessment approaches described in NRC NUREG/CR-5512, *Residual Radioactive Contamination from Decommissioning*, (NRC, 1992) are the primary guidance used herein to infer radioactivity concentration in air based on radioactivity in dust. For the noncarcinogenic approach to a derivation of preliminary

remediation goals, the EPA Risk Assessment Guidance for Superfund Part B (EPA, 1991) and the EPA Regional Screening Levels User's Guide (EPA, 2010) were consulted. The approach documented in NUREG/CR-5512 is consistent with the approaches used in the Department of Energy's RESRAD dose/risk assessment codes and in EPA Risk Assessment Guidance for Superfund. Receptor behavioral/exposure parameters were obtained from varying industry-accepted sources including the EPA Exposure Factors Handbook (EPA, 1997) and NUREG/CR-5512 Volumes 1-3 (NRC, 1992) (NRC, 1999a) (NRC, 1999b).

Two exposure pathways are evaluated in the carcinogenic and noncarcinogenic assessments: inhalation of suspended dust and inadvertent ingestion of contaminated dusts. For each of these pathways three primary receptor activities are evaluated: normal living activities in general living areas of a residence, general activities performed periodically in an attic or other non-living area, and renovation of a portion of the non-living area of the residence. Exposure resulting from normal living activities is assumed to be chronic and occur continuously during occupancy in the residence. Exposure resulting from activities within non-living areas is assumed to occur as a single acute exposure or series of acute exposures, which occur every year. Renovation is assumed to occur as a single event and represent an acute, one-time, exposure.

The dermal absorption pathway was not considered in the carcinogenic and noncarcinogenic assessments. Radiation dose and cancer risk from dermal absorption of uranium under building occupancy and renovation scenarios are insignificant relative to those from inhalation and ingestion. NUREG/CR-5512, Volume 1 (NUREG page 3.4) excludes the dermal absorption pathway for this reason. There is provision for inclusion of the dermal pathway within the Risk Assessment Guidance for Superfund, Part E, (EPA, 2004) for the noncarcinogenic pathway. However, the default dermal permeability for this inorganic is presumed to be very low and would not make an appreciable impact on the overall PRG development.

The external exposure to penetrating radiation pathway was not considered in the carcinogenic assessment. This pathway was excluded because, for a given contaminant concentration, the external exposure dose/risk is negligible compared to internal exposure dose/risk. The validity of this assumption was confirmed by comparing "default" PRGs calculated using the EPA online PRG calculator for inhalation to those for external radiation for the uranium isotopes of concern. "Default" PRGs for external radiation were at least three orders of magnitude higher than those for internal exposure, indicating that dose/risk from the external radiation pathway is over one thousand times less than the internal pathways.

Exposure Scenarios and Pathways

This assessment considers a reasonably conservative exposure scenario to address potential current and future home uses. This scenario, referred to as the "Home Worker/Self Renovator", considers two exposure pathways, inhalation of suspended dust and inadvertent ingestion of contaminated dusts.

The receptor spends the majority of their time in the residence, working from home and self-performing renovation of a non-living area. The remainder of this receptor's time is spent outside or away from the home. The indoor activities for this receptor involve typical home making chores (cooking, cleaning and laundering) and normal indoor living activities. This receptor works from home and spends 2,000 hours more time within the residence than the default resident in NUREG/CR-5512. Activities within the residence may result in the release of contaminants into the air as a result of normal use and cleaning, such as washing the walls or vacuuming the floors, and use of non-living spaces (e.g., attics) for seasonal/periodic storage.

The receptor self-performs a single renovation activity within a non-living area in the residence. The renovation is assumed to occur in the non-living areas for the purpose of conservatism, as dust DU concentrations are considerably greater in non-living areas than in living areas, resulting in substantially greater exposure estimates. During renovation contaminated dust will be disturbed, creating loose contamination. This loose contamination can produce higher concentrations of radionuclides in the air or on surfaces than the levels in an undisturbed building. Expected renovation activities include removal of portions of concrete, carpentry, plumbing, painting and light demolition, all assumed to occur with an elevated amount of loose surface contamination.

Exposure resulting from normal living activities is assumed to be chronic and occur continuously during occupancy in the residence. Exposure resulting from activities within non-living areas is assumed to occur as a single acute exposure or series of acute exposures, which occur every year and are considered chronic. Renovation is assumed to occur as a single event in a non-living area and represent an acute, one-time, exposure.

Under this scenario, for noncarcinogenic purposes, the child of the home worker/self renovator is the most conservative scenario to use as the child has more exposure, even if it is over a shorter span of years. For noncarcinogenic exposures, the acute risks are not included into the derivation of a preliminary remediation goal. Additionally, a value for dust transfer factor to living spaces was not used for the derivation of noncarcinogenic hazard as a conservative measure. The child is assumed to be present in the house during renovation and is assumed to be curious enough to be within the attic space with the renovator parent from time-to-time experiencing higher dust loading factors.

Definition of Source Term

The source term evaluated in this assessment is dust within residential dwellings that has been contaminated by DU discharges from past Site operations. The concentration of DU in the general living areas of residences has not been well characterized and some limited sampling in non-living areas has identified DU contamination. It is expected that non-living areas will have considerably greater concentrations than living areas, where routine cleaning activities over the years have essentially removed any contaminated dust. In order to account for the expected differences in non-living and living areas, this assessment considers two primary source terms: contaminated dust in non-living areas and contaminated dust in living areas.

The source of potential dust contamination from outside the residences has been removed (Site operations ceased in 1984 and soil contamination has been removed). It is assumed that the primary mechanism for contaminated dust to enter living areas in a residence is through physical transfer from non-living areas within the residence. Such physical processes could include human activities or air exchanges between these areas. This assessment conservatively assumes these limited transfer mechanisms will result in living areas having a dust DU concentration that is 0.01 times that in the non-living areas. This is supported by a study conducted in 1996 addressing residential dust contamination from past industrial plant emissions, which concluded that contaminant dust concentrations were 1,000 times greater in attics than in the living areas below (Hansen, 1996). This study was cited by the Agency for Toxic Substances and Disease Registry in a Health Consultation associated with the Nitro School Dioxin Site to describe the potential for transfer of dust from areas not routinely disturbed into occupied areas (ATSDR, 2007).

DU is comprised of three isotopes of uranium: U-234, U-235, and U-238. While the vast majority of the mass of DU consists of the isotope U-238, U-234 contributes a significant amount of the total radioactivity in DU because of its short relative half life. The isotopic composition of DU and its specific activity used in this derivation were obtained from *Health and Environmental Consequences of Depleted Uranium use in the Army: Technical Report*, (USAEPI, 1995). Table I shows the isotopic composition of DU and the half lives of the individual isotopes.

Table I. Isotopic Composition of DU

Isotope	*Half Life*	*Mass Percentage*	*Activity Percentage*
U-234	2.47×10^5 years	0.001 %	15.7 %
U-235	7.1×10^8 years	0.2 %	1.11 %
U-238	4.5×10^9 years	99.8 %	83.2 %

Carcinogenic PRGs

Dose-based PRGs are based on an annual dose constraint of 0.1 mSv/year (10 mrem/year). Risk based PRGs are based on constraining the lifetime probability of contracting cancer as a result of the hypothetical exposure (i.e., increased cancer risk of 10^{-6}). Thus, dose-based PRGs are calculated based on the hypothetical intake of a receptor during a one year period. Conversely, risk-based PRGs are based on estimated lifetime intake.

The concentration of respirable dust in the air will vary depending upon a variety of factors, including the physical condition (such as the particle size) of the material being handled, the quantity of the material present, and the building ventilation or wind conditions (NRC, 1999). In this assessment, concentrations of respirable dust in the air are estimated using dust-loading factors. For this method, the average air concentration is defined in terms of g/m^3 of air. This concentration is converted to units of activity using the concentration of the source material, assuming all airborne particulates derive from dust within the residence. Consistent with EPA, NRC, and DOE guidance, this assessment applies separate mass loading factors for home occupancy and home renovation to address the greater dust-loading created by remodeling activities (NRC, 1999) (EPA, 1997).

Inhalation intake, in units of activity or mass, is then derived from the average air concentration. Two behavioral parameters are necessary to derive inhalation intake from air concentration: receptor breathing rate and exposure duration. Consistent with EPA, NRC, and DOE guidance, this assessment differentiates breathing rates for home occupancy and home renovation to address the higher breathing rates associated with home remodeling.

The following equation, which is consistent with Equation 6.8 in NUREG/CR-5512, Volume 1, is used to estimate inhalation intake:

$$\text{Inhalation Intake} = \overline{DU} \times DLF \times BR \times ED \qquad \text{(Eq. 1)}$$

$\overline{DU}$ = Living area or non-living area dust average DU activity concentration
DLF = Dust Loading Factor
BR = Breathing rate
ED = Exposure duration

It should be noted that this assessment conservatively assumes all depleted uranium in dust can become airborne and is respirable. In fact, the study performed by Parrish et al established that uranium particles in dust and soil in the Site environs ranged from <1 to 40 μm in diameter (Parrish et al, 2008). Particles greater than 10 μm are not considered respirable.

Ingestion of removable surface contamination inside buildings that is transferred from contaminated surfaces via hands, food, and other items to the mouth is referred to as

secondary ingestion. This inadvertent ingestion results in direct intake of contaminated dust. Ingestion intake is estimated based on reasonably conservative inadvertent dust ingestion rates, in units of grams per day, obtained from EPA, NRC, and DOE sources.

The following equation, which is consistent with Equation 3.19 in NUREG/CR-5512, Volume 1, is used to estimate ingestion intake:

$$\text{Ingestion Intake} = \overline{DU} \times IR \times ED \qquad \text{(Eq. 2)}$$

$\overline{DU}$ = Living area or non-living area dust average DU activity concentration
IR = Ingestion Rate
ED = Exposure duration

Annual dose is estimated from calculated intakes by applying a dose conversion factor (dose per unit intake) to translate intake activity into potential annual dose. This assessment uses dose conversion factors from EPA Federal Guidance Report 11, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion* (EPA, 1989), which is consistent with EPA, NRC, and DOE methods. The most conservative (i.e., highest dose per unit intake) inhalation and ingestion conversion factors were selected for each uranium isotope.

Total annual dose is calculated from the sum of the dose from the internal and external pathways using the following equation:

$$\text{Annual Dose} = (I_{inh})(DCF_{inh}) + (I_{ing})(DCF_{ing}) \qquad \text{(Eq. 3)}$$

I_{inh} = Annual inhalation intake
DCF_{inh} = DU composite inhalation Dose Conversion Factor
I_{ing} = Annual ingestion intake
DCF_{ing} = DU composite ingestion Dose Conversion Factor

Risk is estimated using the same general approach that is used to estimate dose. But instead of using dose conversion factors (which convert intakes into radiological dose), cancer morbidity risk coefficients are used (which convert intakes into excess cancer risk). In addition, lifetime cancer risk is calculated based on lifetime intakes. These lifetime intakes are the sum of chronic (residential occupancy and non-living area activities) and acute (one time renovation) exposures.

Risk coefficients are expressed as the probability of radiogenic cancer morbidity per unit intake. This assessment uses cancer morbidity risk coefficients from EPA Federal Guidance Report 13, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides* (EPA, 1999), which is consistent with EPA, NRC, and DOE methods. The most conservative (i.e., highest dose per unit intake) risk coefficients were selected for each isotope.

Lifetime cancer risk is calculated from the sum of the risk from the internal and external pathways using the following equation:

$$\text{Lifetime Cancer Risk} = (LI_{inh})(RC_{inh}) + (LI_{ing})(RC_{ing}) \quad \text{(Eq. 4)}$$

LI_{inh} = Lifetime inhalation intake
RC_{inh} = DU composite inhalation Risk Coefficient
LI_{ing} = Lifetime ingestion intake
RC_{ing} = DU composite ingestion Risk Coefficient

Preliminary remediation goals for uranium as a carcinogen are estimated individually based on total annual dose and total lifetime cancer risk for a given exposure scenario. The total annual dose and lifetime cancer risk per unit DU dust concentration are compared to a 'target' annual dose or risk and the DU activity concentration that would produce that dose or risk is determined. This DU activity concentration represents the PRG. The following equation describes calculation of PRGs.

$$PRG = \frac{\text{'target' dose or risk}}{\text{dose or risk per unit dust concentration}} \quad \text{(Eq. 5)}$$

The target limiting annual dose used in this assessment is 0.1 mSv/year (10 mrem/year). The target limiting lifetime cancer risk used in this assessment is 10^{-6}.

Non-carcinogenic PRGs

The approach for derivation of dose for noncarcinogenic exposures to uranium is different than the approach taken for generating intakes for carcinogenic exposures. Intakes are not derived, rather the guidelines are followed as stated in EPA guidance for the derivation of reference concentrations for inhalation and reference doses for ingestion. See Table II below:

Table II. Reference Concentration and Dose for Uranium

Constituent	Reference Concentration (mg/m^3)	Reference Dose (mg/kg-day)
Uranium	3E-04[a]	3E-03[b]

Notes: (a) (ATSDR 2011), Minimal Risk Level
(b) (EPA, 2011), Integrated Risk Information System

The choice of these values is based on EPA's hierarchy of risk levels (EPA, 2003) which are:

- Tier 1- EPA's Integrated Risk Information System.

- Tier 2- EPA's Provisional Peer Reviewed Toxicity Values – The Office of Research and Development/National Center for Environmental Assessment/Superfund Health Risk Technical Support Center develops these values on a chemical specific basis when requested by EPA's Superfund program.

- Tier 3 - Other Toxicity Values - Tier 3 includes additional EPA and non-EPA sources of toxicity information. Priority should be given to those sources of information that are the most current, the basis for which is transparent and publicly available, and which have been peer reviewed.

The reference dose is a Tier 1 value and the reference concentration is an accepted Tier 3 value as described in EPA, 2003 (there was no available Tier 1 or 2 value for inhalation toxicity for uranium). Soluble salts of uranium were the form of uranium used in the derivation of both of these toxicity values.

The guidelines stated in the *Inhalation Dosimetry Methodology* (EPA, 1994) were followed for derivation of reference concentrations. Under the *Inhalation Dosimetry Methodology*, EPA describes a process whereby the experimental exposures are typically extrapolated to a Human Equivalent Concentration, and a reference concentration is typically calculated by dividing the Human Equivalent Concentration by uncertainty factors. Inhalation rates are not used, rather temporal variables related to exposure are used and doses generated based on the assumed dust loading factor into the air for uranium.

The exposure equation related to the inhalation of particulates emitted from dust and subsequent preliminary remediation goal is:

$$\text{Dust concentration}_{inh} = \frac{THQ \times AT \times ED}{EF \times ED \times ET \times \frac{1}{RfC} \times \frac{1}{DLF}} \qquad \text{(Eq. 6)}$$

THQ = Target Hazard Quotient
AT = Averaging Time
EF = Exposure Frequency
ED = Exposure Duration
ET = Exposure Time
RfC = Reference Concentration
DLF = Dust Loading Factor

The dust loading factor is analogous to the "Particulate Emission Factor" found in EPA's Soil Screening Guidance (EPA, 2002).

The Risk Assessment Guidance for Superfund, Part B (EPA, 1991), outlines specifically how to derive a media concentration for a defined hazard quotient. For noncarcinogenic exposures to uranium, the preliminary remediation goal equation for ingestion of dust is:

$$\text{Dust concentration}_{ing} = \frac{THQ \times AT \times ED \times BW}{EF \times ED \times \frac{1}{RfD} \times IR} \quad \text{(Eq. 7)}$$

THQ = Target Hazard Quotient
AT = Averaging Time
BW = Body Weight
EF = Exposure Frequency
ED = Exposure Duration
RfD = Reference Dose
IR = Ingestion Rate

Using the pathway derivations for preliminary remediation goals as contained in the previous sections of this document, a preliminary remediation goal for uranium in dust based on both exposure pathways can be derived:

$$PRG\ (\text{Dust conc.}) = \frac{1}{\frac{1}{\text{Dust concentration}_{inh}} + \frac{1}{\text{Dust concentration}_{ing}}} \quad \text{(Eq. 8)}$$

RESULTS

This assessment estimates PRGs for DU contaminated dust in non-living areas of residences in the vicinity of the Colonie FUSRAP site based on a reasonably conservative exposure scenario. Estimated PRGs based on residential receptors are considered to be conservatively representative of workers in nearby businesses based on the considerably longer exposure duration of residents relative to workers. Table III presents the annual dose-based, lifetime cancer risk (morbidity), noncarcinogenic PRGs, and the PRG range.

Table III. Estimated PRGs for DU Contaminated Dust in Residential Non-Living Areas

Basis	Estimated Non-Living Area DU PRG (mg/kg)
Annual dose (10 mrem/yr)	2,750 (1,100 pCi/g)
Lifetime cancer risk (10^{-6})	138 (55 pCi/g)
Target Hazard Quotient of 1 [(a)]	348 (139 pCi/g)
PRG range	**138 - 2,750 (55 - 1,100 pCi/g)**

Note: (a) Noncarcinogenic PRG based on child of receptor

This assessment provides reasonably conservative estimates of PRGs for DU contaminated dust in non-living areas within residences in the vicinity of the Site. It should be noted that the PRGs include hypothetical exposures resulting from activities

in both the living areas and non-living areas of a residence. The PRGs are derived and presented in terms of DU dust concentration in non-living areas to facilitate comparison to results of a planned Site Investigation that will characterize concentrations of DU in dust in non-living areas.

It is important to recognize that the exposure assumptions used to derive these PRGs are based on average dust DU concentrations in non-living areas. It is inappropriate to compare these PRGs to the dust DU concentration in an isolated small area. The ongoing Site Investigation addresses this consideration and is designed to provide reasonable estimates of average dust DU concentrations in non-living areas of vicinity properties. In order to accomplish this, sampling is conducted in accordance with *EPA Guidance for the Sampling and Analysis of Lead in Indoor Residential Dust for Use in the Integrated Exposure Uptake Biokinetic (IEUBK) Model*, (EPA 2008), which specifically addresses estimating average contaminant concentrations in dust. Four (4) large-area samples are collected from each VP in accordance with this guidance. It is anticipated that the results of the Site Investigation will be used in conjunction with the results of this assessment, and/or subsequent assessments, to establish whether or not a response action is appropriate.

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