



Radiation Site Cleanup Regulations:

Technical Support Document
For The Development Of
Radionuclide Cleanup Levels
For Soil

Review Draft

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Cleanup Levels For Soil

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NOTICE

The information provided in this draft document is intended for internal review and comment by the U.S. Environmental Protection Agency (EPA) only; it does not represent final EPA policy, action, or guidance. The data, analyses, and conclusions presented in this report are preliminary findings which are subject to revision without notice during the EPA review process. Do not quote from, or reproduce parts of, this report.

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This Draft *Technical Support Document for the Development of Radionuclide Cleanup Levels for Soil* contains the methodology and products of an effort that has involved the input of dozens of individuals.

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Introduction

The U.S. Environmental Protection Agency (EPA) is proposing regulations that set standards for radiation doses received by members of the public as a result of radionuclide contamination on sites under the control of a Federal Agency, and on sites licensed by the Nuclear Regulatory Commission (NRC) or an NRC Agreement State, that are to be released from those licenses or control. The proposed rule will ensure that such sites are cleaned up to a level that is protective of human health and the environment before they are released for public use. This document describes parts of the technical analysis being undertaken in support of those regulations.

EPA is separately developing regulations that will address the disposal of radioactive waste generated during site remediation, and will explore the feasibility of additional regulations that deal with the recycle or reuse of equipment and materials after cleanup.

Background

The total number of sites contaminated with radionuclides in the United States is in the thousands. Contaminated sites range in size from corners of laboratories to sprawling nuclear weapons facilities covering many square miles of land. The contamination extends to all environmental media, as well as to onsite buildings and equipment.

EPA's proposed regulations will set forth clear standards for the remediation of sites contaminated with radionuclides and for the release of those sites for use by members of the public. The regulations will utilize the authority granted to the EPA under the Atomic Energy Act (AEA), and will apply to sites and facilities under the control of the Federal Government or licensed by the NRC or any of its Agreement States.

EPA's *Issues Paper on Radiation Site Cleanup Regulations* (EPA 93a) presents an overview of the major policy issues, options, and preliminary analyses relevant to the development of the proposed rule. Specifically, the *Issues Paper* describes the scope of the cleanup problem, summarizes the statutory authorities available to EPA for developing the regulations, and discusses the advantages and disadvantages of various regulatory approaches.

Technical Analysis Supporting the Rule

The cleanup regulations will benefit society by reducing the number of potential adverse health effects among the people living or working on or near a site following the cleanup of its radioactive contamination. The magnitude of that benefit will depend on the cleanup level selected. At the same time, implementation of the regulations will impose costs on the nation. These costs, too, will depend on the cleanup level selected, and will include not only the economic costs of remediation, but also the public health and ecological impacts of the remediation effort itself.

In support of this rulemaking, EPA is conducting a comprehensive technical analysis aimed at developing the information that will be used to assess these benefits and costs. The analysis in the present report will determine how the health impacts and volumes of soil to be remediated vary as functions of the possible cleanup level. (The cleanup standard will specify one specific dose or risk value, and this is termed "the cleanup level" in this report.) As such, this technical analytical process will require answers to the following critical questions:

- At typical or representative sites, what are the radiation doses and risks to an individual resulting from exposure, via all environmental pathways, to unit concentrations of radionuclides in site soil—*i.e.*, what is the risk or dose per picocurie/gram (pCi/g) for each radionuclide present?
- Conversely, what radionuclide soil concentrations, in units of pCi/g, would have to be achieved in order to meet various possible individual dose or risk cleanup levels?
- At typical or representative sites, how much soil contains radioactivity in excess of any given radionuclide soil concentration (RSC)? That is, what volumes of soil would require remediation (*e.g.*, excavation and/or processing) to ensure that RSCs on-site after cleanup meets various possible cleanup levels?
- How many potential radiogenic cancers, and cancer deaths, would be averted by remediating the soil to RSCs corresponding to various individual risk levels? (These are population rather than individual effects.)

- How many radiogenic health effects might eventually occur among remediation workers and the general public because of the remediation process itself? (Non-radiogenic health effects are considered elsewhere, not in the present report.)

Reference Sites Clearly it is not possible, in this rulemaking process, to answer these questions accurately for each of the thousands of sites in the U.S. known to be contaminated, nor is it necessary to do so.

EPA is performing, rather, a detailed analysis of the remediation of a small set of relatively simple but quasi-realistic "reference" sites that are intended to represent the range of conditions found among real contaminated sites. Each reference site was created partially, but *not completely*, out of information available on one or more real sites. Thus *theset of* reference sites, *taken as a whole*, is intended to cover the universe of actual sites, and the potential current- and future-exposure scenarios, in such a manner that the assessment of remediation costs and benefits for the reference sites is supportive of the cleanup rulemaking. In creating the reference sites, EPA has had to rely extensively on available data on real sites that it, and other Federal agencies, have collected. There is much uncertainty about the nature and extent of contamination at many real contaminated sites, however, and on their hydrogeological and meteorological characteristics, which influence the mobility and dispersion of radionuclides. Since some of the site characterization information required for the present analysis simply does not exist for the real sites, it has been necessary to generate it by extrapolation of available data and by other indirect means described in Chapter 4.

In the creation of reference sites, moreover, certain attributes of the real sites upon which they are partially based have intentionally been simplified. In the analysis of Reference Site I, for example, which is intended to resemble the Hanford Reservation, to some extent, no account was taken of the tank farms and their immediate vicinities. It is assumed, based on reports of the Department of Energy (DOE), that so widely and highly contaminated areas are not likely to be cleaned up and released for public use in the foreseeable future; while of great significance to EPA's radioactive waste disposal rule, also currently under development, the tank farms are felt to lie outside the scope of the site cleanup regulation. For the purposes of the present analysis, it is therefore simply proposed that the major waste disposal areas will be stabilized and/or remediated in an adequately protective manner.

Finally, this analysis greatly simplifies the determination of future land use scenarios and population densities. In particular, simple, reasonable, conservative assumptions on the future utilization of the sites following cleanup have been made.

It must therefore be emphasized that the parameters defining a reference site do not fully coincide with those that would characterize the real site(s) upon which it is based. It would be misleading to assert that any reference site provides an accurate and complete description of the corresponding real site(s). In particular, predicted health impacts and volumes of soil to be remediated refer only to the reference site itself, and must not be used in an attempt to predict future impacts at the vastly more complex real site upon which it is based.

Modeling Individual Risk Estimates of doses and risks to individuals and populations depend on the pathway modeling tools and assumptions used in their calculation, including possible exposure scenarios. Based on consideration of current land use and demographics near some of the sites subject to this rule, two specific scenarios have been considered in the assessment of individual risks at the reference sites: For the *Rural Residential* scenario, people living on-site consume some vegetables, milk, meat, and fish produced there. For the *Commercial/Industrial* scenario, workers spend 2000 hours per year on-site and eat nothing produced there.

EPA has evaluated the suitability of more than two dozen multimedia pathway models and computer codes for analysis of the reference sites. Guided by this evaluation, EPA has employed primarily one of these models—RESRAD 5.19—to estimate individual risk factors. (A "risk factor" is the lifetime risk to individuals resulting from exposure to a unit concentration of a radionuclide in soil (i.e., lifetime risk per pCi/g). Once a risk factor for a radionuclide is determined for a site, the radionuclide soil concentration corresponding to a given risk-based cleanup level can be derived by dividing the cleanup level by the risk factor—i.e., $\text{pCi/g} = (\text{risk})/(\text{risk per pCi/g})$. Because risk factors depend on site-specific parameters, such as the depth of the aquifer and the distribution coefficients (K_d), risk factors must be calculated separately for each reference site.)

To assist in assessing the reliability of such estimates, EPA has compared the results from RESRAD with those from two other models, an updated version of RAGS/HHEM Part B [*Risk Assessment Guidance for Superfund - Human Health Evaluation Manual (Part B)*] (EPA 91a) and PRESTO-CPG, in the calculation of risks to individuals at a simple "generic"

test site; has carried out sensitivity analyses on the generic test site with RESRAD to determine how the results change when the values of certain critical parameters are varied; and has performed a preliminary probabilistic Monte Carlo analysis on the generic test site using updated RAGS/HHEM equations to estimate the degree of uncertainty in the results. In addition, the Agency has performed an extensive qualitative uncertainty analysis on the parameter values used in the modeling of the reference sites, as will be discussed in Chapter 6.

Estimating Numbers of Health Effects in Populations EPA has quantified the radiogenic health impacts in populations that result from achieving alternative individual risk levels—*i.e.*, the numbers of cancers and cancer fatalities averted. The Agency has developed a simple, high-end population health effects model, built on equations similar to those of the updated RAGS/HHEM Part B model, for application to the reference sites.

Several land-use scenarios are assumed for the modeling of health effects in populations at the reference sites, and these fall into two general classes: Between 10 and 300 people per square kilometer inhabit an *Agricultural* site, and all the food they grow is consumed locally (that is, on-site and by near-by communities). The population density ranges from 10/km² to more than 1,000/km² at a *Suburban* site, and no food is produced locally. The calculations track population doses and adverse health effects averted over periods of 100, 1000, and 10,000 years.

Estimating Volumes Of Soil To Be Remediated An important determinant of the costs of cleaning up a site to various possible risk levels is the volumes of soil to be remediated in the process. The present analysis estimates such cleanup volumes for each reference site by combining two kinds of information: risk factors (risk per pCi/g) obtained from site-specific modeling, and pre-cleanup soil volume vs. contaminant concentration relationships derived from published reports on the corresponding real site(s).

A challenging aspect of this analysis has been the extraction of soil volume vs. contaminant concentration information from the available site documents, especially when multiple radionuclides are present. Methods developed for this purpose are described in detail in Chapter 4.

Implementation Once a cleanup level has been established, it is necessary to translate it into quantities that can guide the remediation of real sites. Generic tables of limiting soil concentrations and computer codes for site-specific modeling are two forms that such guidance might take, and these will be available at the time that the final rule is published.

At any site undergoing remediation, compliance with the cleanup level must be demonstrated, in a scientifically rigorous and legally defensible manner, with appropriate radiation detection instruments and techniques. Various kinds of field and laboratory equipment differ in inherent sensitivity and specificity, and these differences are affected by the presence of background radioactivity from naturally occurring and manmade radionuclides. The technical analysis will evaluate issues related to radiation detection capability, to the relationship between measurement and background radioactivity, and to the feasibility of detecting site contamination over background.

As implementation guidance, EPA will provide site owners/operators with procedure manuals for conducting field surveys and for collecting samples for laboratory analysis. EPA is cooperating with the U.S. Department of Energy (DOE), the U.S. Department of Defense (DOD), and the NRC in the development of a MultiAgency Radiological Site Inspection Manual (MARSIM) that describes standard field and sampling procedures. EPA will also provide guidance on standard operating procedures and quality-assurance guidelines for radiochemical analyses.

Scope of EPA's Cleanup Standards Regulatory Development Technical Analysis, And Overview of This Report

EPA is conducting its technical analysis in five separate but related areas to support the development of cleanup standards for sites contaminated with radioactivity. These areas address:

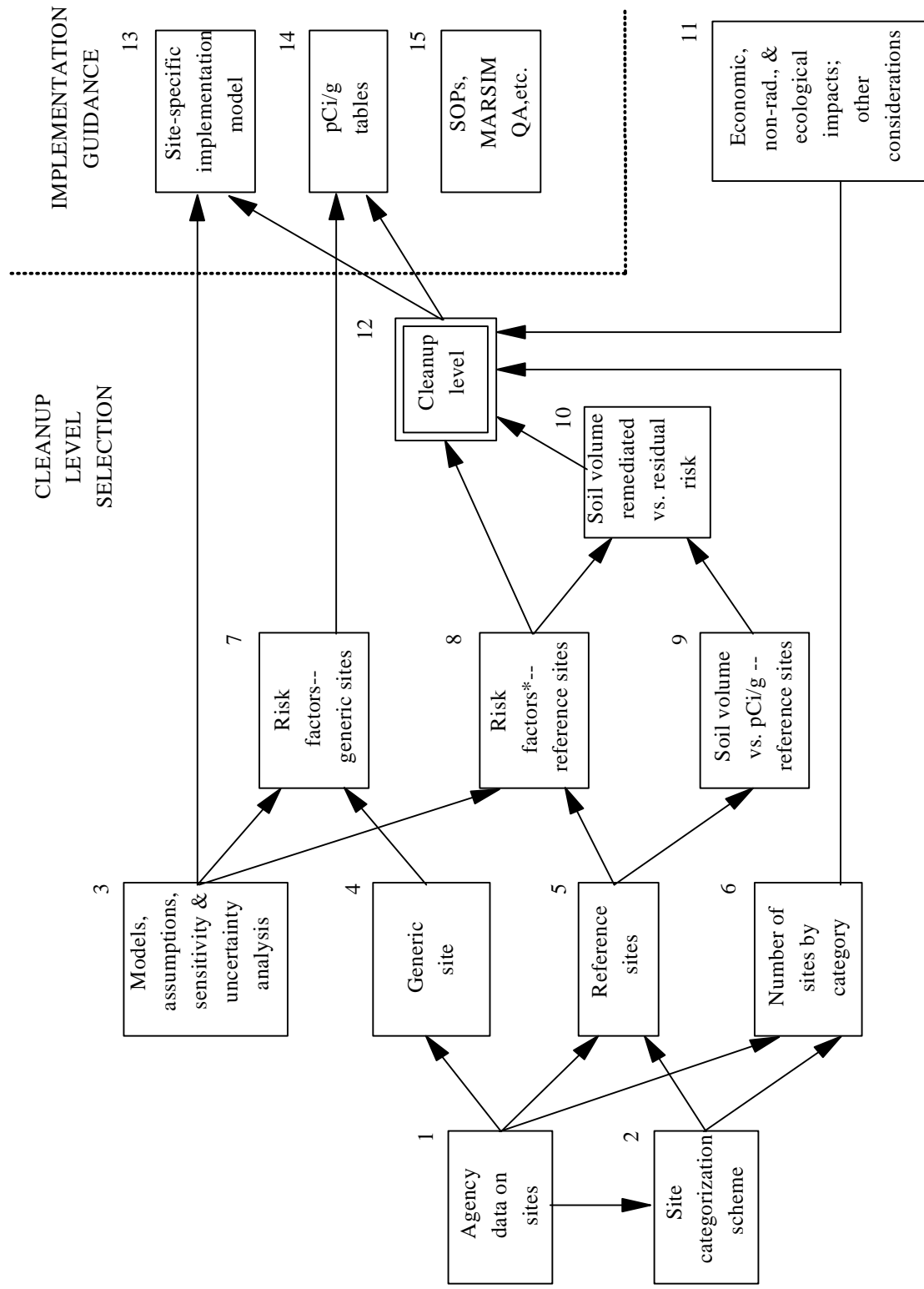
- (1) Soils;
- (2) Aquifers; and
- (3) Structures.

The current report is limited in scope to analyses supporting the development of soil cleanup standards (*i.e.*, item (1) above). It is important to clarify that this report is concerned with

residual levels of radioactivity in the soil following cleanup. The report deals with the radioactivity in waste storage areas and burial grounds only to the extent that they have contaminated the surrounding soils. That is, it is limited to the analysis of areas, away from permanent waste disposal areas, where the soil has been contaminated as a result of spills, local fallout, overflow contamination, runoff from nearby sources of radioactive waste and/or windblown depositions.

The five questions posed early in this Introduction suggest the types of information needed to assess the potential doses and risks to individuals, numbers of health effects, and costs as a function of various alternative cleanup levels. The technical analysis being undertaken to answer those five questions is summarized below, and the headings correspond to the chapters of this technical report. Figure I is a flow diagram indicating the steps in the process, and the "Item" numbers in the text below correspond to the Figure I block numbers. Items noted with an asterisk (*) are not within the scope of this report, but will be addressed in the Background Information Document (BID) or Regulatory Impact Analysis (RIA) supporting the rulemaking.

Figure I. Flow of Work



1. Magnitude of the Cleanup Problem—What's out there⁹
 - Determine nature and extent of the site contamination problem.
 - Compile and review existing data characterizing real contaminated sites. (Item 1)
 - Establish a scheme for partitioning the universe of real contaminated sites into broad functional categories. (Item 2)
 - Estimate the number of real sites in each category. (Item 6)
 - Estimate the total volume of soil that may fall within the scope of this rule.

2. Environmental Pathway Models—selecting the risk assessment tools (Item 3)
 - Characterize the exposure pathways; Tabulate default parameters, distributions, and assumptions for: Rural Residential and Commercial/Industrial land-use scenarios
 - Develop pathway model selection criteria.
 - Test and compare available models; select multi-media pathway model(s) to estimate doses and risks to individuals at the reference sites.
 - Develop a simple, high end population model for application to the reference sites.

¹ Items noted with an asterisk (*) are not within the scope of this report, but will be addressed in the Background Information Document (BID) or Regulatory Impact Analysis (RIA) supporting the rule-making.

Chapter

Description

3. Assessment of Modeling Parameters and Capabilities—Developing and testing the risk assessment tools (Item 4)

- Construct a generic test site for testing the pathway model(s) for individual and population doses and risks. The site is "generic" in the sense that it employs base-case parameters selected to provide reasonable (but conservative) estimates.
- With RESRAD, generate tables of risk factors for the generic test site. (Item 7)
- Compare the analysis of the generic test site using RESRAD with analyses by using other models, RAGS/HHEM and PRESTO-CPG. Assess the sensitive pathways and parameters, and compare the degree of conservatism of the three.
- Perform a sensitivity analysis of RESRAD using the generic test site. Parameters to be varied are radionuclide, site dimensions, thickness of layer of contamination, depth of aquifer, infiltration rate, and distribution coefficient (K_d).
- Perform a preliminary Monte Carlo uncertainty analysis using the updated RAGS/HHEM Part B model.
- The generic test site may be employed later in generating soil concentration limit tables for use in implementation of the rule.

4. Creation of Reference Sites—Preparation for analysis of health effects and volumes of soil undergoing remediation

- Drawing from the data characterizing the source, environmental, and demographic characteristics of actual sites (Item 1), and the site categorization scheme (Item 2), develop a limited number of reference sites that, as a set, together represent the universe of real sites in all categories (Item 5). Descriptions of the reference sites include
 - typical radiological source terms, hydrogeology, etc.
 - volumes of soil at different levels of contamination
- Estimate the number of sites in each category—*i.e.*, the number of sites to be represented by each reference site. (Item 6)
- Develop a site-weighting system, so that results from the analysis of the set of reference sites can be extrapolated to the universe of all real contaminated sites.

Chapter

Description

5. Analysis of Reference Sites—Analysis of health effects and support for analysis of volumes of soil undergoing remediation
 - Develop risk factors for each of the reference sites. (Item 8)
 - From site specific information, develop soil volume vs. contamination concentration curves for each reference site (indicating the volumes of soil contaminated to various degrees of radioactivity, in pCi/g, at the site); extrapolate to lower soil concentrations, if necessary. (Item 9)
 - For each reference site determine, as a function of individual risk (or dose) level, the volume of soil requiring remediation (Item 10).
 - For each reference site determine, as a function of individual risk (or dose) level, the number of potential radiogenic cancers averted among the general public, and the number of potential radiogenic cancers that would be induced among remediation workers. (Non-radiogenic health effects among remediation workers and others are considered elsewhere, not in this Report).
 - Making use of the above information, and of other input (Item 11)*, a cleanup level (risk or dose level) will be selected. (Item 12)*
6. Uncertainty Analysis—How reliable are the results of the analysis of the reference sites?
7. Implementation—Selecting final soil concentrations and demonstrating compliance
 - Translate cleanup level (dose or risk) into something measurable in the field or laboratory (Items 13, 14)
 - Provide means of demonstrating that field and laboratory measurements are appropriately and being performed properly (e.g., MARSIM) (Item 15).