U.S. EPA Superfund Remedial Program's Approach for Risk Harmonization when addressing Chemical and Radioactive Contamination at Sites

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Presented to a CLUIN webinar
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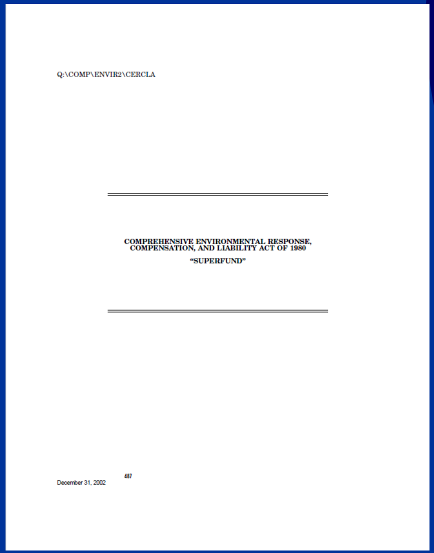
DISCLAIMER

- The views of the author of this presentation are those of the author and do not represent Agency policy or endorsement
- Mention of trade names of commercial products should not be interpreted as an endorsement by the U.S. Environmental Protection Agency

EPA Addresses Site Cleanup Under Several Laws, Programs

- ◆This talk discusses only the Comprehensive Environmental Response, Compensation & Liability Act, CERCLA or “Superfund”
- ◆National Contingency Plan (NCP) is regulation for CERCLA
- ◆National Priorities List (NPL) guides EPA’s remedial program on which sites need further attention



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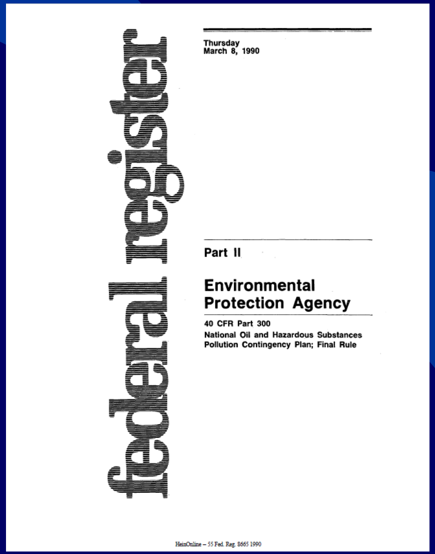
COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT OF 1980

“SUPERFUND”

December 31, 2002

487



federal register

Thursday
March 8, 1990

Part II

Environmental Protection Agency

40 CFR Part 300

National Oil and Hazardous Substances Pollution Contingency Plan; Final Rule

HeinOnline – 55 Fed. Reg. 8665 1990

Purpose

- Provide brief description of CERCLA remedial program process
- Provide overview and comparison of key EPA CERCLA remedial program guidance and tools that specifically address radionuclides and their chemical precursor document
  - Radionuclides are also addressed with other hazardous substances under general EPA CERCLA guidelines
  - EPA's approach has received high-level review
  - EPA began this approach in guidance from the 1980's/1990's

How to Address Radiation in a Chemical Program?

- With only approximately 66 radioactively contaminated NPL sites out of 1,797 total, the focus of the Superfund remedial program has been on chemicals
- **Question:** How to best address radiation?
- **Answer:** Address radiation in a consistent manner with chemicals, except to account for the technical differences posed by radiation
  - » Radiation easily fits within Superfund framework
  - » Improves public confidence by taking mystery out of radiation
  - » Radioactively contaminated NPL sites also have chemical contamination

Why Does Radiation Easily Fit within the Superfund Remedial Program's Framework?

- Primary effect is cancer
- People ingest, inhale, eat, same amount of contaminated dust and food whether it is chemical or radioactive contamination
- Dust gets resuspended the same whether it is chemically or radioactively contaminated
- Inorganic elements move through the subsurface whether they are radioactive or not

Part 1. Technical Guidance & Tools for the Superfund Remedial Program

Regional Screening Levels (RSLs)

To download the most recent Regional Screening Level tables, please go to the Generic Tables page. For assistance/questions please use the RSL Contact Us page.

Regional Screening Levels (RSLs)

- Home Page
- User's Guide
- What's New
- Frequent Questions
- Equations
- RSL Calculator
- Generic Tables
- Contact Us

Welcome

Welcome to the "Regional Screening Levels for Chemical Contaminants at Superfund Sites" screening level/preliminary remediation goal website. This website was developed with DOE's Oak Ridge National Laboratory (ORNL) under an Interagency Agreement as a merger of the EPA Region 3 RBC Table, Region 6 HHMSSL Table and the Region 9 PRG Table. The RSL website is now the source of screening levels for all the EPA regions. The RSL tables provide comparison values for residential and commercial/industrial exposures to soil, air, and tapwater (drinking water). The unified use of the RSLs, to screen chemicals at Superfund sites, promotes national consistency. Here you will find tables of risk-based screening levels, calculated using the latest toxicity values, default exposure assumptions and physical and chemical properties, and a calculator where default parameters can be changed to reflect site-specific risks. To ensure proper use of the screening level tables and the calculator, please review the What's New, User's Guide, Frequent Questions, and Download Area links. Below is a general description of screening levels for chemical contaminants. If the calculator is used with non-default inputs in a decision on a Superfund site, it is recommended that the inputs be clearly identified and justified by the user.

Introduction

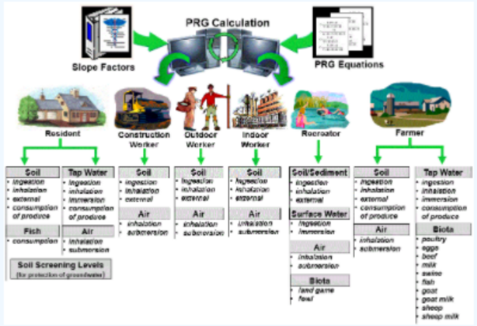
Superfund sites are addressed under the authority of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980, which was amended by the 1986 Superfund Amendments and Reauthorization Act. The purpose of this website is to provide a

Screening Level Calculation Chart

PRG Home

PRGs for Radionuclides

- Home Page
- User's Guide
- What's New
- Frequent Questions
- Equations
- PRG Calculator
- Radionuclide Decay Chain
- Generic Tables



Welcome

Welcome to the EPA's "Preliminary Remediation Goals for Radionuclide Contaminants at Superfund Sites" (PRG) Download and Calculator website. The recommended PRGs on this website are preliminary remediation goals (PRGs) for contaminated soil, water, and air. PRGs are addressed in the NCP and EPA CERCLA guidance. Typically PRGs are risk-based, conservative screening values to identify areas and contaminants of potential concern (COPCs) that may warrant further investigation.

This tool presents risk-based preliminary remediation goals (PRGs) calculated using default input parameters and the latest toxicity values. In addition, you are able to modify the input parameters to create site-specific PRGs to meet the needs of your site. To ensure proper application of the PRGs, please see further guidance on how to use the PRGs presented on this site located in the "PRG User's Guide", "PRG What's New", "PRG FAQ", and "PRG Download Area" links. The EPA has prepared a fact sheet for the general public that describes PRG uses, PRG calculator operation and land uses available for assessment. Additionally, this fact sheet describes the PRG and Dose Compliance Concentrations (DCC) calculators in greater detail for EPA staff. The Office of Solid Waste and Emergency Response (OSWER) Directive, Superfund Radiation Risk Assessment: A Community Toolkit was also developed by the EPA to help the public understand more about the risk assessment process used at Superfund sites with radioactive contamination.

The PRG calculator results were previously verified. The documentation from these may be seen on the Internal Verification and External Verification pages. The PRG calculator was previously peer reviewed and the documentation of those peer reviews may be seen here. The PRG calculator was previously part of several model comparison, and the documentation of one of those reviews may be seen in NCRP Report No. 146: Approaches to Risk Management in Remediation of Radioactively Contaminated Sites. This report examines EPA Superfund and NRC Decommissioning programs approach to radiation site cleanup. Section 3.3.3 is a "Comparison of EPA Preliminary Remediation Goals with NRC Screening Levels." It is part of a larger Section 3.3 "Methods of Site Characterization and Dose or Risk Assessment." Several other comparison reviews that focused on describing the default parameters in various models may be found here.

Introduction

A purpose of this guidance is to provide a PRG calculation tool to assist risk assessors, remedial project managers, and others involved with risk assessment and decision-making at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites (commonly known as Superfund) in developing PRGs.

Nine CERCLA Remedy Selection Criteria – Two Threshold

- Two threshold criteria (both must be met)
  1. Protect human health and the environment
  2. Comply (attain or waive) with other federal and state laws: Applicable or Relevant and Appropriate Requirements (ARARs)
     — Protect current or future sources of drinking water (e.g., attain MCLs or more stringent state standards)

CERCLA Cleanup Levels

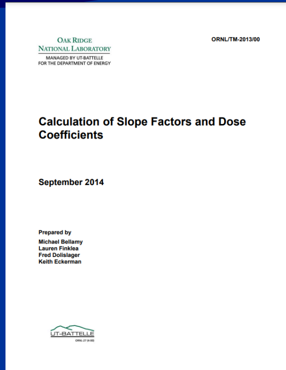
- ARARs often determine cleanup levels
- Where ARARs are not available or protective, EPA sets site-specific cleanup levels that
  - » For carcinogens, represent an increased cancer risk of 1×10^{-6} to 1×10^{-4}
    - —10^{-6} used as "point of departure"
    - —PRGs are established at 1×10^{-6}
  - » For non-carcinogens, will not result in adverse effects to human health (hazard index (HI) <1 is protective)
- Address ecological concerns
- To-be-considered (TBC) material may help determine cleanup level

CERCLA Cleanup Levels Are **NOT** Based On

- NRC decommissioning requirements (e.g., 25, 100 mrem/yr mrem/yr [0.25, 1 mSv/yr] dose limits) 10 CFR 20 Subpart E
  - » If used as an ARAR, 10^{-6} still used as point of departure, and 10^{-4} to 10^{-6} risk range must be met
- Guidance outside risk range and/or if expressed as a dose (# mrem/year). This includes:
  - » DOE orders, NRC guidance (e.g., NUREGs), ICRP guidance, IAEA guidance, NCRP guidance, ANSI/HPS guidance, EPA/DHS PAGs, and Federal guidance

Risk-based Cleanup Levels for Radioactive Contamination

- Superfund uses radiation cleanup levels expressed as risk levels, **not** mrem [mSv], derived from using “slope factors”/ risk coefficients instead of dose conversion tables to estimate cancer risk from radioactive contaminants. These slope factors represent the:
  - » probability of cancer incidence as a result of a unit exposure to a given radionuclide averaged over a lifetime using LNT.
  - » age-averaged lifetime excess cancer incident rate per unit intake (or unit exposure for external exposure pathway) of a radionuclide
- The slope factors used by Superfund are updated values from FGR 13 supplement using ICRP 107 decay data. The derivation is outlined in a 2014 ORNL Technical Manual.


OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

ORNL/TM-2013/00

Calculation of Slope Factors and Dose Coefficients

September 2014

Prepared by
Michael Bellamy
Lauren Finklea
Fred Dolislager
Keith Eckerman

UT-BATTELLE
ORNL-27 (4-00)

EPA

Site consistency

- To help facilitate compliance with NCP and cleanup sites, EPA Headquarters provides:
  - » Guidance documents
  - » Models (calculators)
  - » Training (developed with State led ITRC)
  - » 16 Annual Meetings with EPA Regions
- Guidance, models, training are available for free on the internet
  - » Also provided 47 all day classes on Superfund Radiation Risk Assessment

Guidance: CERCLA Cleanup

- *Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination* (8/22/97) OSWER Directive 9200.4-18
- Radioactive contaminants at CERCLA sites are governed by the NCP like all other contaminants
  - » Cleanups based on ARARs or risk range
  - » Groundwater restored to beneficial reuse
  - » Use reasonably anticipated land use

Guidance: Risk Assessment Q&A
Old Superseded

- *Radiation Risk Assessment at CERCLA Sites: Q&A* (12/99) OSWER Directive 9200.4-31P
- Provides overview of **then** current EPA guidance for radiation risk assessment
- Written for users familiar with Superfund but not radiation
- Adds some new guidance
  - » Dose assessment only for ARAR compliance
  - » No dose-based TBCs (including ***No*** 15 mrem/yr [0.15 mSv/yr])
  - » Direct exposure rate may supplement sampling

Revised 2014 Risk Assessment Q&A issued June 2014

- *Radiation Risk Assessment at CERCLA Sites: Q&A* (5/2014) OSWER Directive 9200.4-40
- Provides overview of **current** EPA guidance for radiation risk assessment
- Written for users familiar with Superfund but not radiation

Summary of Key Policy Points of Revised 2014 Risk Assessment Q&A

1. Still do not use dose-based (expressed as # millirem per year (mrem/yr) guidance as TBCs
   » Including NRC, DOE, or international guidance
2. Dose-based ARARs not protective if greater than 12 mrem/yr [0.12 mSv/yr], instead of 15 mrem/yr [0.15 mSv/yr]
3. Use EPA Superfund risk assessment models (PRG and DCC calculators)
4. Don't use Area Averaging (MARSSIMM) survey method for rad when using Not To Exceed for chemicals

Update Policies Based on Newer Science

- For an effective dose standard ARAR to be considered protective, it should be 12 mrem/yr [0.12 mSv/yr] or less.
  - » Change from 15 mrem/yr [0.15 mSv/yr] based on risk to dose estimate in Federal Guidance 13
  - » Cleanup levels not based on an ARAR continue to be based on cancer risk range (10^{-4} to 10^{-6}) **not** dose

More consistency on Risk Assessments (Rad & Chem)

- Explain what type of circumstances these Superfund guidance and tools are recommended
- Reiterate more strongly that risk assessments (e.g., models used) should be consistent with chemicals at site and with other regional sites
- Don’t use a steady state model for chemical and a transfer/dynamic model for radionuclides
  - Such as using RSL calculator for chemicals then RESRAD for radionuclides

More consistency on Surveys (Rad & Chem)

- Explain what type of circumstances these Superfund guidance and tools are recommended
- Reiterate more strongly that site surveys (e.g., characterization and confirmation) should be consistent with chemicals at a site and with other regional sites
- Don't use not-to-exceed (NTE) for chemicals and area averaging (AA) for radionuclides for residential
  - NTE for residential cleanup of chemicals but AA approach like MARSIMM for the radionuclides

Guidance: chemical SSG

- Soil Screening Guidance [SSG] documents (7 & 5/96) OSWER Directives 9355.4-23 and 9355.4-17A
  - » User Guide
  - » Technical Background Document
- Guidance to screen out areas, pathways, and/or chemicals early in the process
  - » 1 x 10^{-6} and MCLs (leaching from soil)
  - » Residential land use
  - » Survey procedures for site characterization
  - » Evaluates 9 soil to groundwater models

Guidance: Rad SSG

- Soil Screening Guidance for Radionuclides [rad SSG] documents (10/00) OSWER Directives 9355.4-16A and 9355.4-16
  - » User Guide
  - » Technical Background Document
- Guidance to screen out areas, pathways, and/or radionuclides early in the process
- Consistent with 1996 chemical SSG
  - » 1 x 10^{-6} and MCLs (leaching from soil)
  - » Residential land use
  - » Survey procedures for site characterization
  - » Evaluates 5 soil to groundwater models
  - » Accounts for technical differences of radiation

Guidance: Chemical RSL Calculator

- Calculator to establish Screening Levels/PRGs, when:
  - » ARAR is either not available or sufficiently protective
- Electronic equations (risk and leaching to groundwater) also are on Internet
  - » $1x10^{-6}$ and MCLs (leaching from soil)
  - » Includes dermal exposure

Guidance: Chemical RSL Calculator (continued)

- Nine scenarios/land uses available

  1. Residential
  2. Recreator
  3. Construction
  4. Indoor workers
  5. Outdoor workers
  6. Fish ingestion
  7. Tap water
  8. Soil to groundwater
  9. Air

- Includes chemical toxicity of uranium

Guidance: Rad PRG Calculator

- Calculator to establish PRGs, when:
  - » ARAR is either not available or sufficiently protective (e.g., 25 mrem/yr [0.25 mSv/yr] or more)
- Electronic equations (risk and leaching to groundwater) also are on Internet
  - » $1x10^{-6}$ and MCLs (leaching from soil)
  - » Accounts for technical differences of radiation (e.g., gamma, plant uptake)

Guidance: Rad PRG Calculator (continued)

- Ten scenarios/land uses available

1. Residential
2. Recreator
3. Construction
4. Indoor workers
5. Outdoor workers
6. Fish ingestion
7. Tap water
8. Soil to groundwater
9. Air
10. Farmer

- Chemical RSL equations should be used for chemical toxicity of uranium
- EPA developed Internet-based training with States (ITRC) on calculator and radiation risk assessment
  - » http://www.clu-in.org/conf/itrc/rads_051507/

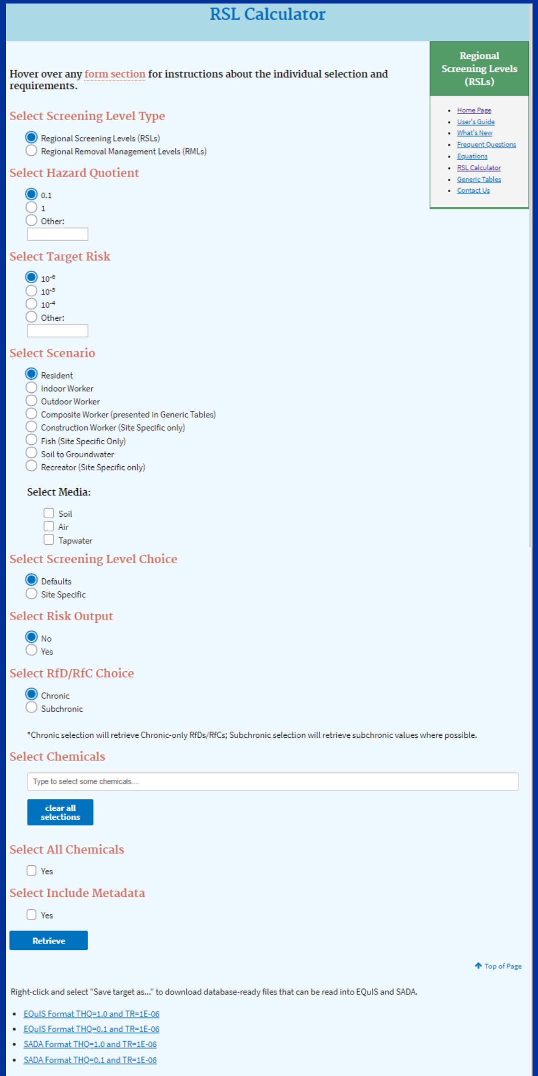
Guidance: ARAR Dose Calculator

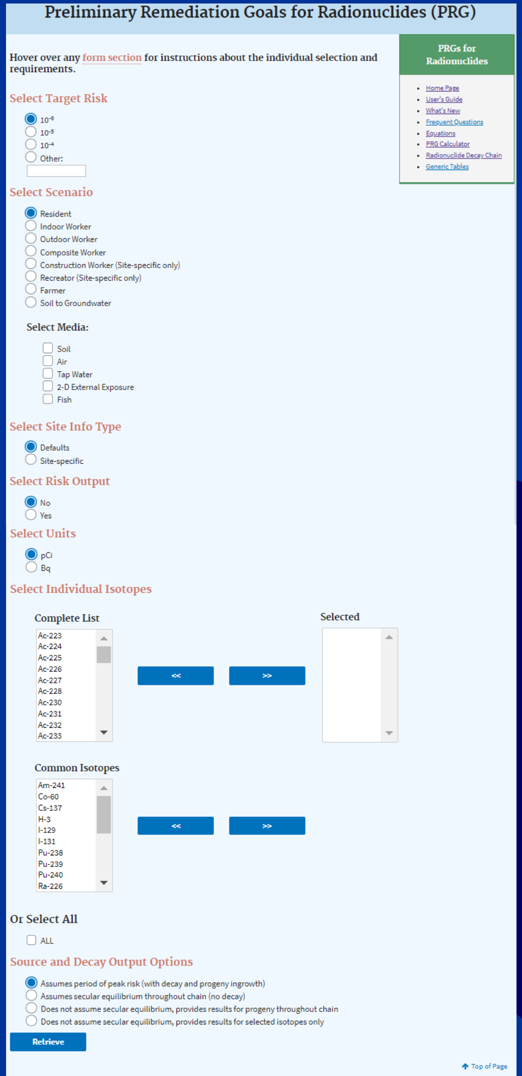
- Calculator to establish Dose Compliance Concentrations (DCC) for single dose limit ARARs requiring a dose assessment
- Ten scenarios/land uses available

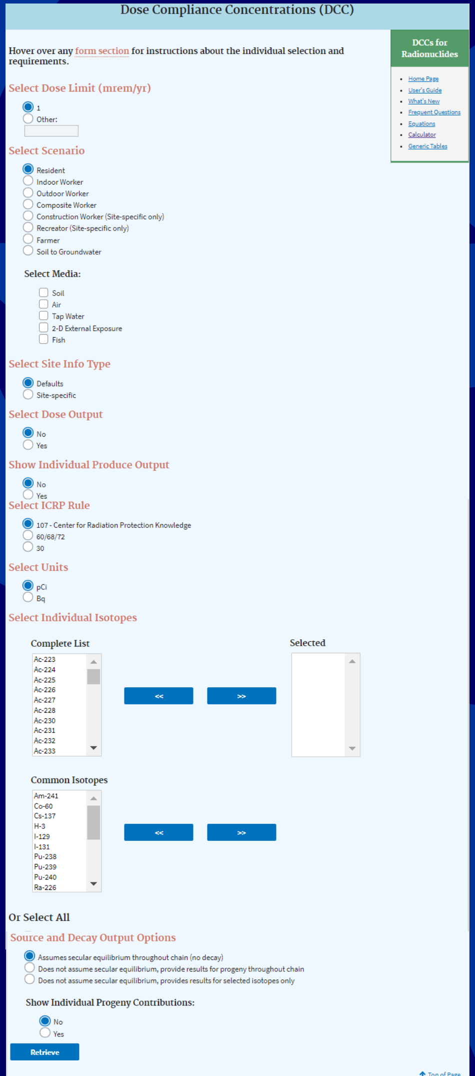
1. Residential
2. Recreator
3. Construction
4. Indoor workers
5. Outdoor workers
6. Fish ingestion
7. Tap water
8. Soil to groundwater
9. Air
10. Farmer

- Equations are similar to those used for PRG calculator, except dose conversion factors (ICRP 107, 72, 32) used instead of slope factors

RSL, PRG, DCC,
Similar Look and Feel







RSL, PRG, DCC, Consistent Exposure Assumptions

Exposure Assessment Details

Age Segment (yr)	AF (mg/cm²)	BW (kg)	ED (yr)	EF (day/yr)	ET (hr/day)	IRS (mg/day)	SA (cm²/day)
0-2	0.2	15	2	350	24	200	2373
2-6	0.2	15	4	350	24	200	2373
6-16	0.07	80	10	350	24	100	6032
16-26	0.07	80	10	350	24	100	6032
Child (0-6)	0.2	15	6	350	24	200	2373
Adult (6-26)	0.07	80	20	350	24	100	6032

Parameters Common to all Exposure Routes

26 ED_{res} (exposure duration - resident) yr
20 $ED_{res\text{-}a}$ (exposure duration - resident adult) yr
6 $ED_{res\text{-}c}$ (exposure duration - resident child) yr
350 EF_{res} (exposure frequency - resident) day/yr
350 $EF_{res\text{-}a}$ (exposure frequency - resident adult) day/yr
350 $EF_{res\text{-}c}$ (exposure frequency - resident child) day/yr
24 ET_{res} (exposure time - resident) hr/day
24 $ET_{res\text{-}a}$ (exposure time - resident adult) hr/day
24 $ET_{res\text{-}c}$ (exposure time - resident child) hr/day
26 t_{res} (time - resident) yr

Parameters Common to all Exposure Route Equations

0.77 $AAF_{res\text{-}a}$ (age adjustment factor - resident adult) unitless
0.23 AAF_{resc} (age adjustment factor - resident child) unitless
26 ED_{res} (exposure duration - resident) yr
20 $ED_{res\text{-}a}$ (exposure duration - resident adult) yr
6 $ED_{res\text{-}c}$ (exposure duration - resident child) yr
350 EF_{res} (exposure frequency - resident) day/yr
350 $EF_{res\text{-}a}$ (exposure frequency - resident adult) day/yr
350 $EF_{res\text{-}c}$ (exposure frequency - resident child) day/yr
24 ET_{res} (exposure time - resident) hr/day
24 $ET_{res\text{-}a}$ (exposure time - resident adult) hr/day
24 $ET_{res\text{-}c}$ (exposure time - resident child) hr/day
1 t_{res} (time - resident) yr

Particulate Emission Factor Wind Driven

PEF Equation

Default City (Climatic Zone) - Selection based on most likely climatic conditions for the site
0.5 A_s (acres)
4.69 U_m (mean annual wind speed) m/s
11.32 U_t (equivalent threshold value)
0.5 V (fraction of vegetative cover) unitless
16.2302 A (PEF Dispersion Constant)
18.7762 B (PEF Dispersion Constant)
216.108 C (PEF Dispersion Constant)
0.194 F(x) (function dependent on U_m/U_t) unitless
1359344438 PEF (particulate emission factor) m³/kg
93.77 Q/C_{wind} (inverse of the ratio of the geometric mean air concentration to the emission flux at the center of a square source) g/m²-s per kg/m³

Particulate Emission Factor Wind Driven

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RSL, PRG, DCC
Consistent treatment of inorganics

- Resuspension – same
- Soil to groundwater – same
- All 3 steady state models. Not depleting source (transfer/dynamic) models

Guidance: World Trade Center (WTC) Benchmark

- Document used to establish $1x10^{-4}$ risk based cleanup levels for the reuse of chemically contaminated buildings after the 9/11 attacks
- Equations and parameters were the latest EPA chemical risk assessment methodology
- Ingestion, inhalation, and dermal
  - » http://www.epa.gov/wtc/reports/contaminants_of_concern_benchmark_study.pdf

World Trade Center Indoor Environment Assessment: Selecting Contaminants of Potential Concern and Setting Health-Based Benchmarks

May 2003

Prepared by the Contaminants of Potential Concern (COPC) Committee of the World Trade Center Indoor Air Task Force Working Group

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Guidance: World Trade Center (WTC) Benchmark (continued)

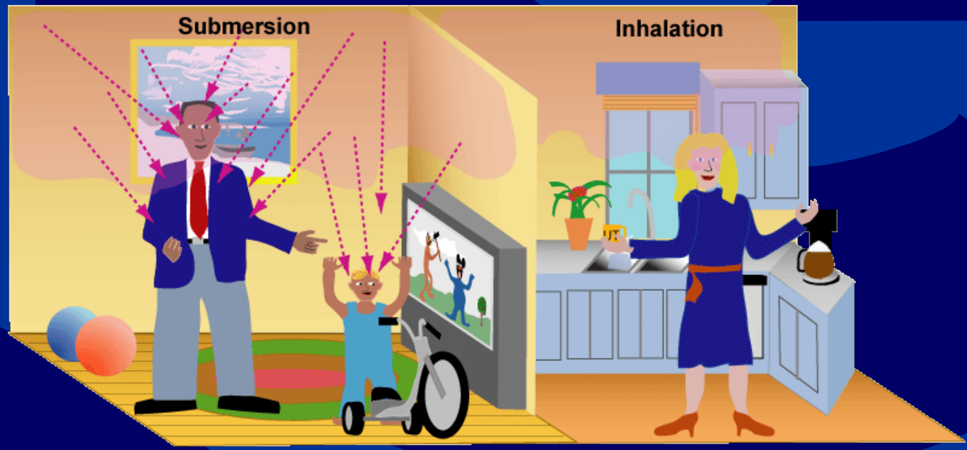
- WTC benchmark document includes 1 land use scenario
  - Residential
- This land use includes 2 exposure media
  - Settled dust
  - Ambient air

Guidance: Building PRG (BPRG) Calculator

- Calculator to establish $1x10^{-6}$ risk based PRGs for the reuse of radioactively contaminated buildings
- Equations and parameters are derived from latest EPA chemical methodology (e.g., assessment at WTC which used $1x10^{-4}$ cleanup level)
  - » Adjusted to account for technical differences posed by radiation
- EPA and ITRC Internet-based training on BPRG calculator and D&D
  - » http://www.clu-in.org/conf/itrc/radsdd_040308/

Guidance: Building PRG (BPRG) Calculator (continued)

- BPRG calculator includes 2 land use scenarios
  - » Residential
  - » Indoor worker
- Both land uses include 3 exposure media
  - » Settled dust
  - » Ambient air
  - » Direct external exposure
    - —5 Room sizes and 4 receptor locations
    - —5 Room materials, and 2 composite rooms
    - —5 Source thickness

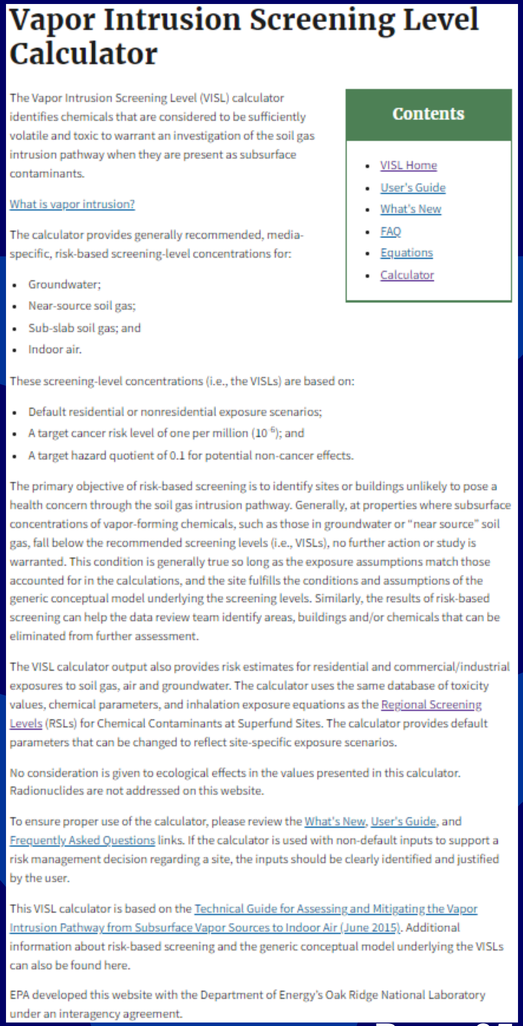


Building Dose Cleanup Concentrations (BDCC) ARAR Dose Calculator

- BDCC Purpose: to establish BCCs for Inside Buildings for single dose limit ARARs (# mrem/yr)
- BDCC includes 2 land use scenarios (Residential, Indoor Worker)
- 2 land uses include 3 exposure routes (Settled dust, Fixed Direct External 3-D, Ambient Air)
- Equations similar to those used for BPRG calculator, except dose conversion factors used instead of slope factors

Vapor Intrusion Screening Level (VISL) Calculator

- Calculator to assesses whether chemicals found in groundwater or soil gas can pose a significant risk through vapor intrusion; and,
  - » if so, whether a site-specific vapor intrusion investigation is warranted



Vapor Intrusion Screening Level Calculator

The Vapor Intrusion Screening Level (VISL) calculator identifies chemicals that are considered to be sufficiently volatile and toxic to warrant an investigation of the soil gas intrusion pathway when they are present as subsurface contaminants.

What is vapor intrusion?

The calculator provides generally recommended, media-specific, risk-based screening-level concentrations for:

- Groundwater;
- Near-source soil gas;
- Sub-slab soil gas; and
- Indoor air.

These screening-level concentrations (i.e., the VISLs) are based on:

- Default residential or nonresidential exposure scenarios;
- A target cancer risk level of one per million (10^{-6}); and
- A target hazard quotient of 0.1 for potential non-cancer effects.

The primary objective of risk-based screening is to identify sites or buildings unlikely to pose a health concern through the soil gas intrusion pathway. Generally, at properties where subsurface concentrations of vapor-forming chemicals, such as those in groundwater or "near source" soil gas, fall below the recommended screening levels (i.e., VISLs), no further action or study is warranted. This condition is generally true so long as the exposure assumptions match those accounted for in the calculations, and the site fulfills the conditions and assumptions of the generic conceptual model underlying the screening levels. Similarly, the results of risk-based screening can help the data review team identify areas, buildings and/or chemicals that can be eliminated from further assessment.

The VISL calculator output also provides risk estimates for residential and commercial/industrial exposures to soil gas, air and groundwater. The calculator uses the same database of toxicity values, chemical parameters, and inhalation exposure equations as the Regional Screening Levels (RSLs) for Chemical Contaminants at Superfund Sites. The calculator provides default parameters that can be changed to reflect site-specific exposure scenarios.

No consideration is given to ecological effects in the values presented in this calculator. Radionuclides are not addressed on this website.

To ensure proper use of the calculator, please review the What's New, User's Guide, and Frequently Asked Questions links. If the calculator is used with non-default inputs to support a risk management decision regarding a site, the inputs should be clearly identified and justified by the user.

This VISL calculator is based on the Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air (June 2015). Additional information about risk-based screening and the generic conceptual model underlying the VISLs can also be found here.

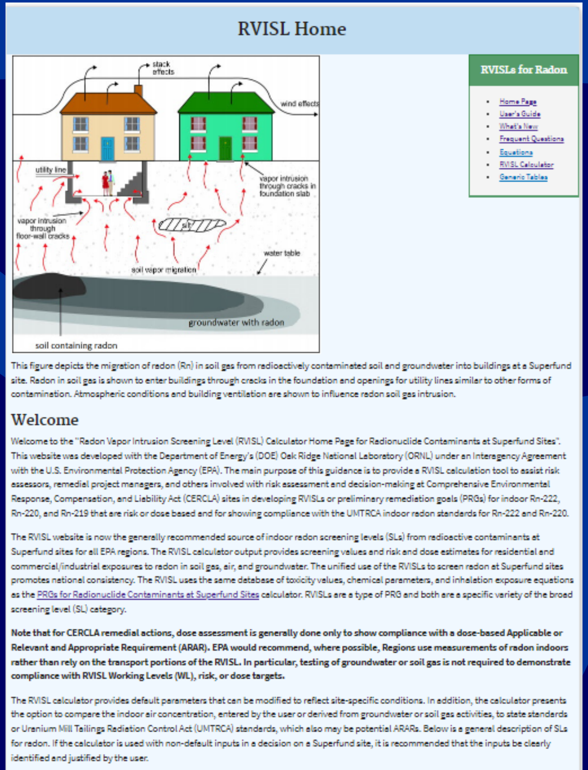
EPA developed this website with the Department of Energy's Oak Ridge National Laboratory under an interagency agreement.

Contents

- VISL Home
- User's Guide
- What's New
- FAQ
- Equations
- Calculator

Radon Vapor Intrusion Screening Level (RVISL) Calculator

- Internet calculator tool developed to provide concentrations of radon and thoron in soil and groundwater that will not result in radon intrusion into buildings that exceed target levels
- Indoor Rn-222, Rn-220, and Rn-219 target level concentrations based on:
  - Risk (default to 1 x 10-6)
  - UMTRCA (only Rn-222 and Rn-220) correspond to 0.02 Working Levels
  - Dose (default to 1 mrem/yr)



RVISL Home

RVISLs for Radon

- Home Page
- User's Guide
- What's New
- Frequent Questions
- Equations
- RVISL Calculator
- Generic Tables

This figure depicts the migration of radon (Rn) in soil gas from radioactively contaminated soil and groundwater into buildings at a Superfund site. Radon in soil gas is shown to enter buildings through cracks in the foundation and openings for utility lines similar to other forms of contamination. Atmospheric conditions and building ventilation are shown to influence radon soil gas intrusion.

Welcome

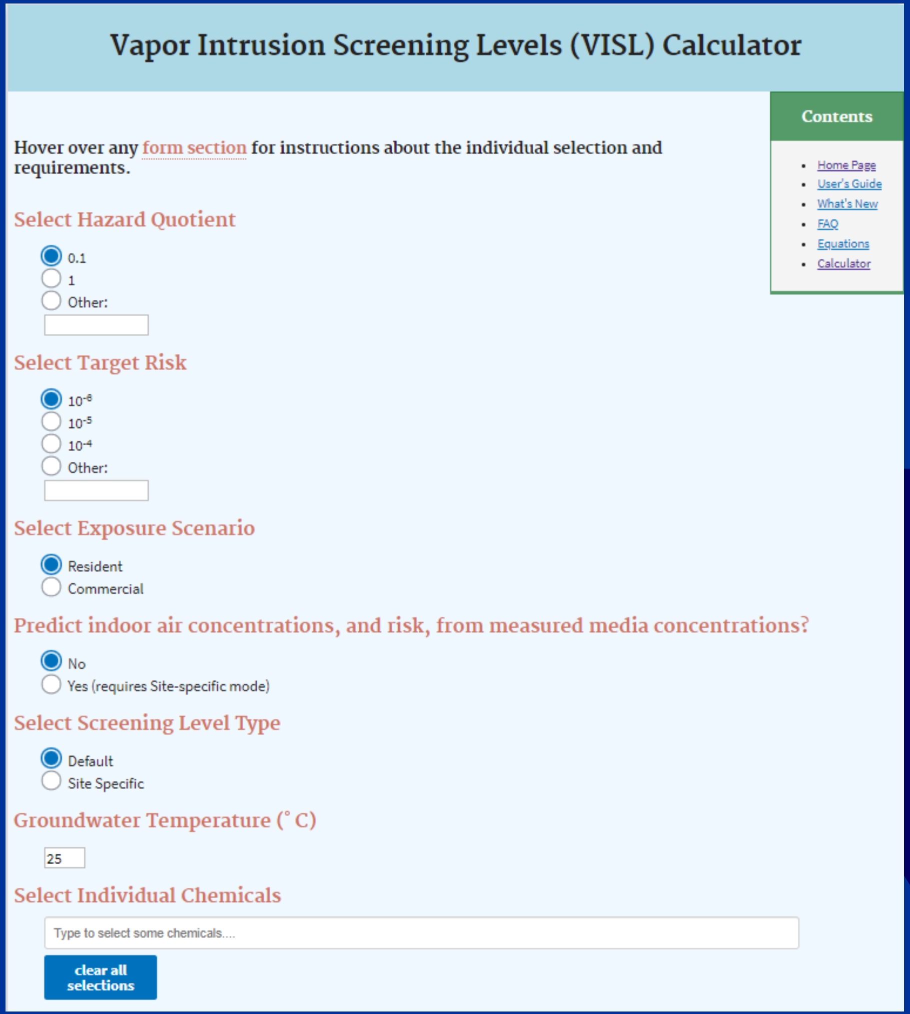
Welcome to the "Radon Vapor Intrusion Screening Level (RVISL) Calculator Home Page for Radionuclide Contaminants at Superfund Sites". This website was developed with the Department of Energy's (DOE) Oak Ridge National Laboratory (ORNL) under an Interagency Agreement with the U.S. Environmental Protection Agency (EPA). The main purpose of this guidance is to provide a RVISL calculation tool to assist risk assessors, remedial project managers, and others involved with risk assessment and decision-making at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites in developing RVISLs or preliminary remediation goals (PRGs) for indoor Rn-222, Rn-220, and Rn-219 that are risk or dose based and for showing compliance with the UMTRCA indoor radon standards for Rn-222 and Rn-220.

The RVISL website is now the generally recommended source of indoor radon screening levels (SLs) from radioactive contaminants at Superfund sites for all EPA regions. The RVISL calculator output provides screening values and risk and dose estimates for residential and commercial/industrial exposures to radon in soil gas, air, and groundwater. The unified use of the RVISLs to screen radon at Superfund sites promotes national consistency. The RVISL uses the same database of toxicity values, chemical parameters, and inhalation exposure equations as the PRGs for Radionuclide Contaminants at Superfund Sites calculator. RVISLs are a type of PRG and both are a specific variety of the broad screening level (SL) category.

Note that for CERCLA remedial actions, dose assessment is generally done only to show compliance with a dose-based Applicable or Relevant and Appropriate Requirement (ARAR). EPA would recommend, where possible, Regions use measurements of radon indoors rather than rely on the transport portions of the RVISL. In particular, testing of groundwater or soil gas is not required to demonstrate compliance with RVISL Working Levels (WL), risk, or dose targets.

The RVISL calculator provides default parameters that can be modified to reflect site-specific conditions. In addition, the calculator presents the option to compare the indoor air concentration, entered by the user or derived from groundwater or soil gas activities, to state standards or Uranium Mill Tailings Radiation Control Act (UMTRCA) standards, which also may be potential ARARs. Below is a general description of SLs for radon. If the calculator is used with non-default inputs in a decision on a Superfund site, it is recommended that the inputs be clearly identified and justified by the user.

VISL and RVISL
Similar look and feel



EPA

VISL and RVISL
Consistent parameters

Indoor Air Screening Level Equations and Parameters

Air Carcinogenic Inhalation

Air Carcinogenic-(Trichloroethylene) Inhalation

Air Carcinogenic-(Vinyl Chloride) Inhalation

Air Non-Carcinogenic Inhalation

26	ED_{res} (exposure duration) years	0.1	THQ (target hazard quotient) unitless
350	EF_{res} (exposure frequency) days/year	70	LT (lifetime) years
24	ET_{res} (exposure time) hours/day	1E-06	TR (target risk) unitless

Indoor Air Screening Level Equations and Parameters

Air Inhalation PRG

Air Submersion PRG

Air Total PRG

0.18	Select air exchanges per hour for F_{eq} and A_{eq}	24	ET_{res-a} (exposure time - resident adult) hr/day
26	ED_{res} (exposure duration - resident) yr	24	ET_{res-c} (exposure time - resident child) hr/day
20	ED_{res-a} (exposure duration - resident adult) yr	1.0	GSF_a (gamma shielding factor - air) unitless
6	ED_{res-c} (exposure duration - resident child) yr	161000	$IFA_{res-adj}$ (age-adjusted inhalation factor) m^3
350	EF_{res} (exposure frequency) day/yr	20	IRA_{res-a} (inhalation rate - resident adult) m^3/day
350	EF_{res-a} (exposure frequency - resident adult) day/yr	10	IRA_{res-c} (inhalation rate - resident child) m^3/day
350	EF_{res-c} (exposure frequency - resident child) day/yr	26	t_{res} (time - resident) yr
24	ET_{res} (exposure time - resident) hr/day	1E-06	TR (target cancer risk) unitless

Groundwater and Soil Gas Equation and Parameters

Correcting the Henry`s Law Constant for GW Temperature

Enthalpy Adjustment for GW Temperature

Groundwater Screening Level Equation

Soil Gas Screening Level Equation

Vapor Concentration at the Source

0.001	AF_{gw} (Attenuation Factor Groundwater) unitless	25	T_{gw} (groundwater temperature) °Celsius
0.03	AF_{ss} (Attenuation Factor Sub-Slab) unitless		

Top of Page

Retrieve Clear

Groundwater and Soil Gas Equation and Parameters

Correcting the Henry`s Law Constant for GW Temperature

Enthalpy Adjustment for GW Temperature

Groundwater Screening Level Equation

Soil Gas Screening Level Equation

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Top of Page

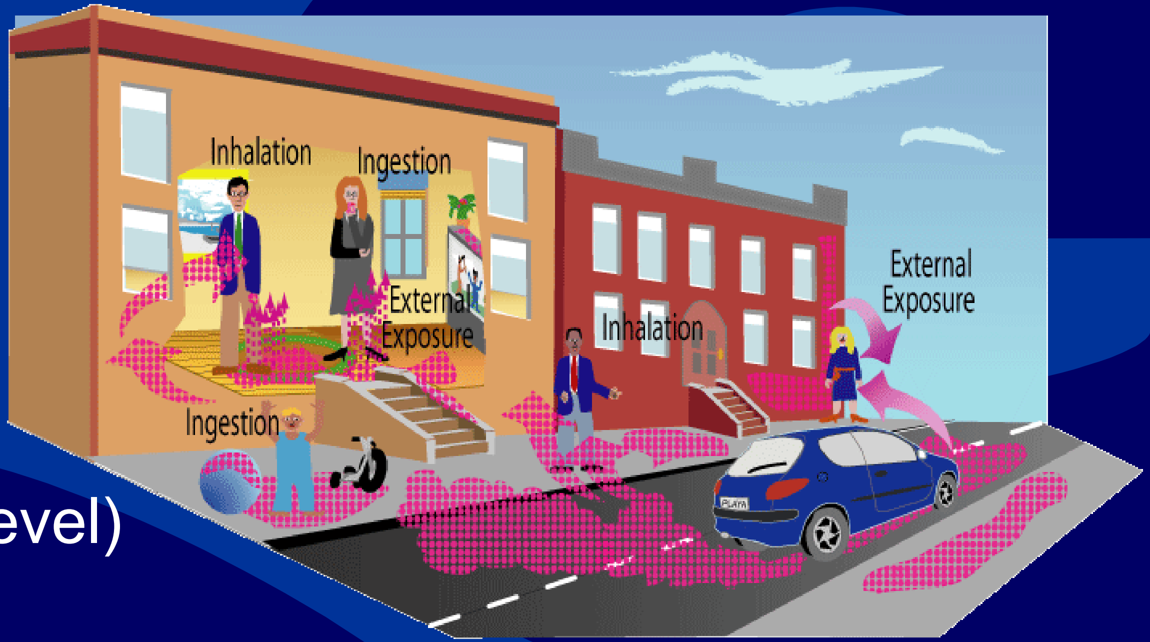
Retrieve Clear

Surfaces PRG (SPRG) Calculator

- Establish 1 x 10^{-6} risk based PRGs for radioactively contaminated ***outside*** hard surfaces (e.g., slabs, pavement, sidewalks, sides of buildings)
- Derived from rad PRG and BPRG calculators

SPRG Exposure Scenarios

- SPRG includes 3 land use scenarios
  - » Residential
  - » Indoor Worker
  - » Outdoor Worker
- 3 land uses include 3 exposure media
  - » Settled dust (pave and unpaved street level)
  - » Fixed Direct External 3-D (street level)
    - —Surface and Volumetric
  - » Fixed Direct External 2-D (slabs)
    - —Surface and Volumetric

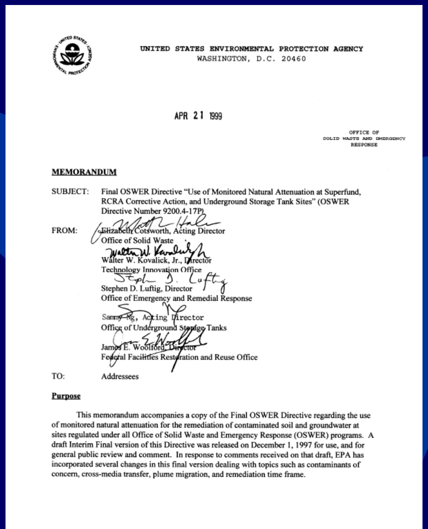


Surface Dose Cleanup Concentrations (SDCC) ARAR Dose Calculator

- SDCC Purpose: to establish DCCs for Outside Hard Surfaces for single dose limit ARARs (# mrem/yr)
- SDCC includes 3 land use scenarios (Residential, Indoor Worker, Outdoor Worker)
- 3 land uses include 3 exposure media (Settled dust, Fixed Direct External 3-D, Fixed Direct External 2-D (slabs))
- Equations similar to those used for SPRG calculator, except dose conversion factors used instead of slope factors

MNA for Inorganics (metals and radionuclides) Policy document

- Complements 1999 overall MNA policy document "Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites"
  - » Helps clarify policy issues unique to inorganics not addressed in 1999
- 3 Volume ORD MNA for inorganics documents is the technical support document for this policy document
  - » Also complemented by 2010 ITRC guidance on MNA for inorganics



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

APR 21 1999

OFFICE OF
SOLID WASTE AND EMERGENCY
RESPONSE

MEMORANDUM

SUBJECT: Final OSWER Directive "Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites" (OSWER Directive Number 9200.4-17P)

FROM: Elizabeth Cotsworth, Acting Director
Office of Solid Waste

Walter W. Kovalick, Jr., Director
Technology Innovation Office

Stephen D. Luftig, Director
Office of Emergency and Remedial Response

Sammy Ng, Acting Director
Office of Underground Storage Tanks

James E. Woolford, Director
Federal Facilities Restoration and Reuse Office

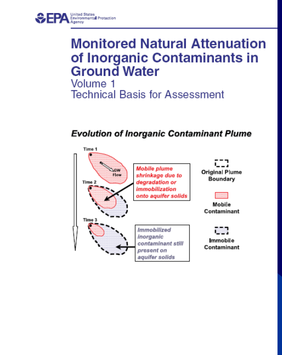
TO: Addressees

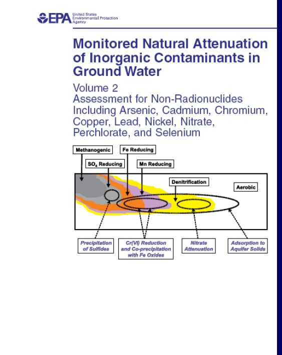
Purpose

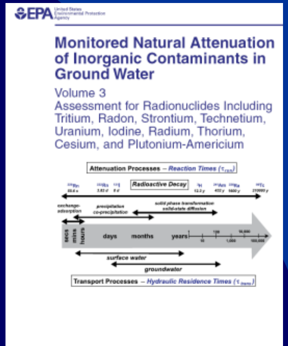
This memorandum accompanies a copy of the Final OSWER Directive regarding the use of monitored natural attenuation for the remediation of contaminated soil and groundwater at sites regulated under all Office of Solid Waste and Emergency Response (OSWER) programs. A draft Interim Final version of this Directive was released on December 1, 1997 for use, and for general public review and comment. In response to comments received on that draft, EPA has incorporated several changes in this final version dealing with topics such as contaminants of concern, cross-media transfer, plume migration, and remediation time frame.

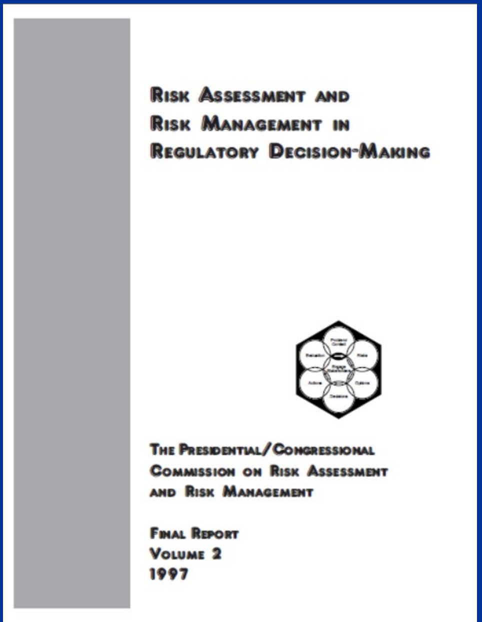
Technical Background Documents for MNA Guidance for Inorganics

- 3 Technical Reports “Monitored Natural Attenuation of Inorganic Contaminants in Ground Water”
  - “Volume 1 - Technical Basis for Assessment” 2007
  - “Volume 2 - Assessment for Non-Radionuclides Including Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Nitrate, Perchlorate, and Selenium” 2007
  - “Volume 3 - Assessment for Radionuclides Including Americium, Cesium, Iodine, Plutonium, Radium, Radon, Strontium, Technecium, Thorium, Tritium, Uranium” 2010





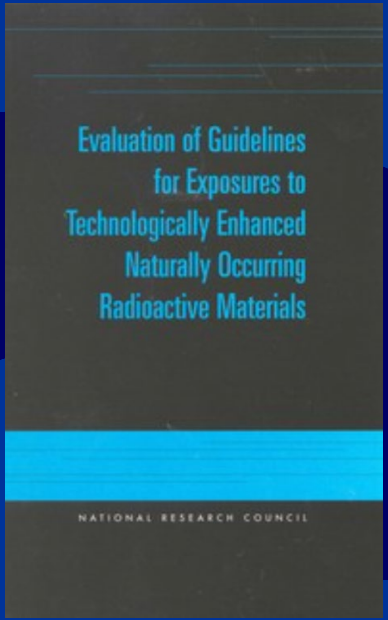




RISK ASSESSMENT AND RISK MANAGEMENT IN REGULATORY DECISION-MAKING

THE PRESIDENTIAL/CONGRESSIONAL COMMISSION ON RISK ASSESSMENT AND RISK MANAGEMENT

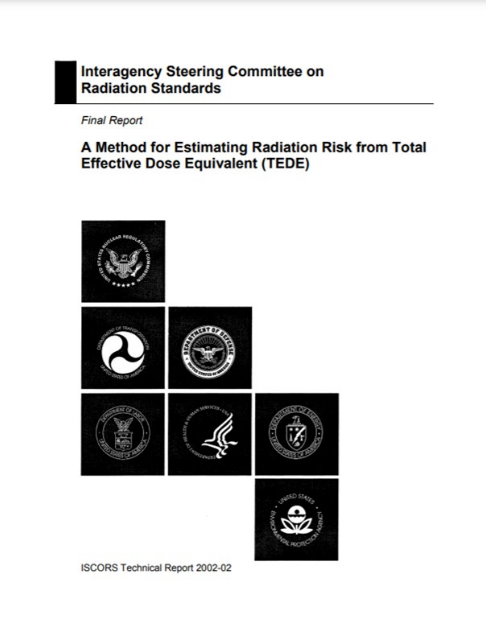
FINAL REPORT
VOLUME 2
1997



Evaluation of Guidelines for Exposures to Technologically Enhanced Naturally Occurring Radioactive Materials

NATIONAL RESEARCH COUNCIL

Part 2.
High Level Scientific and Risk Management/Policy Review of the Superfund Approach

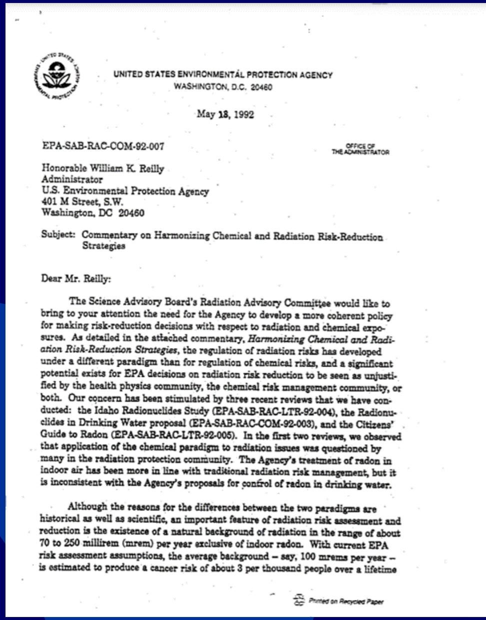


Interagency Steering Committee on Radiation Standards

Final Report

A Method for Estimating Radiation Risk from Total Effective Dose Equivalent (TEDE)

ISCORS Technical Report 2002-02



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

May 18, 1992

EPA-SAB-RAC-COM-92-007

OFFICE OF THE ADMINISTRATOR

Honorable William K. Reilly
Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

Subject: Commentary on Harmonizing Chemical and Radiation Risk-Reduction Strategies

Dear Mr. Reilly:

The Science Advisory Board's Radiation Advisory Committee would like to bring to your attention the need for the Agency to develop a more coherent policy for making risk-reduction decisions with respect to radiation and chemical exposures. As detailed in the attached commentary, *Harmonizing Chemical and Radiation Risk-Reduction Strategies*, the regulation of radiation risks has developed under a different paradigm than for regulation of chemical risks, and a significant potential exists for EPA decisions on radiation risk reduction to be seen as unjustified by the health physics community, the chemical risk management community, or both. Our concern has been stimulated by three recent reviews that we have conducted: the Idaho Radionuclides Study (EPA-SAB-RAC-LTR-92-004), the Radionuclides in Drinking Water proposal (EPA-SAB-RAC-COM-92-003), and the Citizens' Guide to Radon (EPA-SAB-RAC-LTR-92-005). In the first two reviews, we observed that application of the chemical paradigm to radiation issues was questioned by many in the radiation protection community. The Agency's treatment of radon in indoor air has been more in line with traditional radiation risk management, but it is inconsistent with the Agency's proposals for control of radon in drinking water.

Although the reasons for the differences between the two paradigms are historical as well as scientific, an important feature of radiation risk assessment and reduction is the existence of a natural background of radiation in the range of about 70 to 250 millirem (mrem) per year exclusive of indoor radon. With current EPA risk assessment assumptions, the average background – say, 100 mrems per year – is estimated to produce a cancer risk of about 3 per thousand people over a lifetime

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High Level Review of Superfund Approach

- EPA's approach of addressing radiation and chemicals in a similar approach has received outside high- level review, both:
  - » Risk management/policy review
  - » Scientific review
    1. Blue Ribbon (Presidential/Congressional) committee report
    2. National Academy of Science (NAS) report
    3. EPA Science Advisory Board (SAB)
    4. ISCORS report signed by US Federal Agencies

Blue-ribbon committee

- The Presidential/Congressional Commission on Risk Assessment and Risk Management developed a 1997 report to Congress on the appropriate uses of risk assessment and risk management in Federal regulatory programs
- Final Report Volume 2 issued 1997, Risk Assessment and Risk Management In Regulatory Decision-Making recommended:
  - » Radiation and chemicals should be addressed consistently, particularly when co-located
  - » Superfund should continue to use the 10^{-4} to 10^{-6} cancer risk range and reasonably anticipated land use

Blue-ribbon committee screen shots (pp 82, 122)

RISK ASSESSMENT AND
RISK MANAGEMENT IN
REGULATORY DECISION-MAKING

THE PRESIDENTIAL/CONGRESSIONAL
COMMISSION ON RISK ASSESSMENT
AND RISK MANAGEMENT

FINAL REPORT
VOLUME 2
1997

Recommendation

A concerted effort should be made to evaluate and relate the methods, assumptions, mechanisms, and standards for radiation risks to those for chemicals to clarify and enhance the comparability of risk management decisions and investments, especially when both types of hazards are present.

Recommendation

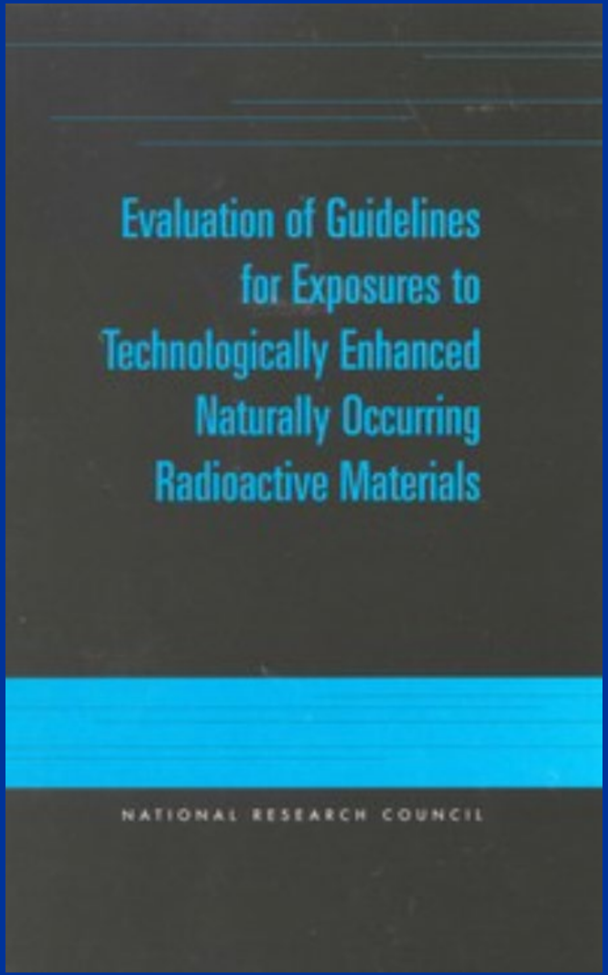
EPA should continue to use its 10^{-6} to 10^{-4} risk range as a guide for site-specific risk-based cleanup goals, related to future land use. Site-

EPA

National Academy of Science (NAS)

- 1999 NAS report "Evaluation of Guidelines for Exposures to Technologically Enhanced Naturally Occurring Radioactive Materials"
  - » NAS compared EPA's approach for risk assessment (slope factors) and NRC's approach (use EDE then convert to risk)
    - —NAS found EPA's approach methodologically more rigorous for assessing risks from chronic exposure to radionuclides.
  - » Compared EPA and NRC risk management approaches and determined differences were a matter of policy and not science, and should reflect societal values

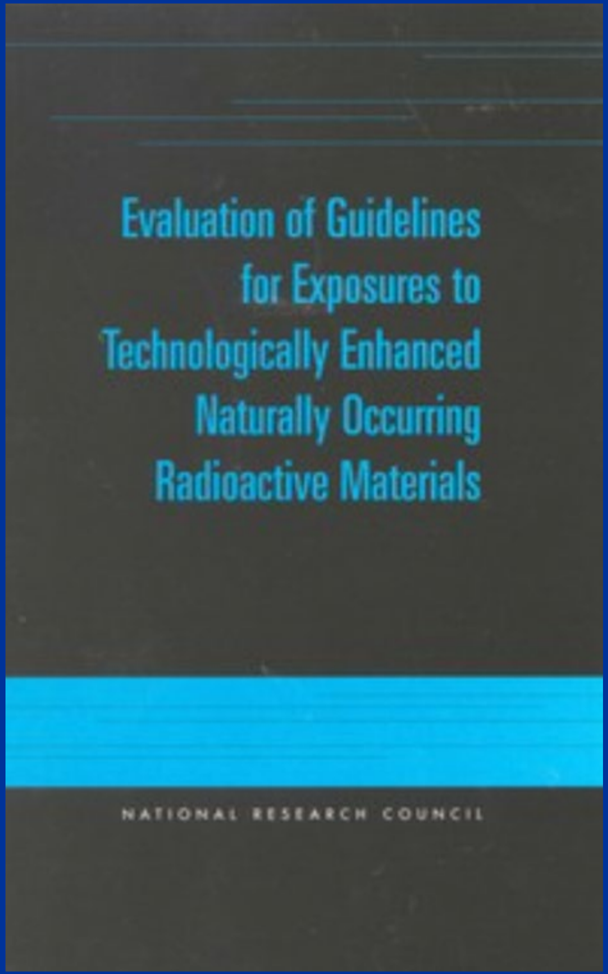
NAS screenshots on comparison of NRC/EPA risk assessment approach (pg 222)



The Nuclear Regulatory Commission's approach to estimating risk posed by chronic radiation exposure of the public normally is based on ICRP recommendations on estimating doses per unit exposure and the risk per unit dose. The Nuclear Regulatory Commission estimates lifetime risks on the basis

EPA has developed a methodologically more rigorous approach to assessing risk posed by chronic lifetime exposure to radionuclides, which is particularly important for internal exposure and differs in several respects from the simple approach described above.

NAS screenshots on comparison of NRC/EPA risk assessment approach (pg 234)



This committee offers the following comments on the issue of a limit on acceptable risk and, therefore, acceptable dose. First, the determination of an acceptable risk for any exposure situation clearly is entirely a matter of judgment (risk-management policy) which presumably reflects societal values. Inasmuch as EPA and the Nuclear Regulatory Commission have used essentially the same assumptions about the risks posed by radiation exposure in establishing radiation standards, it is clear that the determination of a limit on acceptable dose for any exposure situation also is entirely a matter of judgment. Therefore, any differences between the views of EPA and the Nuclear Regulatory Commission on an acceptable dose have no scientific or technical basis.

EPA Science Advisory Board (SAB)

- In 1992 the EPA SAB sent a letter to the EPA Administrator "Commentary on Harmonizing Chemical and Radiation Risk-Reduction Strategies." The SAB:
  - » SAB acknowledged that EPA guidance for Superfund sites, including DOE sites under CERCLA, would use a consistent risk-based approach for addressing radiation and chemical contamination in both risk assessment methodology and cleanup levels (e.g., no more than 10^{-4} cancer risk)
  - » SAB viewed the harmonization of radionuclides to the chemical approach as scientifically valid

SAB screenshots (pg 9)

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Although the reasons for the differences between the two paradigms are historical as well as scientific, an important feature of radiation risk assessment and reduction is the existence of a natural background of radiation in the range of about 70 to 250 millirem (mrem) per year exclusive of indoor radon. With current EPA risk assessment assumptions, the average background – say, 100 mrems per year – is estimated to produce a cancer risk of about 3 per thousand people over a lifetime

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The facilities of the Department of Energy that are part of the nuclear weapons complex form another group of problem sites where radionuclides are a significant or even dominating part of the cancer risk equation. Whether these facilities are treated as Superfund (CERCLA) problems or current waste disposal sites under the Resource Conservation and Recovery Act (RCRA), the treatment of radioactive materials is seen as necessarily being subject to the same types of risk analyses and remedial responses that EPA has used for chemicals. The document "Risk Assessment Guidelines for Superfund" (RAGS), for example, contains a section on how to assess the cancer risks from exposure to radionuclides, but does not suggest any different risk-reduction strategies than for carcinogenic chemicals. The implication is that remediation is expected if the lifetime risks from radionuclides are calculated to exceed about 10^{-4} (or lower in some proposals for radiation sites).

SAB screenshots (pp 10, 12)

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Need for Harmonization

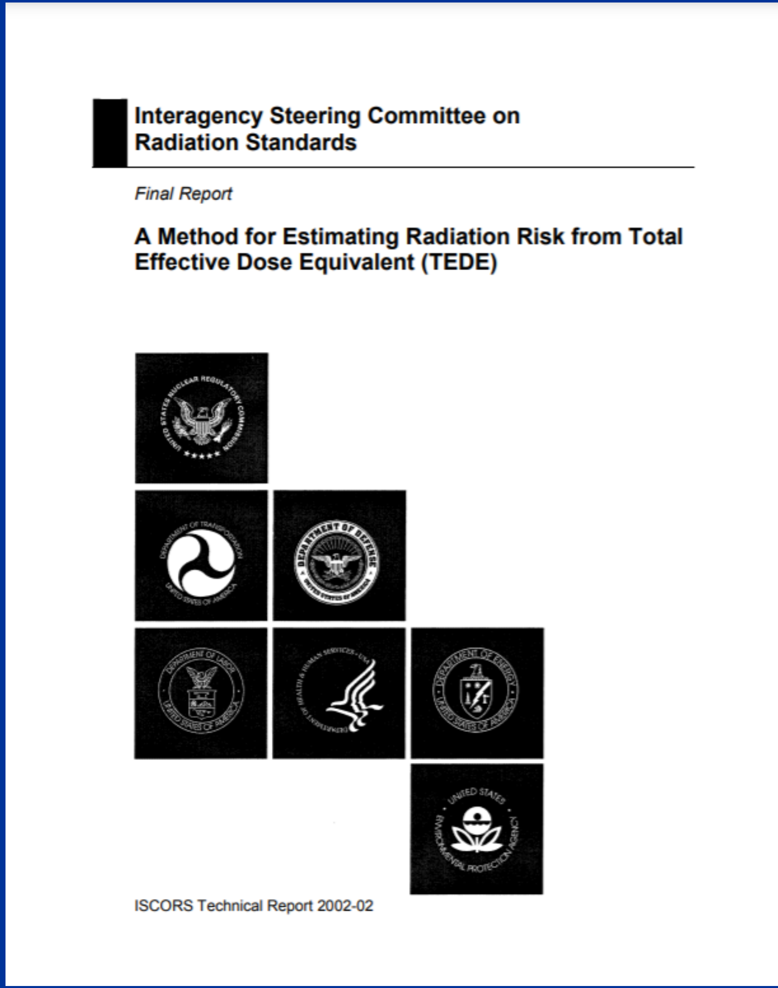
Clearly, EPA needs to adopt policies that will allow its staff, the regulated community, scientific consultants to both parties, and the general public all to know what to expect in EPA's regulation of residual radioactivity and other radiation issues. The Radiation Advisory Committee does not claim any special insight in how the resolution should be accomplished, but does emphasize the importance of achieving such harmonization. Interest in the comparative risks of radiation and chemicals has a substantial history (NCRP, 1989) and is now becoming more widespread (Kocher and Hoffman, 1991).

Clearly, the choice among these options -- and others that may exist -- is a policy choice that transcends scientific analysis. The leadership of the Environmental Protection Agency has the authority and the responsibility to make the choice. We urge the choice to be articulated clearly so that the scientists who assess the risks of radiation and chemicals can understand the basis for subsequent decisions about risk reduction.

Interagency Steering Committee on Radiation Standards (ISCORS) Report

- A 2002 report by ISCORS entitled "A Method for Estimating Radiation Risk from Total Effective Dose Equivalent (TEDE)." ISCORs includes EPA, NRC, DOE, and DOD. The report stated:
  - » The simple method of converting dose to risk is insufficient for a complex risk assessment such as those for CERCLA sites
  - » Recommendation to use slope factors when a complex risk assessment is needed for assessing radionuclides, such as at a CERCLA sites

ISCORS screenshot (pg 1)


Interagency Steering Committee on Radiation Standards

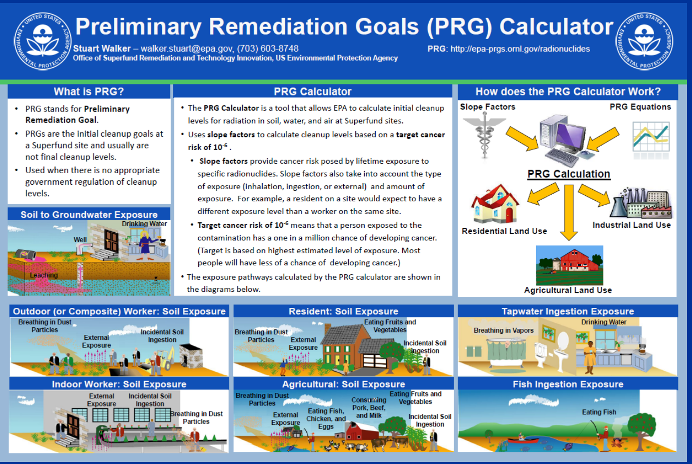
Final Report

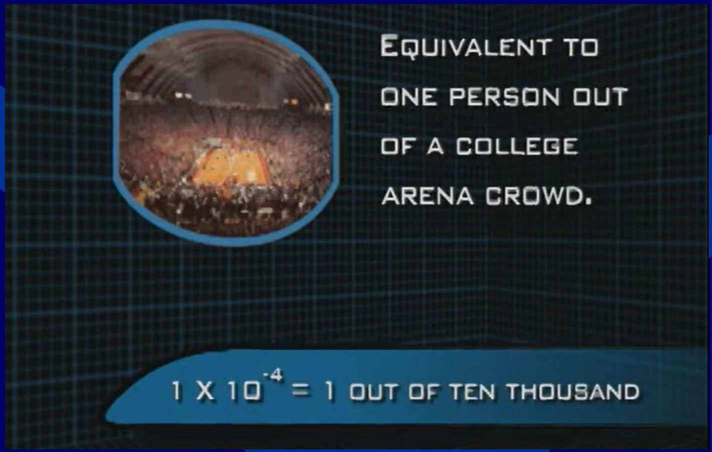
A Method for Estimating Radiation Risk from Total Effective Dose Equivalent (TEDE)

ISCORS Technical Report 2002-02

equivalent to cancer risk may be appropriate when radionuclide-specific data is missing. The conversion of dose to risk referred to in this document refers primarily to a conversion of total effective dose equivalent (TEDE, as defined by the Department of Energy in 10 CFR 835.2)[2] to lifetime cancer incidence and mortality risks. The conversion of TEDE to cancer risks using these conversion factors will not satisfy the requirements for a comprehensive radiation risk assessment, but may be of use for making less rigorous comparisons of risk. For situations in which a radiation risk assessment is required for making risk management decisions, the radionuclide-specific risk coefficients published in Federal Guidance Report No. 13 should be used.[3] For radiation risk assessments required by EPA's Superfund Program, the risk coefficients in EPA's Health Effects Assessment Summary Tables (HEAST)[4] should be used. Although

Part 3. Involving Stakeholders at Superfund Remedial Program Sites



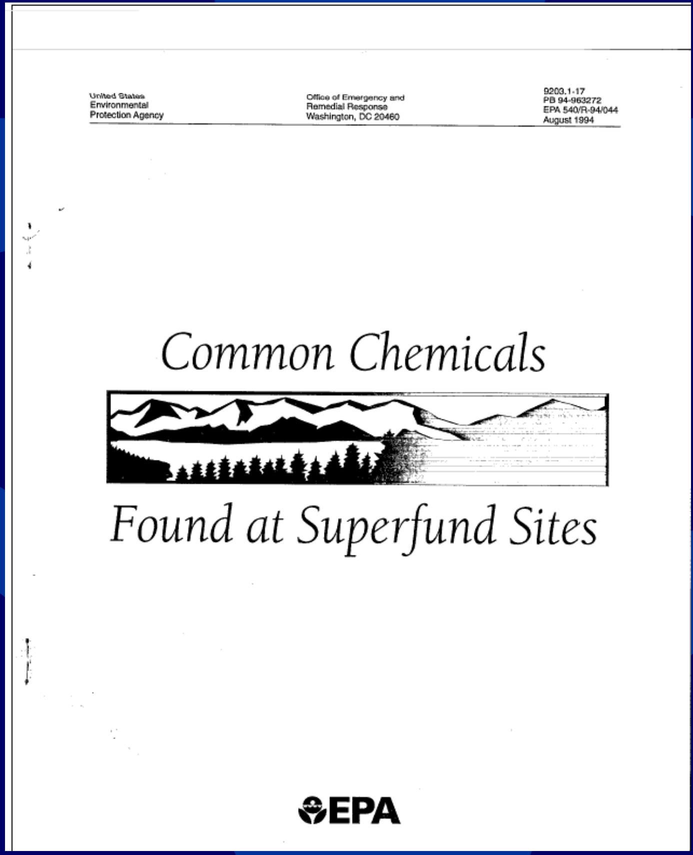


Community Involvement

- EPA has many tools to facilitate meaningful involvement by communities near sites
- EPA hosts a community involvement national conference
- EPA has 2 tools designed specifically for use at radiation sites that are based on earlier tools for chemical sites

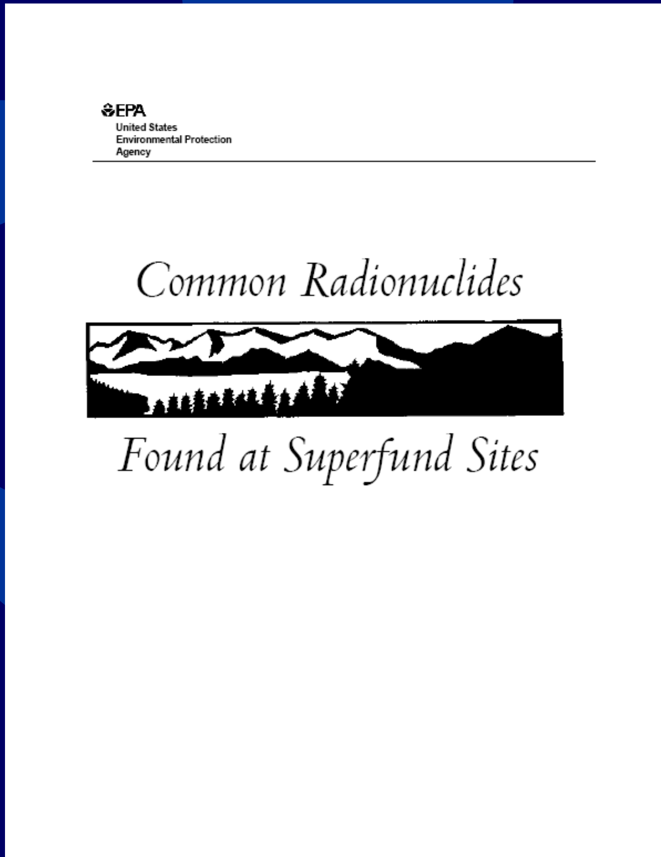
Booklet: Common Chemicals

- *Common Chemicals Found at Superfund Sites* (8/94) OSWER Directive 9203.1-17
- Booklet for the general public. It contains information on
  - » Health effects of chemicals commonly found at Superfund sites
  - » EPA policies for cleaning up these chemicals *Note* this booklet has been superseded by a website



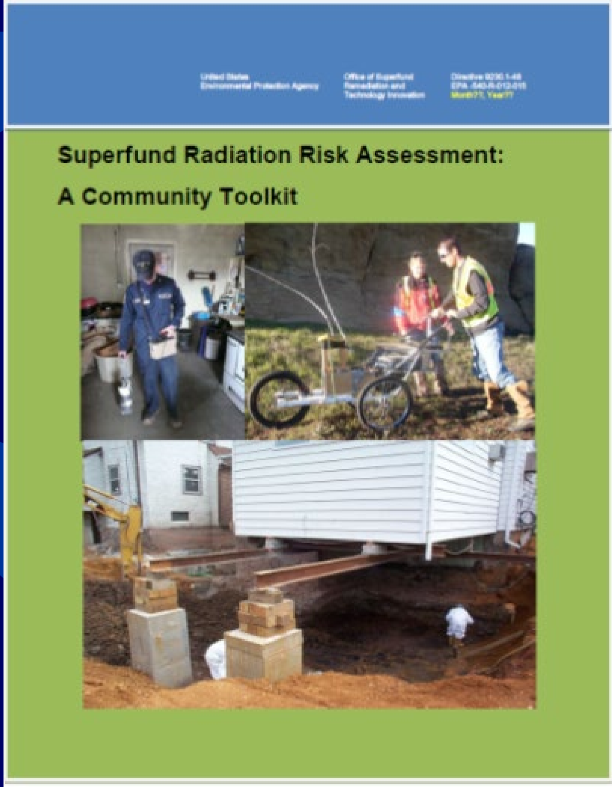
Booklet: Common Radionuclides *Old Superseded*

- *Common Radionuclides Found at Superfund Sites* (7/02) OSWER Directive 9200.1-34
- Booklet for the general public. It contains information on
  - » Health effects of radionuclides commonly found at Superfund sites
  - » EPA policies for cleaning up these radionuclides



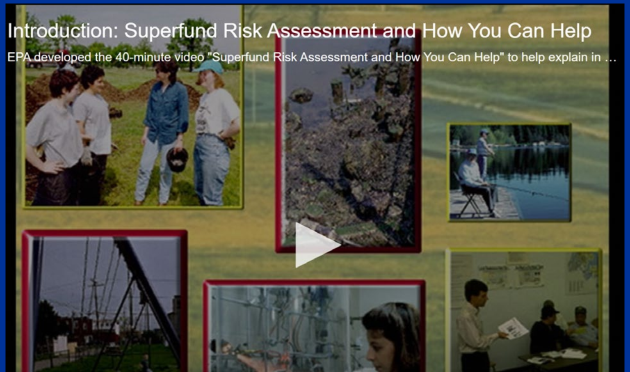
Toolkit: Radiation Risk Assessment

- *Superfund Radiation Risk Assessment: A Community Toolkit* (6/14)
- Collection of 22 fact sheets for the general public. It contains fact sheets on
  - » Superfund and Radiation
  - » Superfund risk assessment process at radiation sites
  - » Each of the 6 PRG and DCC calculators
  - » Replacement for the Common Rad booklet fact sheets



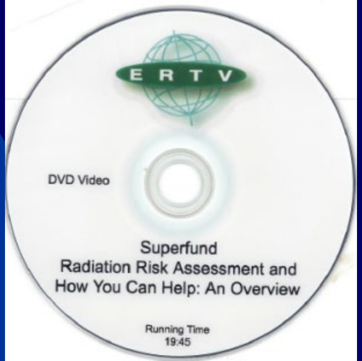
Video: Chemical Risk Assessment

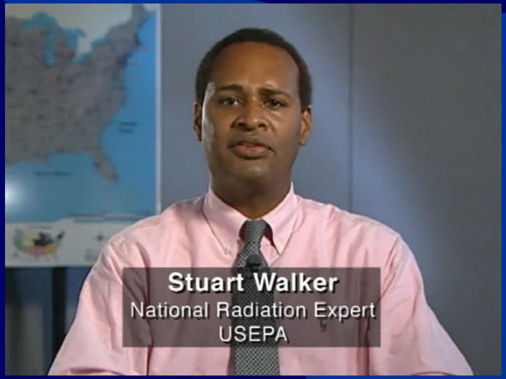
- *Superfund Risk Assessment and How you can Help, an Overview* (1999) OSWER Directive 9285.7-29A https://clu-in.org/video/sf_risk_assessment_overview.htm
- Video for the general public. It contains information on:
  - » The Superfund risk assessment process when addressing chemical contamination
  - » How the public is involved site-specifically

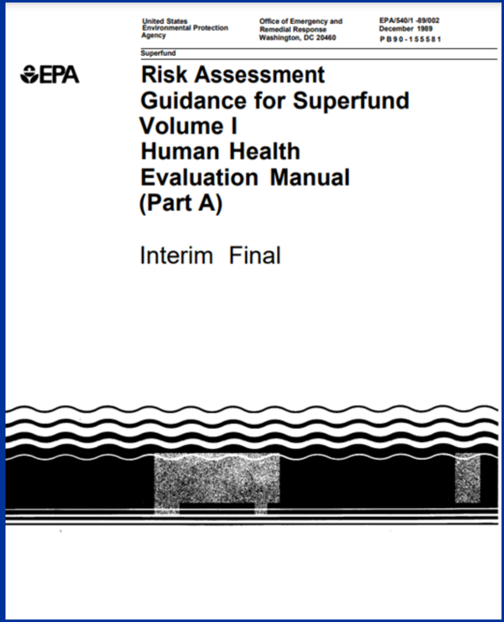


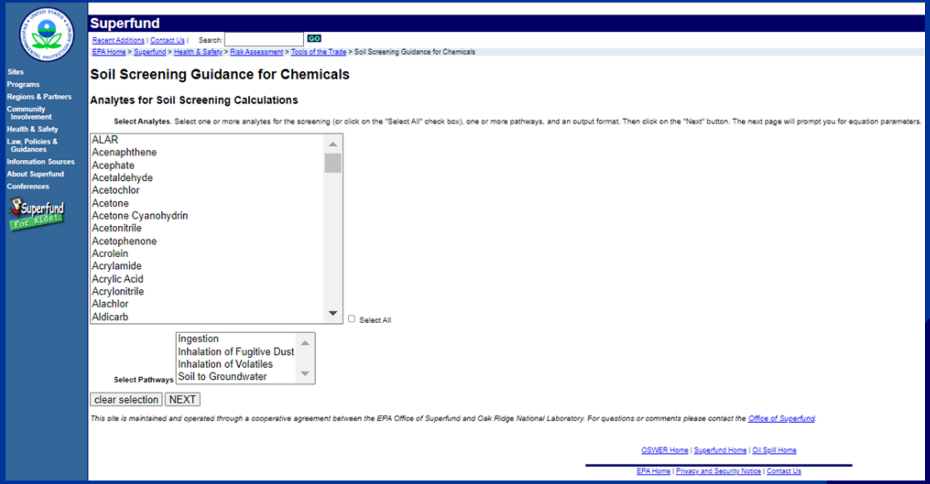
Video: Radiation Risk Assessment

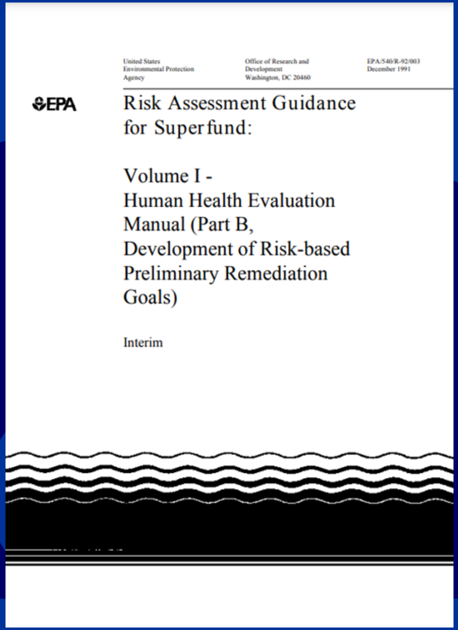
- *Superfund Radiation Risk Assessment and How you can Help, an Overview* (3/05) OSWER Directive 9200.4-37 https://ertvideo.org/content.aspx?video_id=7392
- Video for the general public. It contains information on:
  - » The Superfund risk assessment process when addressing radioactive contamination
  - » How the public is involved site-specifically



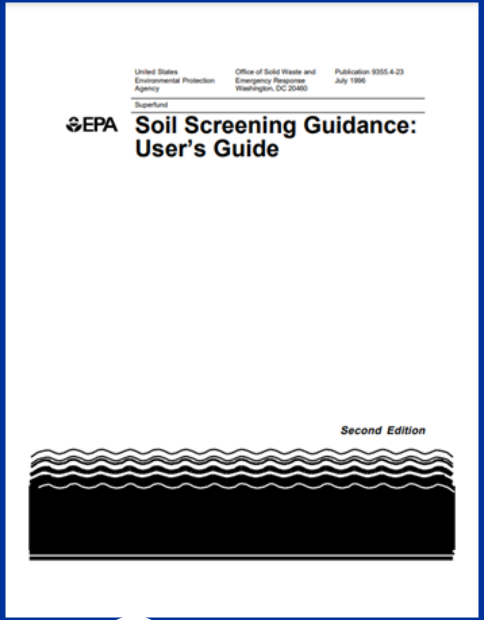


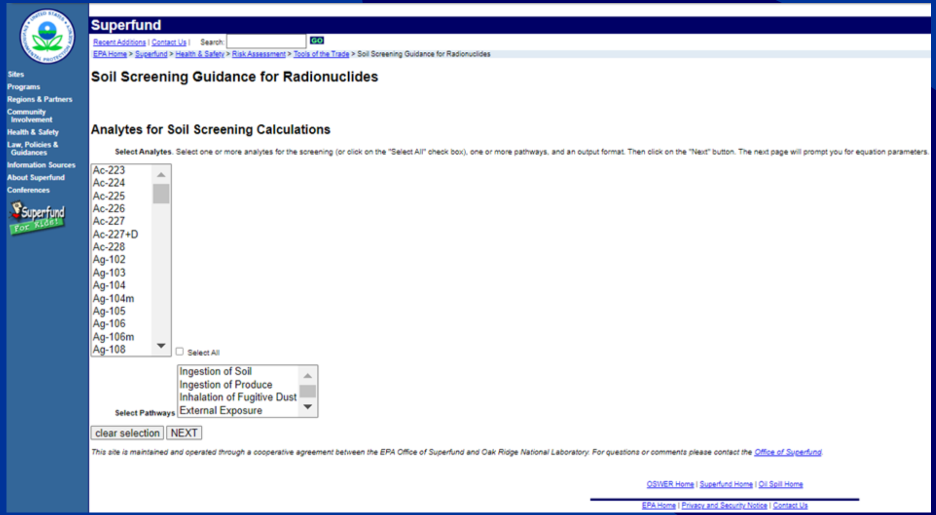


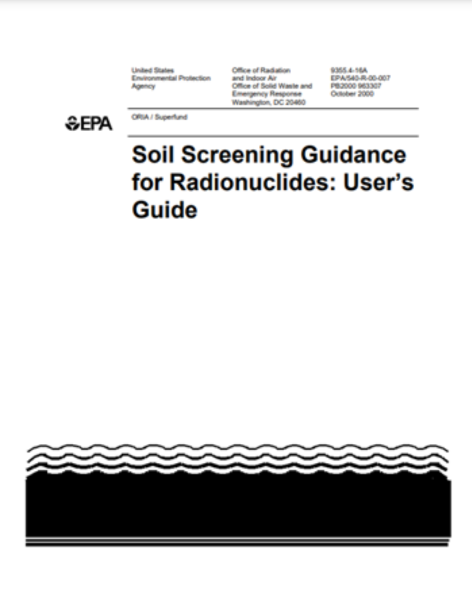




Part 4. Past Practices of EPA Superfund Risk Harmonization Approach





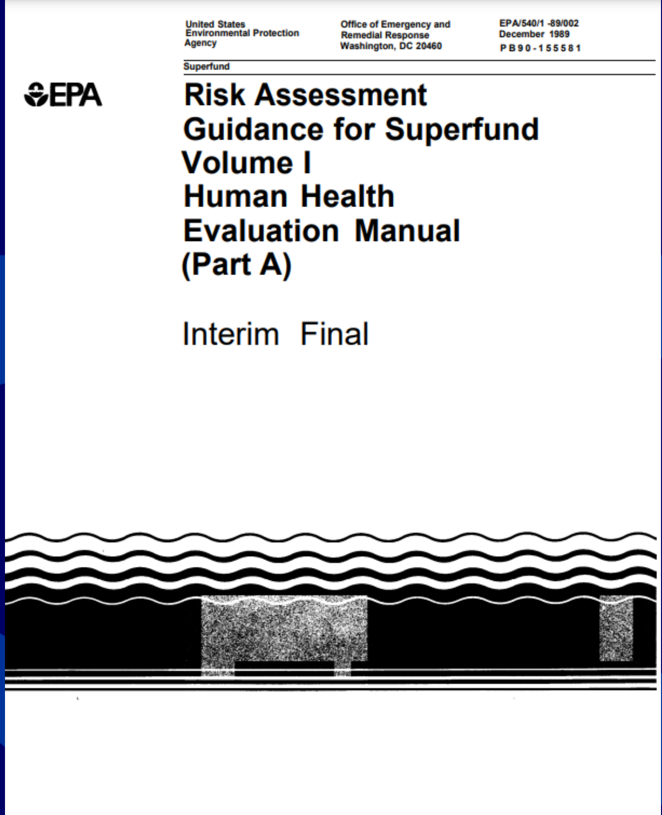


Consistency with Rad and Chem Risk Assessment is EPA's Long-standing Policy

- EPA Superfund remedial approach to address chemical and radiation risks consistently dates back to 1989 guidance of that era
- More recent EPA guidance discussed earlier continues that approach
- Remaining slides in this section will demonstrate that earlier EPA guidance was consistent on this matter

EPA 1989 guidance against using different models for rad and chem risk assessment

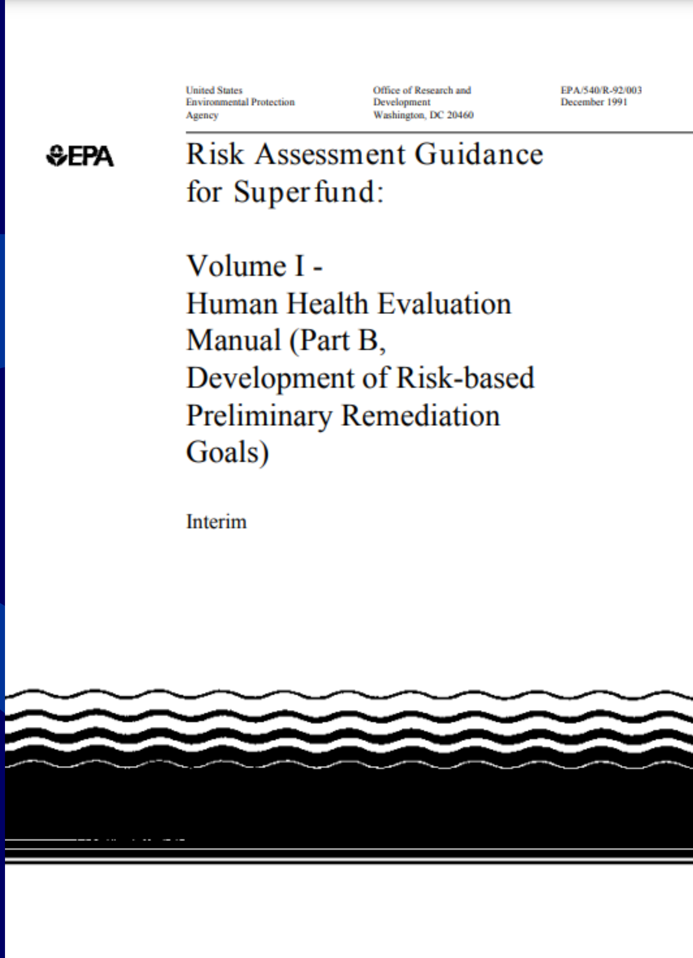
- In "Risk Assessment Guidance for Superfund (RAGS) Part A" (December 1989), Chapter 10 "Radiation Risk Assessment Guidance,"
  - » EPA warned that using different risk assessment models for radionuclides and chemicals may result in incompatibilities when trying to sum the risk assessment (see pg. 10-33)


United States Environmental Protection Agency
Office of Emergency and Remedial Response Washington, DC 20460
EPA/540/1-89/002 December 1989
PB90-155581
Superfund
EPA
Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A)
Interim Final

> In cases where different environmental fate and transport models have been used to predict chemical and radionuclide exposure, the mathematical models may incorporate somewhat different assumptions. These differences can result in incompatibilities in the two estimates of risk. One important difference

EPA 1991 Superfund chem & rad Risk Harmonization efforts

- Since 1991 EPA has been developing consistent approaches for chemical and radiation Superfund risk assessments.
  - » See “Risk Assessment Guidance for Superfund (RAGS) Part B” (RAGS Part B), December 1991, Chapter 4, "Risk-based PRGs for Radioactive Contaminants,” pg. 33



United States Environmental Protection Agency
Office of Research and Development Washington, DC 20460
EPA/540/R-92/003 December 1991

EPA

Risk Assessment Guidance for Superfund:

Volume I - Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals)

Interim

EPA 1991 consistent PRGs

- RAGS Part B includes PRGs for chemicals and radionuclides that use:
  - » Same land uses and similar equations
  - » Standard default exposure parameters for RME risk assessments

In general, standardized default exposure equations and parameters used to calculate risk-based PRGs for radionuclides are similar in structure and function to those equations and parameters developed in Chapter 3 for nonradioactive chemical carcinogens. Both types of risk equations:

- Calculate risk-based PRGs for each carcinogen corresponding to a pre-specified target cancer risk level of 10^{-6}. As mentioned in Section 2.8, target risk levels may be modified after the baseline risk assessment based on site-specific exposure conditions, technical limitations, or other uncertainties, as well as on the nine remedy selection criteria specified in the NCP.

- Use standardized default exposure parameters consistent with OSWER Directive 9285.6-03 (EPA 1991b). Where default parameters are

not available in that guidance document, other appropriate reference values are used and cited.

- Incorporate pathway-specific default exposure factors that generally reflect RME conditions.

EPA 1991 PRGs for residential soil for chem and rad carcinogenic effects

RESIDENTIAL SOIL — CARCINOGENIC EFFECTS

$$TR = \frac{SF_o \times C \times 10^{-6}\ \text{kg/mg} \times EF \times IF_{soil/adj}}{AT \times 365\ \text{days/yr}}$$

$$C\ (\text{mg/kg; risk-based}) = \frac{TR \times AT \times 365\ \text{days/year}}{SF_o \times 10^{-6}\ \text{kg/mg} \times EF \times IF_{soil/adj}} \quad (4)$$

where:

Parameters	Definition (units)	Default Value
C	chemical concentration in soil (mg/kg)	—
TR	target excess individual lifetime cancer risk (unitless)	10^{-6}
SF_o	oral cancer slope factor ((mg/kg-day)$^{-1}$)	chemical-specific
AT	averaging time (yr)	70 yr
EF	exposure frequency (days/yr)	350 days/yr
$IF_{soil/adj}$	age-adjusted ingestion factor (mg-yr/kg-day)	114 mg-yr/kg-day (see Equation (3))

RADIONUCLIDE PRGs: RESIDENTIAL SOIL — CARCINOGENIC EFFECTS

$$\text{Total risk} = RS \times [(SF_o \times 10^{-3}\text{g/mg} \times EF \times IF_{soil/adj}) + (SF_e \times 10^{3}\text{g/kg} \times ED \times D \times SD \times (1\text{-}S_e) \times T_e)]$$

$$RS\ (\text{pCi/g; risk-based}) = \frac{TR}{(SF_o \times 10^{-3} \times EF \times IF_{soil/adj}) + (SF_e \times 10^{3} \times ED \times D \times SD \times (1\text{-}S_e) \times T_e)} \quad (11)$$

where:

Parameters	Definition (units)	Default Value
RS	radionuclide PRG in soil (pCi/g)	—
TR	target excess individual lifetime cancer risk (unitless)	10^{-6}
SF_o	oral (ingestion) slope factor (risk/pCi)	radionuclide-specific
SF_e	external exposure slope factor (risk/yr per pCi/m^2)	radionuclide-specific
EF	exposure frequency (days/yr)	350 days/yr
ED	exposure duration (yr)	30 yr
$IF_{soil/adj}$	age-adjusted soil ingestion factor (mg-yr/day)	3600 mg-yr/day (see Equation (12))
D	depth of radionuclides in soil (m)	0.1 m
SD	soil density (kg/m^3)	1.43×10^3 kg/m^3
S_e	gamma shielding factor (unitless)	0.2 (see Section 4.1.2)
T_e	gamma exposure time factor (unitless)	1 (see Section 4.1.2)

1989 Slope Factors for chemical carcinogens and radionuclide

- Health Effect Summary Tables (HEAST) issued in 1989 includes tables of slope factors for chem and rad

United States Environmental Protection Agency | OSWER (OS-230) ORD (RD-689) | OERR 9200.6-303-(89-4) October 1989

EPA

Health Effects Assessment Summary Tables

Fourth Quarter
FY 1989

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HEALTH EFFECTS ASSESSMENT SUMMARY TABLE C: RADIONUCLIDE CARCINOGENICITY (Expressed in picocuries (pCi)*)

			Slope Factor Age-averaged lifetime excess total cancer risk per unit intake or exposure			Pathway-Specific Unit Risk Age-averaged lifetime excess total cancer risk per unit daily intake or exposure for 70 years		
Nuclide	ICRP** Lung Class	GI*** Absorption Factor (f_1)	Inhalation $(pCi)^{-1}$	Ingestion $(pCi)^{-1}$	Ground Surface $(pCi/m^2/yr)^{-1}$	Air $(pCi/m^3)^{-1}$	Drinking Water $(pCi/L)^{-1}$	External Exposure $(pCi/g\ soil)^{-1}$
Am-241	W	1.0E-03	4.0E-08	3.1E-10	1.6E-12	2.1E-02	1.6E-05	1.6E-05
Am-243	W	1.0E-03	4.0E-08	3.0E-10	3.6E-12	2.1E-02	1.5E-05	3.6E-05
Ba-137m	D	1.0E-01	6.0E-16	2.4E-15	3.4E-11	3.0E-10	1.2E-10	3.4E-04
Bi-214	W	5.0E-02	2.2E-12	1.4E-13	8.0E-11	1.1E-06	7.2E-09	8.0E-04
C-14	*	9.5E-01	6.4E-15	9.1E-13	0.0E+00	3.2E-09	4.7E-08	0.0E+00
Ce-144	Y	3.0E-04	3.4E-10	6.1E-12	1.2E-12	1.7E-04	3.0E-07	1.2E-05
Cm-243	W	1.0E-03	3.1E-08	2.3E-10	8.2E-12	1.6E-02	1.2E-05	8.2E-05
Cm-244	W	1.0E-03	2.7E-08	2.0E-10	5.8E-14	1.4E-02	1.0E-05	5.9E-07
Co-60	Y	3.0E-01	1.6E-10	1.5E-11	1.3E-10	8.1E-05	7.8E-07	1.3E-03
Cr-51	Y	1.0E-01	3.0E-13	4.2E-14	1.9E-12	1.5E-07	2.1E-09	1.9E-05
Cs-134	D	9.5E-01	2.8E-11	4.2E-11	8.9E-11	1.4E-05	2.1E-06	8.9E-04
CS-135	D	9.5E-01	2.7E-12	4.0E-12	0.0E+00	1.4E-06	2.1E-07	0.0E+00
Cs-137	D	9.5E-01	1.9E-11	2.8E-11	0.0E+00	9.6E-06	1.4E-06	0.0E+00
Fe-59	W	1.0E-01	9.8E-12	2.8E-12	6.2E-11	4.9E-06	1.4E-07	6.3E-04
H-3	*	9.5E-01	7.8E-14	5.5E-14	0.0E+00	4.0E-08	2.8E-09	0.0E+00
I-129	D	9.5E-01	1.2E-10	1.9E-10	1.5E-12	6.1E-05	9.6E-06	1.5E-05
I-131	D	9.5E-01	2.4E-11	3.6E-11	2.9E-11	1.2E-05	1.8E-06	2.9E-04
K-40	D	9.5E-01	7.6E-12	1.1E-11	7.8E-12	4.0E-06	5.7E-07	7.8E-05
Mn-54	W	1.0E-01	5.3E-12	1.1E-12	4.7E-11	2.6E-06	5.7E-08	4.8E-04
Mo-99	Y	8.0E-01	2.6E-12	1.7E-12	9.0E-12	1.3E-06	8.7E-08	8.9E-05

HEALTH EFFECTS ASSESSMENTS SUMMARY TABLE B: CARCINOGENICITY
Update: September, 1989

Compound	Exposure Inhalation; Oral	Species Inhalation	Species Oral	Tumor Site Inhalation	Tumor Site Oral	EPA Group/slope factor or Unit Risk Inhalation $(\mu g/m^3)^{-1}$ [$(mg/kg/day)^{-1}$]	EPA Group/slope factor or Unit Risk Oral $(mg/kg/day)^{-1}$	Reference Inhalation/Oral
Acephate	NA; 2-year dietary	NA	mice	NA (also see Table A)	liver	ND	C/8.7E-3[a]	U.S. EPA, 1988/ Chevron Chemical Company, 1982; U.S. EPA, 1984; U.S. EPA, 1988
Acrolein	NA; NA	NA	NA	NA (also see Table A)	NA	C/ND[a]	C/ND[a]	U.S. EPA, 1987a,b/ U.S. EPA, 1987a,b
Acrylamide	NA; 2-year drinking water	NA	rat	NA (also see Table A)	CNS, mammary and thyroid glands, uterus, oral cavity	B2/1.3E-3 [4.5E+0][a,b]	B2/4.5+0[a]	U.S. EPA, 1988/ Johnson et al., 1986; U.S. EPA, 1985; U.S. EPA, 1988
Acrylonitrile	occupational; three drinking water studies	human	rat	lung	multiple	B1/6.8E-5 [2.4E-1][a]	B1/5.4E-1[a]	O'Berg, 1980; U.S. EPA, 1983, 1987a,b/Quast et al., 1980; Bio/dynamics, Inc., 1980a,b; U.S. EPA, 1983, 1987a,b
Aldrin	three dietary studies[b]; three dietary studies	mouse	mouse	liver (also see Table A)	liver	B2/4.9E-3 [1.7E+1][a,b]	B2/1.7E+1[a]	NCI, 1977; Davis and Fitzhugh, 1962; Epstein, 1975; Davis, 1965; U.S. EPA, 1986, 1987b/ NCI, 1977; Davis and Fitzhugh, 1962; Epstein, 1975; Davis, 1965; U.S. EPA, 1986, 1987a,b
Aniline	NA; 2-year dietary	NA	rat	NA	spleen	ND	B2/5.7E-3[a]	U.S. EPA, 1987/ CIIT, 1982; U.S. EPA, 1985, 1987

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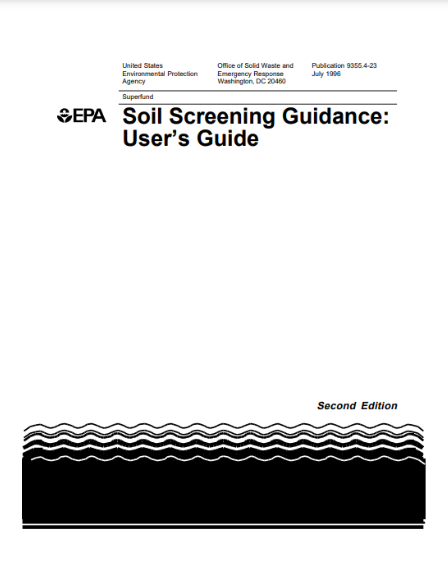
EPA 1996 and 2000 SSG

- Earlier mention of:
  - » 1996 Soil Screening Guidance
  - » 2000 Soil Screening Guidance for Radionuclide
- Similar User Guides and Technical Background Documents


United States Environmental Protection Agency
Office of Solid Waste and Emergency Response Washington, DC 20460
Publication 9355.4-23
July 1996
Superfund
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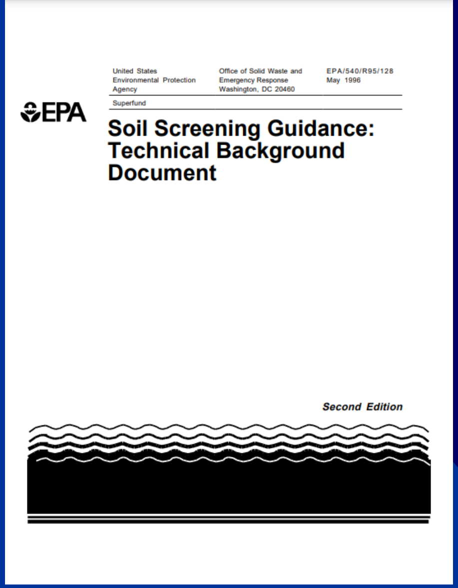
Second Edition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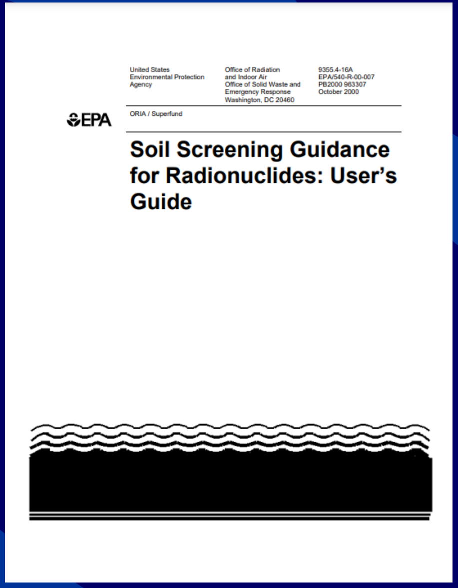
United States Environmental Protection Agency
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PB2000 963307
October 2000
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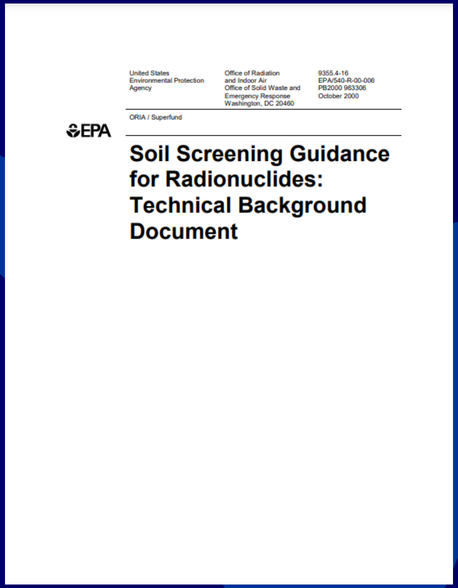
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EPA/540-R-00-006
PB2000 963306
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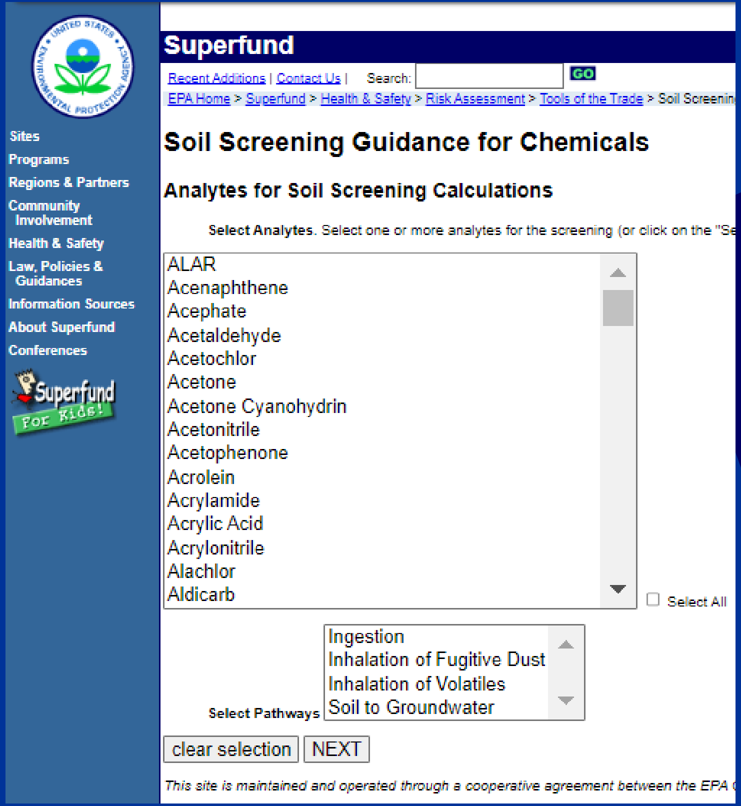
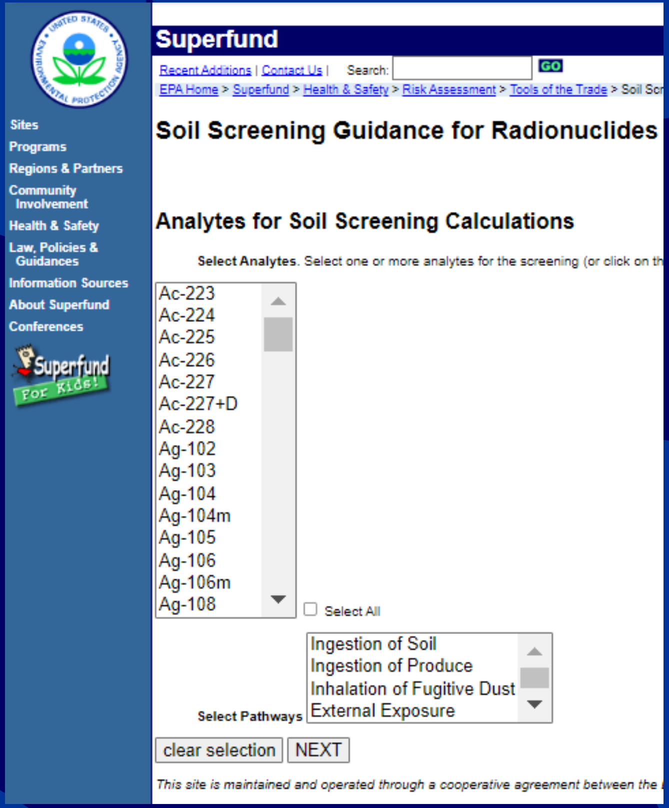
Soil Screening Guidance for Radionuclides: Technical Background Document

EPA SSG chem and rad calculators

- The 1996 chem and 2000 rad SSG superseded the 1991 RAGs Part B equations with consistent calculators developed with ORNL
  - » These were superseded by the RSL and PRG calculators





For Copies or More Information

- Guidance documents for radiation cleanup are on Superfund Radiation Webpage:
  - » https://www.epa.gov/superfund/radiation-superfund-sites
- For further information or questions, contact Stuart Walker at
  - » Phone: (202) 566-1148
  - » Email: Walker.Stuart@epa.gov


Questions
Answers