1.0 INTRODUCTION

1.1 Purpose

The Soil Screening Guidance for Radionuclides is a tool that the U.S. Environmental Protection Agency (EPA) developed to help standardize and accelerate the evaluation and cleanup of soils contaminated with radioactive materials at sites on the National Priorities List (NPL) with future residential land use.[1] This guidance provides a methodology for environmental science/engineering professionals with a background in radiological risk assessment to calculate risk-based, site-specific, soil screening levels (SSLs) for radionuclides in soil that may be used to identify areas needing further investigation at NPL sites. [1]

SSLs are not national cleanup standards. SSLs alone do not trigger the need for response actions or define "unacceptable" levels of radionuclides in soil. In this guidance, "screening" refers to the process of identifying and defining areas, radionuclides, and conditions, at a particular site that do not require further Federal attention. Generally, at sites where radionuclide concentrations fall below SSLs, no further action or study is warranted under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). Generally, where radionuclide concentrations equal or exceed SSLs, further study or investigation, but not necessarily cleanup, is warranted.

This radionuclide SSL guidance is a continuation of other EPA documents related to SSL for chemicals. These include EPA's *Soil Screening Guidance: User's Guide* (U.S. EPA, 1996a) and the *Soil Screening Guidance: Technical Background Document* (U.S. EPA, 1996b) that apply the SSL framework to NPL sites with hazardous organic and inorganic soil contaminants. They do not address sites with radioactive contaminants. These documents provide standardized exposure equations for deriving generic and site-specific SSLs for chemicals under a residential land use setting, assuming three soil exposure pathways—soil ingestion, inhalation of volatiles and fugitive dusts, and ingestion of contaminated ground water. Chemical- specific SSLs are based on a target risk of one-in-a-million (10^{-6}) for carcinogens, a hazard quotient of 1 for noncarcinogens, or, for the ground water migration pathway, a nonzero maximum contaminant level goal (MCLG), maximum contaminant level (MCL), or a risk-based level. For each contaminant, the lowest pathway-specific SSL is selected as the appropriate screening level.

An overview of a comparison between the key features of the soil screening frameworks for chemicals and radionuclides is provided in Table 1 below. Much of the guidance for radionuclides is based on or cites information presented in the chemical Soil Screening Guidance documents. Users are therefore strongly encouraged to become familiar with these documents.

This guidance elaborates a framework developed for soil screening levels for radionuclides that is consistent and compatible with the SSL framework for chemicals. Radionuclide SSLs are risk-based concentrations, in activity units of picocuries per gram of soil (pCi/g), derived from equations combining exposure information assumptions with EPA radiotoxicity data. This User's Guide focuses on the application of a simple site-specific approach by providing a step-by-step methodology to calculate site-specific SSLs and is part of a larger framework that includes both generic and more detailed approaches to calculating screening levels. The Soil Screening Guidance for Radionuclides: Technical Background Document (TBD) (U.S. EPA, 2000), provides detailed information about these other approaches. Generic SSLs for the most common radionuclides found at NPL sites are included in the TBD. Generic SSLs are calculated from the same equations presented in this guidance, but are based on a number of default assumptions chosen to be protective of human health for most site conditions. Generic SSLs can be used in place of site-specific screening levels; however, in general, they are expected to be more conservative than site-specific levels. The site manager should weigh the cost of collecting the data necessary to develop site-specific SSLs with the potential for deriving a higher SSL that provides an appropriate level of protection.

The framework presented in the TBD also includes more detailed modeling approaches for developing screening levels that take into account more complex site conditions than the simple site-specific methodology

[1] Note that the Superfund program defines "soil" as having a particle size under 2 mm, while the RCRA program allows for particles under 9 mm in size.

emphasized in this guidance. More detailed approaches may be appropriate when site conditions (e.g., very deep water table, very thick uncontaminated unsaturated zone, soils underlain by karst or fractured rock aquifers) are different from those assumed in the simple site-specific methodology presented here. The technical details supporting the methodology used in this guidance are provided in the TBD.

SSLs developed in accordance with this guidance are based on future residential land use assumptions and related exposure pathways. Using this guidance for sites where residential land use assumptions do not apply could result in overly conservative screening levels; however, EPA recognizes that some parties responsible for sites with non-residential land use might still find benefit in using the SSLs as a tool to conduct a conservative initial screening.

SSLs developed in accordance with this guidance could also be used for Resource Conservation and Recovery Act (RCRA) corrective action sites as "action levels," since the RCRA corrective action program currently views the role of action levels as generally fulfilling the same purpose as soil screening levels.[2] In addition, States may use this guidance in their voluntary cleanup programs, to the extent they deem appropriate. When applying SSLs to RCRA corrective action sites or for sites under State voluntary cleanup programs, users of this guidance should recognize, as stated above, that SSLs are based on residential land use assumptions. Where these assumptions do not apply, other approaches for determining the need for further study might be more appropriate.

1.2 Role of Soil Screening Levels

In identifying and managing risks at sites, EPA considers a spectrum of radionuclide concentrations. The level of concern associated with those concentrations depends on the likelihood of exposure to radioactive soil contamination at levels of potential concern to human health.

Exhibit 1 illustrates the spectrum of soil contamination encountered at Superfund sites and the conceptual range of risk management responses. At one end are levels of contamination that clearly warrant a response action; at the other end are levels that warrant no further study under CERCLA. Screening levels identify the lower bound of the spectrum—levels below which EPA believes no further study is warranted under CERCLA, provided conditions associated with the SSLs are met. Appropriate cleanup goals for a particular site may fall anywhere within this range depending on site-specific conditions.

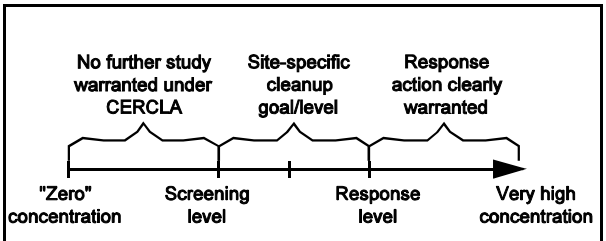

Exhibit 1. Conceptual Risk Management Spectrum for Contaminated Soil

EPA anticipates the use of SSLs as a tool to facilitate prompt identification of radionuclides and exposure areas of concern during both remedial actions and some removal actions under CERCLA. However, the application of this or any screening methodology is not mandatory at sites being addressed under CERCLA or RCRA. The framework leaves discretion to the site manager and technical experts (e.g., risk assessors, hydrogeologists) to determine whether a screening approach is appropriate for the site and, if screening is to be used, the proper method of implementation. If comments are received at individual sites questioning the use of the approaches recommended in this guidance, the comments should be considered and an explanation provided as part of the site's Record of Decision (ROD). The decision to use a screening approach should be made early in the process of investigation at the site.

EPA developed the Soil Screening Guidance for Radionuclides to be consistent with and to enhance the current Superfund investigation process and anticipates its primary use during the early stages of a remedial investigation (RI) at NPL sites. It does not replace the Remedial Investigation/Feasibility Study (RI/FS) or risk assessment, but use of screening levels can focus the RI and risk assessment on aspects of the site that are more likely to be a concern under CERCLA. By screening out

[2] Further information on the role of action levels in the RCRA corrective action program is available in an Advance Notice of Proposed Rulemaking (signed April 1996).

areas of sites, potential radionuclides of concern, or exposure pathways from further investigation, site managers and technical experts can limit the scope of the remedial investigation or risk assessment. SSLs can save resources by helping to determine which areas do not require additional Federal attention early in the process. Furthermore, data gathered during the soil screening process can be used in later Superfund phases, such as the baseline risk assessment, feasibility study, treatability study, and remedial design. This guidance may also be appropriate for use by the removal program when demarcation of soils above residential risk-based numbers coincides with the purpose and scope of the removal action.

The process presented in this guidance to develop and apply simple, site-specific soil screening levels is likely to be most useful where it is difficult to determine whether areas of soil are contaminated to an extent that warrants further investigation or response (e.g., whether areas of soil at an NPL site require further investigation under CERCLA through an RI/FS). As noted above, the screening levels have been developed assuming residential land use. Although some of the models and methods presented in this guidance could be modified to address exposures under other land uses, EPA has not yet standardized assumptions for those other uses.

Applying site-specific screening levels involves developing a conceptual site model (CSM), collecting a few easily obtained site-specific soil parameters (such as the dry bulk density and percent moisture), and sampling to measure radionuclide levels in surface and subsurface soils. Often, much of the information needed to develop the CSM can be derived from previous site investigations [e.g., the Preliminary Assessment/Site Inspection (PA/SI)] and, if properly planned, SSL sampling can be accomplished in one mobilization.

An important part of this guidance is a recommended sampling approach that balances the need for more data to reduce uncertainty with the need to limit data collection costs.

Knowledge of background radionuclide concentrations at the site is critical when screening site soils, since facility operations may have contaminated site soils with some of the same radionuclides that are found naturally-occurring in background soil. In many cases, the concentration of the radionuclide of concern in background soil, and the variability of the background soil concentration, may be much greater than the screening level. In these situations, the site manager should not exclude the radionuclide of potential concern from being evaluated in the risk assessment, as the contamination from the facility may pose a threat to human health and the environment. Risk management options for the radionuclides of concern will be evaluated in the CERCLA remedy selection process.

This guidance provides the information needed to calculate SSLs for 60 radionuclides (See Attachment C for list of radionuclides). Sufficient information may not be available to develop soil screening levels for additional radionuclides. These radionuclides should not be screened out, but should be addressed in the baseline risk assessment for the site. The *Risk Assessment Guidance for Superfund* (RAGS), *Volume 1: Human Health Evaluation Manual* (HHEM), *Part A, Interim Final.* (U.S. EPA, 1989a) provides guidance on conducting baseline risk assessments for NPL sites. In addition, the baseline risk assessment should address the radionuclides, exposure pathways, and areas at the site that are not screened out.

Although SSLs are "risk-based," they do not eliminate the need to conduct a site-specific risk assessment. SSLs are concentrations of radionuclides in soil that are designed to be protective of exposures in a residential setting. A site-specific risk assessment is an evaluation of the risk posed by exposure to site contaminants in various media. To calculate SSLs, the exposure equations and pathway models are run in reverse to backcalculate an "acceptable level" of radionuclides in soil. For each pathway, radiotoxicity criteria are used to define an acceptable level of contamination in soil, based on a one-in-a-million (10^{-6}) individual excess lifetime cancer risk. SSLs are backcalculated for the migration to ground water pathway using ground water concentration limits [maximum contaminant levels (MCLs)].

Table 1. Comparison of Soil Screening Frameworks for Chemicals and Radionuclides

Guidance	Chemicals	Radionuclides	Comments
Applicable land use exposure scenarios	Residential only	Same as chemicals	EPA may include additional guidance for other land uses (e.g., commercial/ industrial, suburban, playground, and hunter/fisher) in future updates.
Target receptor	RME individual	Same as chemicals	Ecological receptors are not addressed
Standardized equations for deriving SSLs for soil exposure pathways	• Soil ingestion • Inhalation of volatiles and fugitive dusts • Ingestion of potable ground water containing chemicals leached from soil Identifies dermal absorption, plant uptake, and migration of volatiles into basement pathways but does not calculate SSLs for these pathways	• Soil ingestion • Inhalation fugitive dusts • Ingestion of potable ground water containing radionuclides leached from soil • Direct external radiation exposure • Ingestion of home grown fruits and vegetables	Chemical-specific SSLs are expressed in mass concentration units of milligrams of contaminant per kilogram of soil (mg/kg). Radionu-clide-specific SSLs are expressed in activity concentration units of picocuries per gram of soil (pCi/g). Additional equations are required for radionuclides to account for other significant soil exposure pathways while some chemical pathways are not applicable to radionuclides.
Basis for SSLs	• Target risk limit of 10^{-6} for carcinogens • Hazard quotient of 1 for noncarcinogens • Nonzero MCLGs or MCLs (whichever is most protective), or if neither were available risk-based limits, for the ground water migration pathway	• Uses same target risk limit as chemicals • Uses MCLs, proposed MCLs (for uranium), or risk-based limits for the ground water migration pathway for radionuclides	EPA classifies all radionuclides as known human (Group A) carcinogens. For noncarcinogenic chemicals, nonzero MCLGs are considered (if available). MCLs exist for almost every radionuclide.
Default values for the age-adjusted soil ingestion factor	• $IF_{soil/adj}$ = 114 mg-yr/kg-day	• $IF_{soil/adj}$ = 120 mg-yr/day	The radionuclide slope factors for soil ingestion use a biokinetic model that accounts for the age and sex weighted mass of the affected organs. Therefore, it is not necessary to include the mass of the receptor in the default $IF_{soil/adj}$ for radionuclides.

Table 1. Comparison of Soil Screening Frameworks for Chemicals and Radionuclides

Guidance	Chemicals	Radionuclides	Comments
Default values for the dilution/attenuation factor (DAF) and the particulate emission factor (PEF)	• DAF = 20 • PEF = 1.32E+9 m^3/kg	Same as chemicals	The default PEF is the same as for chemicals. A key assumption in the derivation of the PEF is that the 1/2 acre lot has only 50% vegetative cover. Although the ingestion of homegrown produce is not quantitatively evaluated in the SSG for chemicals, the assumption of 50% vegetative cover allows for the presence of a family garden.
Soil measurement/ verification of guidelines	• Measured average soil contaminant concentrations in exposure areas of concern • Exposure area (EA) for averaging concentrations: 0.5 acres (residential lot) • Averaging depth for surface soils: 0-2 cm • Evaluation depth for subsurface soil contamination: surface to the limit of detectable contamination or to the top of the saturated zone • Number of surface soil samples required: Based on site-specific conditions or a default value of 6 randomly-selected specimens composited into 4 samples for analyses. • Number of subsurface soil samples required: For each source area, takes 2 or 3 soil borings in areas suspected of having the highest contaminant concentrations.	• Measures same parameter as for chemicals • Uses same exposure area (EA) as chemicals • Averaging depth for surface soils: 0-15 cm • Uses same evaluation depth for subsurface soil contamination as for chemicals • Uses same number of surface soil samples as for chemicals. • Uses same number of subsurface soil samples as for chemicals • Conducts surface scans for small areas of elevated activity	See Step 3, Defining Data Collection Needs for Soils for more detailed guidance.

One exception to the above approach is uranium, which presents both chemical and radiological hazards. SSLs for uranium must consider both of these types of hazards. As a general rule, the radiological hazard dominates inhalation of insoluble forms of uranium, while the chemical toxicity is the major hazard from intake of soluble forms of uranium. Chemical toxicity of uranium in the kidney has been a concern in establishing health protection standards for workers and the general public for many years. EPA developed for its rulemaking addressing radionuclide MCLs an updated oral RfD for uranium of 0.6 μg/kg/day (U.S. EPA, 1998c). SSLs for uranium should be calculated using both the radiological guidelines presented in this document and the approach provided in the Soil Screening Guidance for non-carcinogenic chemicals. Since the SSL is a numerical concentration, it should be based on the most protective health quantity whether it be kidney toxicity or radiological risk.

SSLs can be used as Preliminary Remediation Goals (PRGs) provided appropriate conditions are met (i.e., conditions found at a specific site are similar to conditions assumed in developing the SSLs). The concept of calculating risk-based contaminant levels in soils for use as PRGs (or "draft" cleanup levels) was introduced in the RAGS HHEM, *Part B, Development of Risk-Based Preliminary Remediation Goals*. (U.S. EPA, 1991c). **The models, equations, and assumptions presented in the Soil Screening Guidance for Radionuclides supersede those described in RAGS HHEM, Part B, for residential soils. In addition, this guidance presents methodologies to address the leaching of contaminants through soil to an underlying potable aquifer. This pathway should be addressed in the development of PRGs.**

PRGs may then be used as the basis for developing final cleanup levels based on the nine-criteria analysis described in the National Contingency Plan [Section 300.430 (3)(2)(I)(A)]. The directive entitled *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions* (U.S. EPA, 1991d) discusses the modification of PRGs to generate cleanup levels. The SSLs should only be used as cleanup levels when a site-specific nine-criteria evaluation of the SSLs as PRGs for soils indicates that a selected remedy achieving the SSLs is protective, complies with Applicable or Relevant and Appropriate Requirements (ARARs), and appropriately balances the other criteria, including cost. Note that potential soil ARARs exist for several of the more common naturally-occurring radionuclides (^{226}Ra, ^{228}Ra, ^{230}Th, ^{232}Th, ^{235}U, and ^{238}U) under 40 CFR Part 192.12(a), Part 192.32(b)(2), and Part 192.41, and 10 CFR Part 40 Appendix A, I, Criterion 6(6). For further guidance on using these ARARs, see OSWER Directive 9200.4-25 (U.S. EPA, 1998b), dated February 12, 1998 and OSWER Directive 9200.4-35P (U.S. EPA, 2000a), dated April 11, 2000. The equations presented in this document supersede those described in RAGS HHEM, Part B, and should be used to determine PRGs and RGs.

1.3 Scope of Soil Screening Guidance for Radionuclides

In a residential setting, potential pathways of exposure to radionuclides in soil included in this guidance are as follows (see Exhibit 2):

- Direct ingestion of soil
- Inhalation of fugitive dusts
- Ingestion of contaminated ground water caused by migration of radionuclides through soil to an underlying potable aquifer
- External radiation exposure from photon-emitting radionuclides in soil
- Ingestion of homegrown produce that has been contaminated via plant uptake

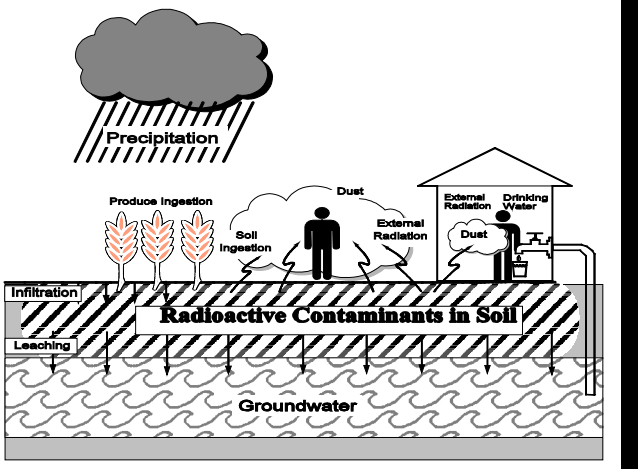

Exhibit 2: Exposure Pathways Addressed by SSLs for Radionuclides

The Soil Screening Guidance for Radionuclides addresses each of these pathways to the greatest extent practical. The mode of exposure to radionuclides is different than that of chemicals. This renders some chemical pathways inapplicable to radionuclides (e.g., inhalation of volatiles, dermal absorption) while adding other pathways unique to radiation (e.g., external exposure to photons emitted by radionuclides). The radiological pathways listed above represent the most likely exposure mechanisms for individuals in a residential setting. The external exposure pathway is, for most radionuclides, the dominant exposure and typically represents the most significant risk. For some radionuclides, the ingestion of contaminated produce and drinking water constitute the most likely exposure pathways provided that these items are obtained from onsite sources. The inhalation of fugitive dust pathway is included in the analysis; however, it is of significance for only a very few radionuclides. All of these pathways have generally accepted radiological risk methods, models, and assumptions that lend themselves to a standardized approach.

The Soil Screening Guidance for Radionuclides addresses the human exposure pathways listed previously and will be appropriate for most residential settings. The presence of additional pathways or unusual site conditions does not preclude the use of SSLs in areas of the site that are currently residential or likely to be residential in the future. However, the risks associated with additional pathways or conditions (e.g., fish consumption, raising of livestock for meat or milk consumption, fugitive dusts caused by heavy truck traffic on unpaved roads) should be considered in the RI/FS to determine whether SSLs are adequately protective.

The Soil Screening Guidance for Radionuclides should not be used for screening out areas with chemical contaminants.

Exhibit 3 provides key attributes of the Soil Screening Guidance for Radionuclides: User's Guide.

Exhibit 3: Key Attributes of the User's Guide

- Standardized equations are presented to address human exposure pathways in a residential setting consistent with Superfund's concept of "Reasonable Maximum Exposure" (RME).
- Source size (area and depth) can be considered on a site-specific basis using mass-limit models.
- Parameters are identified for which site-specific information is needed to develop SSLs.
- Default parameter values are provided to calculate generic SSLs when site-specific information is not available.
- SSLs for the migration to ground water pathway are based on maximum contaminant levels (MCLs), while SSLs for all other pathways are based on a 10^{-6} lifetime cancer risk to an individual.
- Radiation risk coefficients used to calculate SSLs represent the average risk per unit exposure to members of a population exposed throughout life to a constant concentration of a radionuclide in a specific environmental medium. They assume no radioactive decay.