Welcome to ITRC's Internet-Based Training: "Radiation Risk/Dose Assessment: Updates and Tools"

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Thank you for joining us. Today's training course addresses needs identified in the ITRC document entitled:

" Determining Cleanup Goals at Radioactively Contaminated Sites"

This training is sponsored by:
ITRC and the EPA Office of Superfund Remediation and Technology Innovation

Creating Tools & Strategies to Reduce Technical & Regulatory Barriers for the Deployment of Innovative Environmental Technologies

Presentation Overview:

The ITRC Radionuclides Team's *Determining Cleanup Goals at Radioactively Contaminated Sites: Case Studies* (RAD-2, 2002) examines the factors influencing variations in cleanup level development at various radioactively contaminated sites and underscores the need for training to enhance consistency in radiation risk assessment application. The document also acknowledges the differences between the 'dose approach' used at some sites and EPA's 'risk-based approach.' Since most radioactively contaminated DOE and DOD sites are developing cleanup goals under CERCLA authority, there is a need for training that clarifies the variations between these approaches and elaborates on the methodology used to develop risk-based remediation goals. This training course has been collaboratively developed by the ITRC Radionuclides Team and EPA's Superfund Office to meet these needs. The focus of this training is EPA's new radiation risk assessment tools, which can facilitate better decision making for accelerated cleanups. Course modules have the following specific purposes:

1. Regulatory Background and Case Studies: Provide an overview of the regulatory requirements for cleanup of radioactive waste

2. Existing Practices in Radiation Risk Assessment: Clarify differences between existing radiation risk assessment practices (dose- and risk-based approaches) and provide updates

3. Use of Radiation PRG Calculator: Explain how to use EPA's risk-based PRG and ARAR dose calculators for radionuclides

4. Case Study Application for PRG Calculator: Demonstrate site-specific challenges in application of tools

Sponsors:

ITRC – Interstate Technology and Regulatory Council (www.itrcweb.org)

EPA Office of Superfund Remediation and Technology Innovation (www.clu-in.org)

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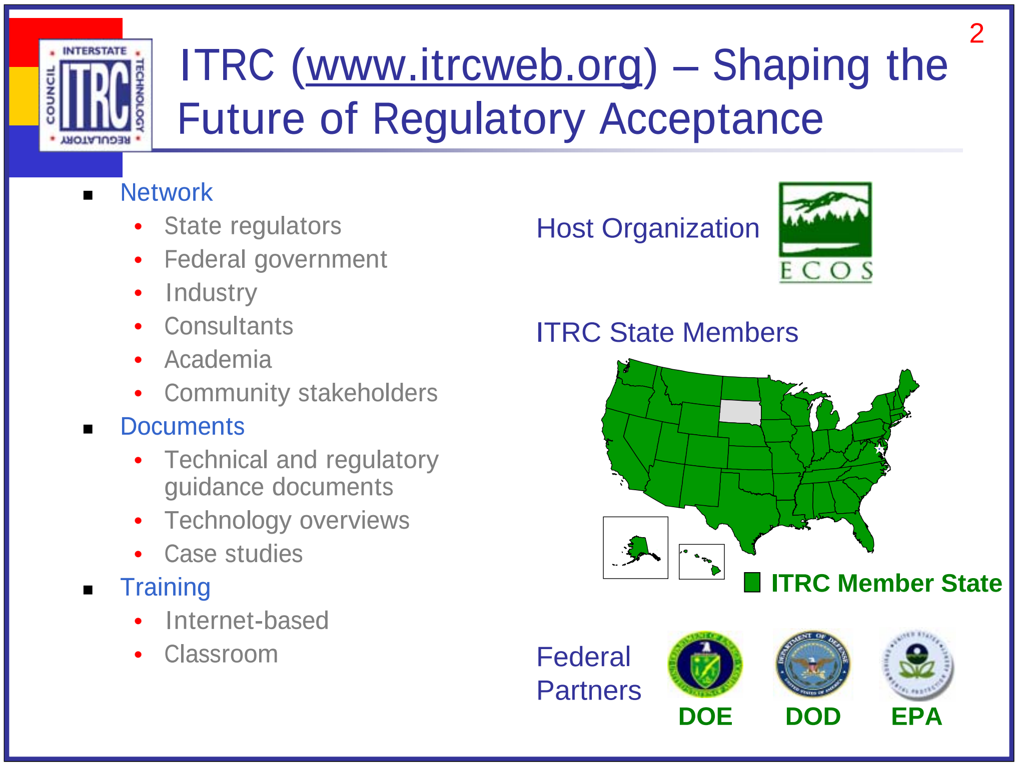

The Interstate Technology and Regulatory Council (ITRC) is a state-led coalition of regulators, industry experts, citizen stakeholders, academia and federal partners that work to achieve regulatory acceptance of environmental technologies and innovative approaches. ITRC consists of 49 states (and the District of Columbia) that work to break down barriers and reduce compliance costs, making it easier to use new technologies and helping states maximize resources. ITRC brings together a diverse mix of environmental experts and stakeholders from both the public and private sectors to broaden and deepen technical knowledge and advance the regulatory acceptance of environmental technologies. Together, we're building the environmental community's ability to expedite quality decision making while protecting human health and the environment. With our network approaching 7,500 people from all aspects of the environmental community, ITRC is a unique catalyst for dialogue between regulators and the regulated community.

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ITRC Course Topics Planned for 2007

Popular courses from 2006

- Characterization, Design, Construction, and Monitoring of Bioreactor Landfills
- Direct Push Well Technology for Long-term Monitoring
- Evaluate, Optimize, or End Post-Closure Care at MSW Landfills
- Perchlorate: Overview of Issues, Status and Remedial Options
- Planning & Promoting Ecological Re-use of Remediated Sites
- Real-Time Measurement of Radionuclides in Soil
- Remediation Process Optimization Advanced Training
- Risk Assessment and Risk Management
- Site Investigation and Remediation for Munitions Response Projects

New in 2007

- Performance-based Environmental Management
- Protocol for Use of Five Passive Samplers
- Survey of Munitions Response Technologies
- Vapor Intrusion Pathway: A Practical Guideline
- More in development…

Training dates/details at

www.itrcweb.org

Training archives at

http://cluin.org/live/archive.cfm

More details and schedules are available from www.itrcweb.org under "Internet-based Training."

Radiation Risk/Dose Assessment: Updates and Tools

Logistical Reminders

- Phone Audience
  - Keep phone on mute
  - * 6 to mute your phone and * 7 to un-mute
  - Do NOT put call on hold
- Simulcast Audience
  - Use ? at top of each slide to submit questions
- Course Time = 2 ¼ hours
- 2 Question & Answer Periods
- Links to Additional Resources
- Your Feedback

Presentation Overview

- **Module 1: Regulatory Background & Case Studies**
- **Module 2: Human Health Assessment Approaches for Radionuclides**
- **Questions & Answers**
- **Module 3: Risk Assessment Tools for Calculating PRGs for Radionuclides**
- **Module 4: Application of EPA's Radionuclide PRG Calculator**
- **Questions & Answers**
- **Wrap-up**

No associated notes.

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Meet the ITRC Instructors

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Don Siron - SC Dept. of Health & Environmental Control
Kathy Setian - EPA Region 9
Tom Schneider - OH Environmental Protection Agency
Victor Holm - Rocky Flats Citizens Advisory Board

Instructor Biographies:

Carl Spreng is a project manager at the Colorado Department of Public Health and Environment overseeing environmental restoration at DOE's Rocky Flats site and has been with the Department since 1991. Previously, he worked as an energy exploration geologist involved in searching for such diverse energy sources as oil shale, tar sands, coal, uranium, and oil & gas. Since 1999, Carl has been the co-leader of ITRC Radionuclides Team and is an instructor on all of the team's Internet-based training courses. Carl earned a bachelor's degree in 1975 and a master's in 1977, both in geology from Brigham Young University in Provo, Utah.

Smita Siddhanti, a recognized expert in risk assessment and risk management, has more than 15 years of experience in managing work related to hazardous and radioactive waste management, human health and environmental risk assessment. Currently, she is the lead support to the radionuclide work group of the Interstate Technology & Regulatory Council (ITRC). She also managed and provided technical leadership for EPA's Soil Screening Guidance for both hazardous and radioactive waste. Dr. Siddhanti holds a B.S. and M.S. in Biology, M.S. in Technology Policy from Rensselaer Polytechnic Institute, and Ph.D. in Technology and Public Policy from University of Pittsburgh.

Stuart Walker has a BA in political science and economics from the American University in Washington, DC and a MPA in policy analysis and development from George Washington University in Washington, DC. He has over 19 years in EPA working either on regulatory compliance or regulation development. Stuart Walker has been employed by U.S. EPA since 1990 in either the Superfund program (the Office of Superfund Remediation and Technology Innovation) or the Office of Radiation and Indoor Air working on issues regarding the cleanup of contaminated sites. His primary areas of responsibility include serving as the Superfund program's national lead on issues regarding radioactively contaminated CERCLA sites. In this latter role, Stuart develops national policy for characterization, cleanup and management of radioactive contamination at CERCLA sites. Previously Stuart was the lead staff person on remedy selection issues for EPA's CERCLA reauthorization team.

Purpose of today's training event

To facilitate cleanup by explaining radiation risk assessment approaches and tools, and by enhancing consistency in setting risk-based remediation goals for radionuclides.

- Provide overview of regulatory requirements for cleanup of radioactive contamination
- Clarify variations in risk assessment approaches (Dose-based vs. Risk-based)
- Elaborate on updates to CERCLA Radiation Risk Assessment
- Present tools: EPA's PRG Risk Calculator and ARAR Dose Calculator
- Apply PRG Calculator in a case study setting

Module 1, Regulatory Background and Case studies, based on a document developed by the ITRC Radionuclides Team, provides the overview of regulatory requirements for cleanup of radioactive contamination and describes lessons learned in terms of risk assessment used for developing cleanup goals at various contaminated sites.

Module 2, Human Health Assessment Approaches for Radionuclides, clarifies the variation in Dose-based and Risk-based Radiation Risk Assessment and provides and updates for both the approaches.

Module 3, Risk Assessment Tools for calculating PRGs for Radionuclides, elaborates on the PRG Risk Calculator and the ARAR Dose Calculator developed by USEPA Superfund Office.

Module 4, Application of Radionuclides PRG Calculator, goes into the observations from application of the PRG calculator in a case study setting.

Acronyms

AEA	Atomic Energy Act
AEC	Atomic Energy Commission
ALARA	As Low As Reasonably Achievable
ACF	Area Correction Factor
ARARs	Applicable or Relevant and Appropriate Requirements
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DAF	Dilution Attenuation Factor
DCF	Dose Conversion Factor
SSLs	Soil screening levels
TEDE	Total Effective Dose Equivalent
TMR	Total media risk
TRU	Transurannic
UMTRCA	Uranium Mill Tailings Radiation Control Act of 1978
RAGS	Risk Assessment Guidance for Superfund
RESRAD	Computer Model for Residual Radioactive Materials
PRGs	Preliminary Remedial Goals
ROD	Record of Decisions
RGOs	Remedial goal options
RI/FS	Remedial Investigation/Feasibility Study
RME	Reasonable Maximum Exposure

Acronym List for reference

Acronyms (Contd.)

- ICRP International Commission on Radiologic Protection
- LET Linear Energy Transfer
- LLW Low Level Waste
- MARSSIM Multi-Agency Radiation Survey and Site Investigation Manual
- MCLs Maximum Contaminant Levels
- NARM Naturally Occurring or Accelerator-Produced Radioactive Material
- NCP National Oil and Hazardous Substances Pollution Contingency Plan
- NORM Naturally Occurring Radioactive Material
- NRC Nuclear Regulatory Commission
- OSHA Occupational Safety and Health Administration
- OSWER Office of Solid Waste and Emergency Response
- PPM Part Per Million
- RI/FS Remedial Investigation/Feasibility Studies
- CRv consumption rate – vegetables
- TR Target risk level
- HEAST Health Effects Assessments Summary Tables
- SF Slope Factors
- CEDE Committed Effective Dose Equivalent
- TEDE Total Effective Dose Equivalent
- RBE Relative Biological Effectiveness

Acronym List for reference

Radiation Risk / Dose Assessment: Updates and Tools

MODULE 1:
Regulatory Background and Case Studies

Regulations are complex due to:

•multiple agencies,

•overlapping authorities, and

•multiple categories of radioactive materials.

Major Federal Laws on Radiation Protection

- Atomic Energy Act (1954) - weapons development, nuclear power plants
- Marine Protection, Research, and Sanctuaries Act (1972)
- Energy Reorganization Act (1974)
- Safe Drinking Water Act (1974) – permissible levels (MCLs) of radionuclides in drinking water systems
- Clean Air Act Amendments (1977) - NESHAPS
- UMTRACA (1978) – uranium mining/milling
- CERCLA (1980) – site cleanup
- Nuclear Waste Policy Act (1982) – Yucca Mtn.
- Low-Level Radioactive Waste Policy Act & Amendment (1980 & 1985) – Disposal Rule

Major categories of materials:

•Source materials,

•Special nuclear material,

•By-product materials and mill tailings,

•Naturally Occurring Radioactive Material (NORM) and

•Naturally Occurring or Accelerator-Produced Radioactive Material (NARM).

Agencies regulating nuclear materials:

U.S. Environmental Protection Agency (EPA)

U.S. Nuclear Regulatory Commission (NRC)

U.S. Department of Transportation (DOT)

U.S. Department of Energy (DOE)

Defense Nuclear Facility Safety Board (DNFSB)

Various state agencies

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Radiological Cleanup Standards: Variation and Influence

Different Regulatory Authorities

↓

Different Regulatory Standards

↓

Different Methodologies for Calculating Cleanup Goals

Differences between cleanup levels from site to site are due to variations in one or more of the elements in the cleanup level development process. The process begins with determining which regulatory authority applies. Calculations of cleanup levels vary from site to site due to different physical settings, cleanup authorities, risk assessment methodologies, etc

<u>Cleanup authorities:</u>

CERCLA

RCRA

NRC decommissioning criteria

DOE orders

State radiation control regulations

Etc.

Major U.S. Radiation Standards

Regulation	Agency	Standard / Numerical limit
General public	NRC	100 millirem/year
Uranium mill tailings	EPA; NRC	Ra-226/228: 5/15 pCi/g (surface/subsurface) Rn-222: 20 pCi/m^2-sec (outdoors) Rn-220/222: 0.02 working levels (indoors) U234/238: 30 pCi/L
High-level waste operations	NRC	100 millirem/year
Spent fuel, high-level and TRU waste	EPA	All pathways: 15 millirem/year Groundwater: 4 millirem/year
Low-level waste	NRC	25 millirem/year (75 mrem/year to thyroid)

Not a comprehensive list – most major radiation standards.

There are more standards than those listed in the table. For example, the Uranium Mill Tailings regulations have other standards such as 0.5 pCi per liter limit for radon at the perimeter of a disposal site (40 CFR 192.02 (b) (2)) and a 20 micro-roentgen per hour over background standard for occupied or habitable buildings.

There is a compliance criteria in the Drinking Water Standards for beta radiation – 50 picocuries per liter [40 CFR 191.03(a)]

The complete set of standards under the Uranium Fuel Cycle are 25 millirem/year (whole body), 25 millirem/year (per other critical organ) and 75 millirem/year (thyroid) [40 CFR 191.03 (a)].

Major U.S. Radiation Standards (continued)

Regulation	Agency	Standard / Numerical limit
Drinking water	EPA	Ra-226/228: 5 pCi / L U: 30 µg/L Gross alpha: 15 pCi / L Beta/photon (man-made): 4 millirem/yr
Uranium fuel cycle	EPA	25 millirem/yr
Superfund (CERCLA) cleanup	EPA	1 in 10,000 to 1 in 1,000,000 (10^{-4}-10^{-6}) increased lifetime risk of getting cancer
Decommissioning	NRC	25 millirem/yr (up to 100 mrem/yr)
Occupational standards	OSHA	5,000 millirem/yr (all workers)
Occupational standards	NRC	5,000 millirem/yr (radiation workers)
NESHAPS air pollutants	EPA	10 millirem/year to nearest offsite receptor

Most states have radiological drinking water standards which are potential ARARs.

Most existing standards are expressed in dose.

In addition, existing standards, CERCLA site decision makers must also consider risk.

There are more standards than those listed in the table. For example, the Uranium Mill Tailings regulations have other standards such as 0.5 pCi per liter limit for radon at the perimeter of a disposal site (40 CFR 192.02 (b) (2)) and a 20 micro-roentgen per hour over background standard for occupied or habitable buildings.

Basis of Radiological Risk Assessments

1. Ionizing radiation is a carcinogen, a mutagen and a teratogen.
2. Cancer risks are usually the most harmful, so most assessments of harmful effects only consider carcinogenic effects.
3. Risk from radiological exposures are generally estimated in a manner similar to exposures to chemical contaminants.
4. Total incremental lifetime cancer risk from radiation exposure = sum of risks from all radionuclides in all exposure pathways.

Uranium:

A kidney toxin in soluble form.

Chemical toxicity comparable to or greater than the radiotoxicity.

A reference dose (RfD) established for chemical toxicity.

Both radiogenic cancer risk and chemical toxicity should be considered for uranium.

Chemical exposures:

-soil ingestion

-dust inhalation

-drinking water

-dermal exposure

Radiation exposures:

(in addition to chemical exposure pathways)

-external gamma radiation

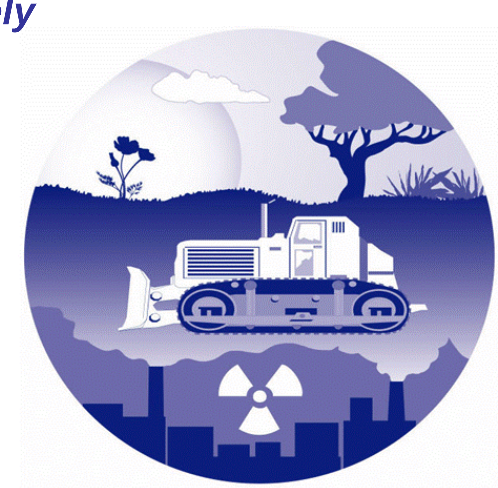
-radon

-consumption of produce

-no dermal exposure

ITRC Radionuclides Team

"Determining Cleanup Goals at Radioactively Contaminated Sites: Case Studies"



(RAD-2, April 2002)

Download at:
www.itrcweb.org under "Guidance Documents"

This document published in 2002 summarizes the various regulatory standards and requirements that dictate cleanup at radioactively contaminated sites. It reports processes used to develop cleanup levels and presents case studies from 12 selected sites to demonstrate variations in decision-making framework and basis. This document can be found at

www.itrcweb.org

Click on → Guidance Documents (under ITRC icon)

Click on → Radionuclides

Click on → Determining Cleanup Goals at Radioactively-Contaminated Sites (PDF file)

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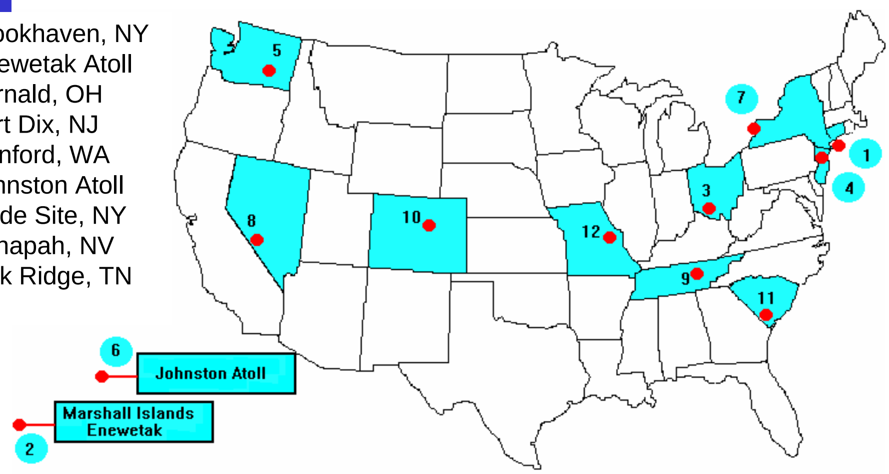
Case Studies

1. Brookhaven, NY
2. Enewetak Atoll
3. Fernald, OH
4. Fort Dix, NJ
5. Hanford, WA
6. Johnston Atoll
7. Linde Site, NY
8. Tonapah, NV
9. Oak Ridge, TN



10. Rocky Flats, CO
11. Savannah River Site, SC
12. Weldon Spring, MO

Case studies:

Brookhaven National Laboratory, New York

Enewetak Atoll, Marshall Islands

Fernald Environmental Management Project, Ohio

Fort Dix, New Jersey

Hanford Site, Washington

Johnston Atoll

Linde Site, New York

Nevada Test Site and Associated Ranges, Tonapah, Nevada

Oak Ridge, Tennessee

Rocky Flats, Colorado

Savannah River Site, South Carolina

Weldon Spring Site, Missouri

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Rocky Flats - Colorado

•One of DOE’s closure sites.

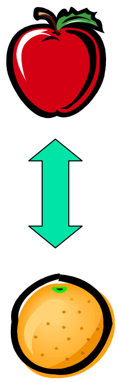
CASE STUDIES (cont.)

Differences in Cleanup Levels Due to Differences in:

- Regulatory Authority
- Radiation Standards / ARARs
- Health Assessment Approaches
- Land Uses / Exposure Scenarios
- Computer Codes
- Input Parameters
- Physical Settings
- State and Community Acceptance
- Types of Cleanup Goals reported

No associated notes

Terminology Used at Case Study Sites



- Preliminary Remediation Goals
- Soil Screening Levels
- *Action Levels*
- Risk-Based Concentrations
- **Cleanup Standards**
- ALARA Goal Levels
- Soil Cleanup Criteria
- Derived Concentration Guideline Levels
- Final Remediation Levels
- Remedial Goal Options
- Allowable Residual Soil Concentrations
- Guideline Concentrations
- **Release Criteria**

No Associated Notes

Example Case Study: Oak Ridge – Melton Valley Watershed

Radionuclide	10^{-4} Risk (pCi/g)	25 mrem/yr Dose (pCi/g)	Limiting criteria for selection
Cesium-137	14	40	Risk
Cobalt-60	7.4	8.4	Risk
Curium-244	2300	950	Dose
Europium-154	11	18	Risk
Lead-210	450	270	Dose
Radium-226	5 *(Alternative*	*Concentration)*	ARAR
Strontium-90	1200	3400	Risk
Uranium-233	5100	5500	Risk
Uranium-234	6500	6000	Dose
Uranium-235	81	170	Risk
Uranium-238	310	850	Risk

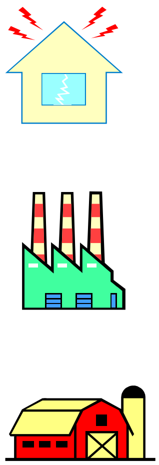
Oak Ridge Case Study (see Table 18 in *Determining Cleanup Goals at Radioactively-Contaminated Sites,* 2002). Oak Ridge calculated soil concentrations for the Melton Valley Record of Decision using input parameters for risk calculations and dose calculations that were as equivalent as possible. The risk levels represent a 10^{-4} incremental lifetime cancer risk. The more conservative value for each radionuclide was then selected as the cleanup level. The cleanup level for radium was based on an ARAR value.

•Neither approach necessarily leads to more conservative cleanup values than the other.

Rocky Flats Case Study (see Tables 20-22 in *Determining Cleanup Goals at Radioactively-Contaminated Sites,* 2002). In 1996, dose calculations (15 mrem/year) were compared to risk calculations (1 x 10^{-4}). Re-calculations in 2002 again compared dosed-based values (25 mrem) to risk-based values (1 x 10^{-5}).

Case Studies

Selection of Exposure Scenarios



	Resident	Rancher	Farmer	Park/open space user	Commercial industrial	Fish wildlife service	Ecotourist	Homesteader	Subsurface
Brookhaven	●				●				
Enewetak	●		●						●
Fernald			●	●					
Fort Dix	●				●				
Hanford	●								
Johnston Atoll	●					●	●	●	
Linde Site					●				
Nevada	●	●	●		●				
Oak Ridge					●				
Savannah River					●				
Rocky Flats	●			●	●	●			
Weldon Spring	●		●	●		●			

See Table 4 in *Determining Cleanup Goals at Radioactively-Contaminated Sites* (RAD-2, 2002).

Download at www.itrcweb.org

Selecting appropriate current and future land use and exposure scenarios is a critical step in calculating cleanup levels:

•Residential/agricultural scenario ➔ usually allow unrestricted use of a site

•Other scenarios ➔ institutional controls required

Case Studies – Pathway Contributions from Calculated Residential Cleanup Levels for Plutonium

Site:	Clean Slate (1997)	Hanford (1997)	Johnston Atoll (2000)	Rocky Flats (1996)	Rocky Flats (2002)
Cleanup Level (pCi/g)	200	35	2.1- 210	252	116
Basis	100 mrem/yr dose to various receptors	15 mrem/yr dose to resident	10^{-6} to 10^{-4} risk to wildlife researcher	15 mrem/yr dose to resident	10^{-5} risk to refuge worker
Pathway:					
-inhalation	30%	30%	5%	93%	49%
-soil ingestion	31%	23%	87%	6%	50%
-water	0%	0%	0%	0%	0%
-plant ingestion	29%	45%	0%	1%	0%
-other	10%	1%	8%	0%	1%

Updated from Table 27 in *Determining Cleanup Goals at Radioactively-Contaminated Sites* (RAD-2, 2002).

1. Variation in cleanup levels from site to site.
2. Variation in pathway contributions from site to site.

Basis for Calculated Plutonium Soil Concentrations

Site:	*Exposure Scenario*	*Concentration (pCi/g)*	*Date (Basis / Authority)*
Enewetak	Residential Agricultural Food-gathering Subsurface	40 80 160 400	1973 (NEPA, Atomic Energy Act (AEA))
Fernald	Park user (on site) Resident farmer (off site)	77 9	1995 (CERCLA)
Fort Dix	-Not described- Resident	8 26	1992 (EPA guidance) 2000 (state statute)
Hanford Reservation	Rural resident Commercial/Industrial	34 245	1995 (draft proposed rule, Part 196)
Johnston Atoll	-ALARA- Fish & wildlife researcher Resident EcoTourist Homesteader	13.5 2.1–210 1.9–190 38–3800 0.32–32	1989 (EPA guidance) 2000 (CERCLA)

See Table 25 in *Determining Cleanup Goals at Radioactively-Contaminated Sites* (RAD-2, 2002). The slide shows the basis for calculating soil cleanup concentrations for Plutonium at various sites. Note that most of the sites are dictated by CERCLA authority.

Shows:

•which exposure scenarios were assessed

•how cleanup levels at the same site vary depending on land use assumptions.

•residential scenario is 3-7 times more conservative than industrial/commercial

Enewetak

•Nuclear weapons test site in Marshal Islands (1946-58)

•Defense Nuclear Agency report (1981)

Ft. Dix

•USAF site on an US Army base

•BOMARC missile accident (1960)

•DOE ROD: 4 mrem/year → 8 pCi/g (1992)

•NJ Standards: 15 mrem/year → 26 pCi/g (2000)

Hanford

•Washington Department of Health

•PRGS: 15 mrem/year; calculated using RESRAD version 5.7

Fernald

•Cleanup levels developed by DOE/USEPA/Ohio EPA

•10^{-6} risk (on site receptors); 10^{-5} risk (off site receptors)

Johnston Atoll – 13.5 pCi/g established as cleanup level by EPA Region 9 since it had previously been achieved and thus was considered ALARA; equivalent to 7.1 x 10^{-6} residential risk; 2000 values recommended in Defense Threat Reduction Agency report which used RESRAD version 5.82 to calculate.

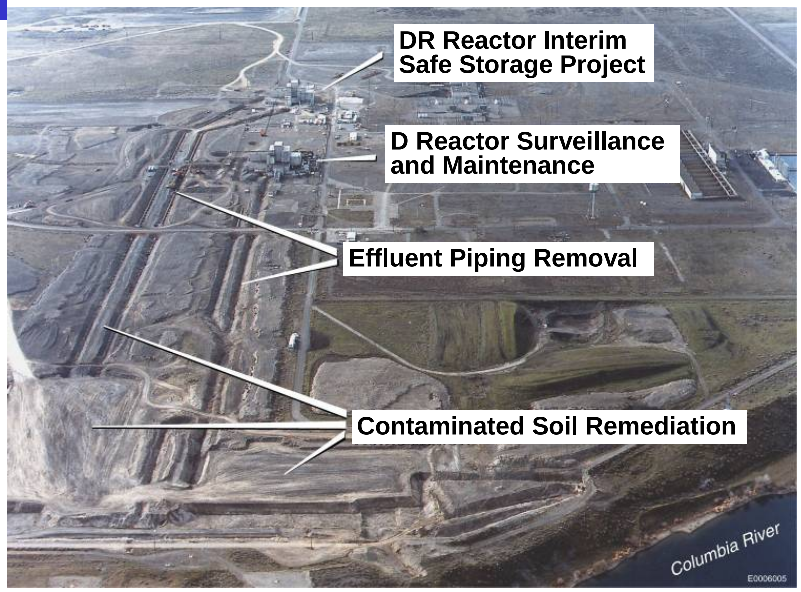
Fernald – Waste Pit 5 Excavation

View to the east of sludges exposed in the Waste Pit 5 excavation with the On-Site Disposal Facility in the background (2004).

Fernald – On-Site Disposal Facility

View to the west from the top of the On-Site Disposal Facility (2004).

Hanford –
D Reactor / DR Reactor Remediation



No associated notes

Johnston Island – Thor Missile

The Thor missile used in the Bluegill Prime nuclear device test in 1962. This missile and test device caught fire and was destroyed on the launch pad.

Basis for Calculated Plutonium Soil Concentrations (continued)

Site:	*Exposure Scenario*	*Concentration (pCi/g)*	*Date (Basis / Authority)*
Lawrence Livermore NL	Resident Industrial/Office worker	2.5 10	1998 (Soil Screening Level (SSL) guidance)
Rocky Flats (Cleanup Agreement)	Office worker Open space user Resident	1088 1429 252	1996 (draft proposed rule, Part 196)
Rocky Flats (PRGs)	Resident Office worker Open space user	2.5 10 17.5	2000 (CERCLA)
Rocky Flats (Cleanup Agreement)	Wildlife refuge worker Rural resident Office worker Open space user	116 28 81 114	2002 (CERCLA)

See Table 25 in *Determining Cleanup Goals at Radioactively-Contaminated Sites* (RAD-2, 2002).

Lawrence Livermore National Laboratory (CA)

•Big Trees Park (offsite);

•EPA Region 9 soil screening levels (1998);

•not intended as cleanup levels

Rocky Flats – DOE/USEPA/ CDPHE:

1996 – Action levels based on a 15-mrem annual dose (withdrawn draft Part 196); used RESRAD version 5.61

2000 – PRGs are 10^{-6} risk

2002 – Refuge worker and resident action levels are derived from probabilistic risk calculations (10^{-5} risk using the 95th percentile of risk distribution); Wildlife refuge worker action level set at 50 pCi/g – well below the calculated value; office worker and open space user action levels correspond to point estimates of a 10^{-5} risk. These risk-based action levels are more conservative than RESRAD-calculated 25-mrem/year dose levels, derived to satisfy ARARs.

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Rocky Flats - Colorado

One of DOE’s closure sites; view to the northwest.

Rocky Flats – Remediation at 903 Pad

Removal of plutonium-contaminated soil occurred under large, moveable tent structures.

Rocky Flats – Building Decontamination & Decommissioning

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Some of the decontamination and decommissioning work at Rocky Flats.

Conclusions from ITRC Case Studies

- Determining cleanup levels and selecting remedies can involve complex and emotional issues; each cleanup action should be evaluated on its own merits
- Cleanup numbers used at one site should not be used to justify similar cleanup numbers at another site
- The risk assessment and risk management processes should be distinct and separate

See Section 6 in *Determining Cleanup Goals at Radioactively-Contaminated Sites* (RAD-2, 2002).

Conclusions from ITRC Case Studies (continued)

- Consistency within given risk assessment approaches is a worthwhile and achievable goal
- Land use assumptions have major consequences for cleanup levels, cleanup costs, and long-term stewardship
- Training would help lend consistency to assessment of risks and selection of remedies during cleanup

See Section 6 in *Determining Cleanup Goals at Radioactively-Contaminated Sites* (RAD-2, 2002).

Many DOE sites are being regulated by CERCLA authority (Joint Policy EPA and DOE, 1995)*, which requires the sites to cleanup on the basis of acceptable risk range calculated by methods defined by EPA. The next two modules elaborate on the details of CERCLA requirements and the EPA guidance issued to assist at various stages of cleanup at radioactively contaminated sites.

**Policy on Decommissioning DOE Facilities under CERCLA*, May 22, 1995.

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Radiation Risk / Dose Assessment: Updates & Tools

MODULE 2:

Human Health Assessment Approaches for Radionuclides

The objective of this module is to provide an overview of approaches, basis of their variation and updates.

By the end of this module, participants should:

•Understand differences between risk-based and dose-based approaches to radiation risk assessment

•Be familiar with the recent updates to these radiation risk assessment approaches

Radiation Human Health Assessment Approaches

- **RISK APPROACH**
  - Where **risk** is calculated directly by assigning a unit of risk for every unit of exposure (Cancer Slope Factor) and multiplying by the total exposure.
- **DOSE APPROACH**
  - Where **dose** is calculated by multiplying a dose conversion factor by the total intake/exposure.
  - The calculated dose can also be multiplied by a probability coefficient to arrive at a risk value.

Risk Approach is where risk is calculated as the likelihood of excess cancer incidence using slope factors, which measure the likelihood of incremental cancer induction per unit of exposure, while the Dose Approach uses dose conversion factors (DCFs) expressed in terms of unit dose/unit intake.

Both methods use “Absorbed Dose” as the basis of further determination.

The methodology used to evaluate health effects due to radiation at contaminated sites depends on the regulatory authority. The use of the two different methods are due to the historical variation of missions or EPA and NRC. Since regulated by NRC, DOE orders have followed International Commission of Radiological Protection (ICRP) effective dose equivalent approach. This Dose approach originated with the need to protect the workers and the public from ongoing nuclear operations and dose can be measured on site, the ICRP methods are based on “safe dose” below which exposures are protective. EPA approached the cleanup of radioactively contaminated sites from the perspective of having studied cancer-causing chemicals, they were used to expressing future risks in terms of excess cancer causing probabilities.

Note – risk is unitless. The risks to potentially exposed human receptors is computed as the product of the estimated lifetime intake or external exposure for a contaminant times a measure of the likelihood of incremental cancer induction per unit of exposure for that contaminant.

Radiation Human Health Assessment Approaches

Risk = Exposure X Cancer Slope Factor

Dose = Exposure X Dose Conversion Factor (DCF)

The two methods for calculating adverse health effects associated with radiation exposure (Absorbed Dose) are as follows:

1. Risk Approach (Cancer Slope Factor approach) – where risk is calculated directly by assigning a unit of risk for every unit of exposure (slope factor), and multiplying by the total exposure. For radiation, exposure is an ionization term applied only to photons and measured in roetegen.

The slope factor is an estimate of the probability of response, i.e. probability of an individual developing cancer per unit intake. (i.e., probability of adverse effect/pCi). Here, the cancer slope factors have taken the intake and used a set of assumptions and calculated the absorbed dose. The dose is compared to human exposure/cancer data and a risk of cancer is assigned.

Radionuclide cancer slope factors are best estimates of the age-averaged, lifetime excess total cancer risk per unit intake of a radionuclide or per unit external radiation exposure. EPA has slope factors for most radionuclides and also for different routes of exposure (inhalation vs. ingestion)

2. Dose Assessment Approach – where a dose is calculated by multiplying a dose conversion factor (expressed in terms of unit dose/unit intake) for a given radionuclide by the total intake/exposure to that radionuclide (i.e. ingestion, inhalation, or external exposure). The calculated dose can also be multiplied by a probability coefficient to arrive at a risk value.

The dose approach is based on an annual exposure to radiation. "Dose" refers to the effective dose equivalent (EDE), a unit of measure developed by ICRP to adjust organ doses so that they may be added to the dose from external exposure for a total dose.

DCFs are set by ICRP and expressed as dose per unit of exposure. Each radionuclide has a unique DCF, depending on type of radiation, relative strength of radiation, target organs and tissues, and cancer induction rates.

A slope factor is similar to a dose conversion factor, but instead of assigning a unit dose for every unit of exposure (i.e., mrem/pCi), a unit of risk is assigned for every unit of exposure (i.e., probability of adverse effect/pCi).

Inhalation Pathway Example:

- **RISK =**
  (Inhalation Slope Factor) X (radionuclide concentration in air) X (breathing rate) X (exposure duration)

- **DOSE =**
  (DCF) X (radionuclide concentration in air) X (breathing rate) X (exposure duration)

No Associated Notes

Basis for Risk and Dose Approaches

RISK	DOSE
▪Lifetime exposure to an individual with a reasonable maximum exposure (EPA)	▪Annual exposure to an average member of the "critical group" (NRC)
▪Risk is a unitless measurement of the likelihood of an adverse affect	▪Dose equivalent is measured in units of rem, mrem, or sievert
▪Standards expressed in terms of risk (e.g., EPA's 10^{-4}-10^{-6} CERCLA risk range)	▪Standards expressed in terms of dose equivalent (e.g., NRC's 25 mrem/year)
▪Slope factors based primarily on US population	▪DCFs based on populations from other nations

Since both approaches are being used at radiological sites, it is important to understand the basis of variation and which is better to use for what purpose.

This slide compares the use of NRC's Dose Approach to EPA's Risk Approach in calculating cleanup goals at sites. This is a summary of the detailed Tables 2 and 3 in the document "*Determining Cleanup Goals at Radioactively Contaminated Sites: Case Studies"* referred to earlier.

As we discussed before, standards vary for both – for Risk approach, they are expressed as a target risks of lifetime excess cancer incidence. For Dose, standards are generally expressed as annual dose limits. This dose is usually treated as the committed dose based upon an annual intake.

Depending on the regulatory framework, risk assessors are directed to construct a "reasonable maximum exposure" or the "average member of the critical group".

Reasonable maximum exposure (RME) = highest exposure that is reasonably expected to occur at a site; resulting from a combination of all intake variables

Average member of critical group = the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances"

When calculating Dose, EPA uses RME while NRC uses the Average member of critical group.

The magnitude of discrepancy in the two methods depends on the particular radionuclide and exposure pathways for the site-specific conditions. These differences may be attributed to factors, such as the consideration of competing mortality risks and age-dependent weights assigned to individual organ risks in the two methods, and differences in dosimetric and toxicological assumptions. The comparison between the bases of the two methods is summarized in tables in this and the next two slides.

Basis for Risk and Dose Approaches (cont.)

RISK	DOSE
▪Age- and sex-dependent risk models in Slope Factors	▪Age-dependent (separate DCFs, for infants, children, and adults)
▪Slope Factor does not consider genetic risk	▪DCFs consider genetic risk
▪Considers causes of death other than radiation-induced cancer	▪Does not consider other competing causes of death
▪Low-LET & high-LET estimates considered separately for each target organ	▪Dose equivalent includes both low-LET and high-LET radiation multiplied by appropriate Relative Biological Effectiveness (RBE) factors

The first point here relates to the risk models used for slope factors and DCFs. For slope factors, age-dependent and sex-dependent risk models for 14 cancer sites are considered individually and integrated into the slope factor estimate. For DCFs, no sex-dependent models but annual dose is required for infants, children and adults separately.

Effective Dose Equivalent (EDE) values include a genetic risk component, while slope factors do not.

Competing risks or causes of death (e.g. disease, accident) are considered in slope factors based on the mortality rate from all causes at a particular age in the 1979-81 US population. DCFs do not.

Dose estimate from low-LET (Linear Energy Transfer) and high-LET dose estimates are considered separately for each target organ. Dose equivalent includes both, using RBE factors.

Basis for Risk and Dose Approaches (cont.)

RISK	DOSE
▪RBE for most sites = 20; RBE for breast =10; for leukemia =1	▪RBE for alpha radiation = 20 for all sites
▪Estimates of absorbed dose to 16 target organs/tissues	▪Effective dose considers dose estimates to 12+ target organs (+ average of 10 other organs)
▪Lung dose based on absorbed dose to tracheobronchial and pulmonary regions	▪Lung dose based on average dose to tracheobronchial, nasopharyngeal and pulmonary regions
▪Variable length to integration period (< 110 years)	▪Fixed length of 50 years for integration period

RBE = relative biological effectiveness for alpha radiation, is used in both approaches but the application differs as shown.

Organs considered for estimation of absorbed dose differ as shown. (for slope factors, 16 organs considered for 13 specific cancer sites plus residual risk, while for DCFs (ICRP, 1991), dose estimates to 12 specified target organs plus average of 10 other organs are taken into account. Under Risk, the RBE is associated with sites (organs), breast (organ) and leukemia (disease), while for Dose, the RBE is associated with only organs (both target and others).

Definition of Lung-Dose varies. For slope factors, absorbed dose used to estimate lung cancer risk computed as weighted sum of dose to tracheobronchial region (80% and pulmonary region (20%), while DCFs consider average dose to total lung (shown in slide)

The integration period, over which the effect is integrated, is variable in slope factors and fixed in DCFs. Variable length (depending on organ specific risk models and considerations of competing risks) not to exceed 110 years. Fixed length is 50 years for dose assessments.

In summary, calculating risk directly using slope factors generally yields a lower result than calculating risk using DCFs. EPA believes that for internal exposures to alpha and beta emitters, the slope factor method produces a more reliable estimate of risk. A National Research Council (1999) report concluded that “EPA has developed a methodologically more rigorous approach to assessing risk posed by chronic lifetime exposures to radionuclides…and EPA’s approach should provide more realistic estimate of risk than the approach used by NRC.”

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Radiation Human Health Assessment Approaches

- **Dose and Risk are closely related**
- **Most national and international guidelines and standards for radiation protection are in terms of dose or concentration**
- **Dose values may be converted into risk and vice versa using conversion factors**
  [Risk = (total dose) X (probability coefficient in risk/unit dose)]
- **Converted values may be somewhat different than directly-calculated values (i.e., risks converted from dose may vary as much as 10 times from risks based on slope factors for some types of exposure)**

In general, most radiation standards are concerned with radiological doses, we do not calculate the risk associated with a given dose. One simply compares the dose to an appropriate dose-based standard, e.g., 100 mrem/year for public exposure or 5,000 mrem/year for occupational exposure. However, the risk associated with a given dose can be calculated using a probability coefficient, which from fatal cancers, nonfatal cancers, and severe hereditary effects has been derived by ICRP as 7.3 x 10-2/sievert (1 sievert = 100,000 mrem). This risk coefficient is based on low LET (gamma) radiation (clearly not appropriate for some radionuclides) and considers all cancers. Thus,

Risk = (total dose) X (probability coefficient in risk/unit dose)

EPA believes that Dose Calculations using DCFs may be applicable in limited circumstances for low Linear Energy Transferring gamma radiating radionuclides, but for CERCLA cleanup, DCFs are not adequate for assessing risks, especially from internal exposures to alpha- and beta-emitting radionuclides.

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Dose Equivalent Approach

- **Absorbed Dose** – an expression of energy imparted per unit mass of tissue (rad)
- **Dose Equivalent** – a measure of the energy absorbed by living tissue, adjusted by the Quality Factor of different types of radiation (sievert, rem)
- **Effective Dose Equivalent (EDE)** – Dose Equivalent adjusted by an organ-based weighting factors to provide a risk-based equivalence to external radiation dose
- **Committed Effective Dose Equivalent (CEDE)** - is EDE summed over projected 50 y of exposure from internal radiation
- **Total Effective Dose Equivalent (TEDE)**
  = Effective Dose Equivalent (EDE for external)
  \+ Committed Effective Dose Equivalent (CEDE for internal)

Effective Dose Equivalent – accounts for the different cancer induction rates exhibited by different organs and tissues

EDE from external radiation

CEDE from internal radiation

Absorbed Dose - term is used differently for chemicals vs. radionuclides. For radionuclides, it is the expression of energy imparted per unit mass of tissue (measured in rad) while in chemicals, the absorbed dose is the uptake of the chemical itself.

Updates to Dose Equivalent Approach

- Most standards are based on DCFs in ICRP Publications 26/30 (1979)
- Revised DCFs in ICRP Publication 72 (1996).
  - ✓ Based on additional scientific data
  - ✓ More applicable to general public
  - ✓ Correspond to current cancer slope factors

DCFs are set by International Commission or Radiation Protection (ICRP), and expressed as dose per unit of exposure. Most workplace standards are based on DCFs in ICRP Publication 30 (ICRP, 1979). Revised DCFs in ICRP Publication 72 (ICRP, 1996) have not been used to update dose standards. However, the newer DCFs in ICRP Publication 72 have been utilized recently at some sites since they are based on additional scientific data and are more applicable to general public. The newer DCFs place more emphasis on the ingestion pathway at the expense of the inhalation pathway. The following factors are considered in developing these DCFs:

- Type of radiation
- Relative strength (or energy) of radiation
- Different radionuclides target different organs/tissues
- Different organs/tissues exhibit different cancer induction rates

Each radionuclide has a unique DCF and therefore produce different doses. A total dose is the sum of doses from all applicable pathways (ingestion of contaminated soil, water and plants, inhalation, and external exposure)

Superfund Radiation Risk Assessment Guidance

- **Updates of EPA Superfund guidance on Radiological Risk Assessment:**
  1. Risk Assessment Guidance for Superfund (RAGS), Part A (1989)
  2. RAGS, Part B (1992)
  3. Soil Screening Guidance for Radionuclides (2000)
  4. Soil Screening Levels - Supplemental guidance (2001)
  5. Radionuclides Preliminary Remediation Goals (RADS-PRG) Calculator (2002)

1. "Risk Assessment Guidance for Superfund (RAGS) Part A" December, 1989. OSWER Publication EPA/540/1-89/002. RAGS Part A provides guidance on the human health evaluation activities that are conducted during the baseline risk assessment. The baseline risk assessment is an analysis of the potential adverse health effects (current or future) caused by hazardous substance releases from a site in the absence of any actions to control or mitigate these releases (i.e., under an assumption of no action).

2. "Risk Assessment Guidance for Superfund (RAGS) Part B" (RAGS Part B), December 1991. OSWER Publication EPA/540/R-92/003. RAGS Part B provides guidance on using EPA toxicity values and exposure information to derive risk-based preliminary remediation goals (PRGs) for a Superfund site. Initially developed at the scoping phase using readily available information, risk-based PRGs generally are modified based on site-specific data gathered during the remedial investigation/feasibility study. Chapter 4 of RAGS Part B presents standardized exposure for calculating PRGs radionuclides. The guidance in RAGS Chapter 4 has been updated in the "Soil Screening Guidance for Radionuclides" and the Radionuclide PRGs Superfund electronic calculator.

Updates to Slope Factor Approach

- New Slope Factors for radionuclides in HEAST (EPA, 2001)
- Based on updated and improved radiation risk coefficients in Federal Guidance Report No. 13 (EPA 1999) and ICRP Publication 72.
- Updated risk coefficients are based on developments in radiation risk and dosimetry:
  - ✓ Most recent epidemiological evidence for cancer risk
  - ✓ Updated vital statistics
  - ✓ Improved ICRP biokinetic and dosimetry models
  - ✓ More relevance to general public, and
  - ✓ Most recent external dosimetry

Federal Guidance No. 13 provides updated and improved radiation risk coefficients for cancer incidence and mortality. These updated risk coefficients are the basis for new slope factors in the Health Effects Assessments Summary Tables (HEAST, 2001). The risk coefficients were revised because there have been significant developments in the scientific information concerning radiation risk and dosimetry, including

•Most recent epidemiological evidence for cancer risk

•Updated vital statistics

•Improved ICRP biokinetic and dosimetry models

•More relevance to the general public, and

•Most recent external dosimetry

Updates to Slope Factor Approach (cont.)

Changes to Slope Factors (EPA, 2001) include:

- Cancer Risk Model updated
  - ✓ Vital statistics from 1989-91 (vs. 1979-81)
- Biokinetic and dosimetry models
  - ✓ Lung Model – ICRP Publ. 66 (vs. ICRP Publ. 30)
  - ✓ Gut F1 – ICRP Publs. 56, 67, 71, 72 (vs. ICRP Publ. 30)
  - ✓ Systemic models – ICRP Publs.56, 67, 69, 71 (vs. ICRP Publ. 30)
  - ✓ Intake Rates & Organ Mass – now age and gender-specific
- External Dosimetry Models
  - ✓ Now based on *Federal Guidance Report No. 12*
- Exposure Pathways expanded
- Population Group now based on average member of general public (vs. adult worker)

External dosimetry models earlier were based on MMSOILS and SLSOILS models

Exposure pathways added are for ingestion – tap water, food, milk (radioiodine)

Updated Soil Screening Levels (SSL) Guidance

- SSL Supplemental Guidance (2001) added:
  - ✓ New methods for non-residential land use and construction activities
  - ✓ New equations for combined exposures via ingestion and dermal absorption
  - ✓ Updated dispersion modeling data for the residential air exposure models; and
  - ✓ New methods to develop SSLs for the migration of volatiles from subsurface sources into indoor air.

SSL Guidance is publicly available, in March 2001 peer review draft.

The same new SSL equations are used to calculate PRGs in the newly developed PRG calculator.

SSLs and PRGs are both risk-based concentrations, except that:

▪PRGs are medium-specific values that incorporate all exposure pathways. PRGs are based on the combined risk from multiple pathways from exposure to a single medium (e.g. residential water, industrial soil, etc.)

▪SSLs are derived from specific pathways, i.e., they are pathway-specific (ingestion, inhalation, etc.),

EPA continues to update PRG calculator consistent with new policies and science, earlier radiation SSL calculator is no longer being update

2002 MOU between EPA and NRC

- Coordination between CERCLA and NRC decommissioning
- Does not apply to Agreement States
- Does not affect how CERCLA cleanup standards are selected
- A step in the right direction for more efficient and more consistent cleanups

NRC = proponent of dose-based standards

EPA = proponent of risk-based standards

EPA and the Nuclear Regulatory Commission (NRC) developed this Memorandum of Understanding (MOU) to identify the interactions of the two agencies for only the decommissioning and decontamination of NRC-licensed sites and the ways in which those responsibilities will be exercised. Except for Section VI, which addresses corrective action under the Resource Conservation and Recovery Act (RCRA), this MOU is limited to the coordination between EPA, when acting under its CERCLA authority, and NRC, when a facility licensed by the NRC is undergoing decommissioning, or when a facility has completed decommissioning, and the NRC has terminated its license. **EPA believes that implementation of the MOU between the two agencies will ensure that future confusion about dual regulation does not occur regarding the cleanup and reuse of NRC-licensed sites.**

This MOU was distributed through a transmittal memo entitled "Distribution of Memorandum of Understanding between EPA and the Nuclear Regulatory Commission" (OSWER No. 9295.8-06a, October 9, 2002). This transmittal note includes guidance to the EPA Regions to facilitate Regional compliance with the MOU and to clarify that the MOU does not affect CERCLA actions that do not involve NRC (e.g., the MOU does not establish cleanup levels for CERCLA sites).

Selected Tools for Human Health Assessments for Radionuclides

1. Radionuclides PRG Risk Calculator (see Module 3)

2. Radionuclides ARAR Dose Calculator (see Module 3)

3. RESRAD
   - Dose Calculations
   - Risk Calculations

   Website = http://web.ead.anl.gov/resrad

Both the PRG Risk and ARAR Dose calculators are tools developed by EPA for calculating risk and then PRGs for specific radionuclide exposures. The Risk calculator first calculates risk and then back-calculates PRGs (soil concentrations) for E-06 risk

The ARAR calculator, instead of using risk, uses DCFs based on Applicable or Relevant and Appropriate Requirements (ARARs). The ARAR Dose Calculator computes an Effective Dose Equivalent using DCFs instead of Slope Factors, e.g. in inhalation scenario:

Dose = (DCF) X (radionuclide concentration in air) X (breathing rate) X (exposure duration)

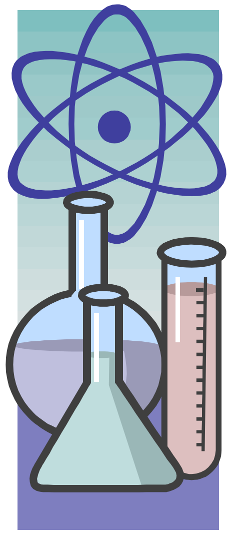
RESRAD computer code evaluates multiple exposure pathways to calculate both dose and risk. RESRAD performs forward risk/dose assessments and has been used by many sites to back-calculate cleanup levels. Version 6.0 and higher:

- performs sensitivity and uncertainty analyses
- allows various probabilistic inputs and outputs
- new external exposure model
- new area factor for inhalation
- updated and editable DCFs, slope factors, and risk coefficients

Widely used by DOE, NRC, EPA, and DoD.

EPA Superfund Policy recommends using the PRG Risk and ARAR Dose Calculators in place of RESRAD

Questions and Answers



No associated notes

Radiation Risk / Dose Assessment: Updates and Tools

Module 3:

Risk Assessment Tools for Calculating PRGs for Radionuclides

By the end of the module, the participants should be able to:

•Understand the concept and assumptions of PRGs

•Be able to use PRGs appropriately at site

•Learn how to calculate PRGs

•Become acquainted with EPA's PRG and ARAR Dose calculators for radionuclides

•This Radionuclide PRG calculator is part of a continuing effort by EPA's Office of Superfund Remediation and Technology Innovation (OSRTI) to provide updated guidance for addressing radioactively contaminated sites consistent with EPA's guidance for addressing chemically contaminated sites, except to account for the technical differences between radionuclides and chemicals.

Preliminary Remediation Goals (PRGs)

- PRGs for the Superfund program are:

  1) concentrations based on ARARs;
  2) risk-based concentrations, derived from equations combining standardized exposure assumptions with EPA toxicity data.

- PRGs are <u>not</u> de facto cleanup standards and should not be applied as such.

PRGs (Preliminary Remediation Goals) for Radionuclides, the focus of Module 3 of this training, presented on this site, for the Superfund/RCRA programs are risk-based concentrations, derived from standardized equations combining exposure information assumptions with EPA toxicity data. They are considered by the Agency to be protective for humans (including most sensitive groups), over a lifetime. However, these risk-based PRGs are not always applicable to a particular site and do not address non-human health endpoints such as ecological impacts. The PRGs contained in the PRG table are generic; that is, they are calculated without site-specific information. They may be re-calculated using site-specific data.

They are used for site "screening" and as initial cleanup goals if applicable. PRGs are not de facto cleanup standards and should not be applied as such. The PRG's role in site "screening" is to help identify areas, contaminants, and conditions that do not require further federal attention at a particular site. Generally, at sites where contaminant concentrations fall below PRGs, no further action or study is warranted under the Superfund program, so long as the exposure assumptions at a site match those taken into account by the PRG calculations. Chemical concentrations above the PRG would not automatically designate a site as "dirty" or trigger a response action. However, exceeding a PRG suggests that further evaluation of the potential risks that may be posed by site contaminants is appropriate. PRGs are also useful tools for identifying initial cleanup goals at a site. In this role, PRGs provide long-term targets to use during the analysis of different remedial alternatives. By developing PRGs early in the decision-making process, design staff may be able to streamline the consideration of remedial alternatives.

What are Risk-Based PRGs?

- They are contaminant levels considered by the EPA to be protective for humans (including most sensitive groups), over a lifetime.
- PRGs role in site "screening" is to help identify areas, contaminants, and conditions that do not require further attention at a particular site.

No associated notes

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Recommended Approach for Developing PRGs

1. Identify PRGs at scoping
2. Modify them as needed at the end of the Remedial Investigation (RI) or during the Feasibility Study (FS) based on site-specific information from the baseline risk assessment, and
3. Ultimately select remediation levels in the Record of Decision (ROD)

PRGs are identified early in the CERCLA process. PRGs are modified as needed at the end of the Remedial Investigation (RI) or during the Feasibility Study (FS) based on site-specific information from the baseline risk assessment. Ultimately the remediation levels are selected through the use of the 9 NCP remedy selection criteria. The 9 NCP criteria are:

Threshold - the two most important criteria that must be satisfied by any alternative in order to be eligible for selection

1. Overall protection of human health and the environment
2. Compliance with applicable or relevant and appropriate requirements

Primary Balancing Criteria - are used to identify major trade-offs between remedial alternatives

1. Long-term effectiveness and permanence
2. Reduction of toxicity, mobility, or volume through treatment
3. Short-term effectiveness
4. Implementability
5. Cost

Modifying Criteria

1. State acceptance
2. Community acceptance

The NCP describes how the detailed analysis of alternatives is to be performed using these 9 criteria (see 55 FR 8719 to 8723, March 8, 1990).

PRG Calculator for Radionuclides

- A PRG calculation tool to assist risk assessors, remedial project managers, and others involved with risk assessment and decision-making at CERCLA sites.
- Web address:
  http://epa-prgs.ornl.gov/radionuclides/

This tool presents standardized risk-based PRGs and variable risk-based PRG calculation equations for radioactive contaminants. PRGs are presented for residential soil, outdoor worker soil, indoor worker soil, tap water, and fish ingestion. The risk-based PRGs for radionuclides are based on the carcinogenicity of the analytes. Non-carcinogenic effects are not considered for radionuclide analytes, except for uranium for which carcinogenic and non-carcinogenic effects are considered. To determine PRGs for the chemical toxicity of uranium, and for other chemicals, go to the Soil Screening Guidance webpage. The standardized PRGs are based on default exposure parameters and incorporate exposure factors that present RME conditions. This database tool presents PRGs in both activity and mass units. Cancer slope factors used are from HEAST.

NOTE: For uranium, HI = 1 (see Risk Q&A)

This Radionuclide PRG calculator is part of a continuing effort by EPA's Office of Superfund Remediation and Technology Innovation (OSRTI) to provide updated guidance for addressing radioactively contaminated sites consistent with EPA's guidance for addressing chemically contaminated sites, except to account for the technical differences between radionuclides and chemicals.

PRG Calculator for Radionuclides (cont.)

- Based on the carcinogenicity (risk-based) of the analytes. In general, only uranium is considered significant for non-carcinogenic toxicity.
- Quantities expressed in units of activity (e.g., pCi) in addition to units of mass (e.g., mg).
- Does not address non-human health endpoints such as ecological impacts.

At Superfund radiation sites, EPA generally evaluates potential human health risks based on the radiotoxicity, rather than on the chemical toxicity, of each radio-nuclide present. Uranium, in soluble form, is a kidney toxin at mass concentrations slightly above background levels, and is the only radionu-clide for which the chemical toxicity has been identified to be comparable to or greater than the radiotoxic-ity, and for which a refer-ence dose (RfD) has been established to evaluate chemical toxicity. For radioisotopes of uranium, both effects (radiogenic cancer risk and chemical toxicity) should be considered. To determine PRGs for the chemical toxicity of uranium, and for other chemicals, go to the Soil Screening Guidance webpage at:

http://www.epa.gov/superfund/resources/soil/index.htm”.

Typically units of decay rate (activity) instead of mass are used to quantify the concentration of radioactive material in soil because the carcinogenic risks of exposure to soils contaminated with radioactive materials are related more to the decay rate of the material than to its mass. The Radionuclide PRG calculator provides outputs in mass units also since mass provides insight and information into treatment selection, treatment compatibility, and treatment efficiency, particularly for remedial actions involving mixed waste. For more discussion of activity and mass units, see Appendix B to the Soil Screening Guidance for Radionuclides: Technical Background Document.

The EPA guidance “Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments” contains an eight step process for using benchmarks for ecological effects in the remedy selection process.

Calculating Radionuclide PRGs

- This calculation tool provides the ability to:
  - ✓ Generate generic PRGs based on standard default exposure parameters
  - ✓ Modify the standard default exposure parameters to calculate site-specific PRGs
- In order to set radionuclide-specific PRGs in a site-specific context, we need:
  - ✓ information on the radionuclides that are present onsite
  - ✓ the specific contaminated media
  - ✓ land-use assumptions
  - ✓ assumptions behind pathways of individual exposure

The recommended approach for developing remediation goals is to identify PRGs at scoping, modify them as needed at the end of the RI or during the FS based on site-specific information form the baseline risk assessment, and ultimately select remediation levels in the ROD. In order to set radionuclide-specific PRGs in a site-specific context, however, assessors must answer fundamental questions about the site. Information on the radionuclides that are present onsite, the specific contaminated media, land-use assumptions, and the exposure assumptions behind pathways of individual exposure is necessary in order to develop radionuclide-specific PRGs.

This calculation tool provides the ability to modify the standard default PRG exposure parameters to calculate site-specific PRGs. The Soil Screening Guidance for Radionuclides documents (Users Guide and Technical Background Document) and the Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites provide information on adjusting the default parameters in the calculator with site-specific information.

The PRG calculator establishes PRG concentrations for each radionuclide, as if it were the only radionuclide present. Cancer risk from all radiological and non-radiological contaminants should be summed to provide risk estimates for persons exposed to both types of carcinogenic contaminants .

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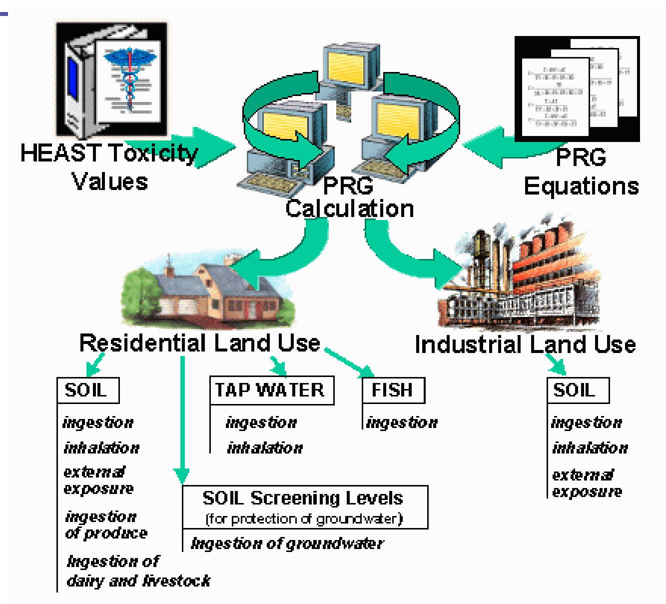
Preliminary Remediation Goals: Risk-based Calculation



PRG Calculator ➔ the latest updated compilation of radiation risk assessment factors and methodology.

Does not include an air pathway.

The next 20 slides will show how the calculator works

Following slides are in order presented in PRG Calculator.

PRG Rad Calculator –

Risk-Based PRG Selection

1) Please select PRGs and analytes you wish to search:

- ❑ Residential Soil
- ❑ Outdoor Worker Soil
- ❑ Indoor Worker Soil
- ❑ Tap Water
- ❑ Fish Ingestion
- ❑ Soil to Ground Water
- ❑ Agricultural Soil

2) Please select desired units option:

- ❑ pCi/g
- ❑ Bq/g

Step 1, select one or more of the exposure scenarios for which you want to develop PRGs.

Step 2, select output units for activity in either picocuries per gram or bequerals per gram. Outputs will also be given in units of mass.

PRG Rad Calculator –

Risk-Based PRG Selection

3) Radionuclides

Ac-223
Ac-224
Ac-225
Ac-226
Ac-227
Ac-227+D
Ac-228
Ag-102
Ag-103
Ag-104
Ag-104m
Ag-105
Ag-106
Ag-106m
Ag-108
Ag-108m
Ag-109m

4)

- ❑ Get Default PRGs
- ❑ Calculate Site-specific PRGs

5) You must select one of the following output options:

- ❑ View on Screen
- ❑ Tab delimited file
- ❑ Comma delimited file

Step 3, that allows for selection of radionuclide of concern, allows selection anywhere from Actinium to Zirconium, including the radioactive decay chain products (with suffix "+D")

First Order Decay

- Selected radionuclides and radioactive decay chain products are designated with the suffix "+D" (e.g., U-238+D, Ra-226+D, Cs-137+D) to indicate that cancer risk estimates for these radionuclides include the contributions from their short-lived decay products, assuming equal activity concentrations (i.e., secular equilibrium) with the principal or parent nuclide in the environment.
- Assumes secular equilibrium with the parent radionuclide in the environment.
- Decay chain ends @ 100 years

Step 4 – allows for selection of PRGs using default parameters or using site-specific measurements. The calculations used to come up with PRGs is shown in the following slides.

Step 5 is basically providing the output mode to show the calculated PRGs.

Particulate Emission Factor

(Needed for Residential Soil, Agricultural Soil, Outdoor Worker Soil, and/or Indoor Worker Soil)

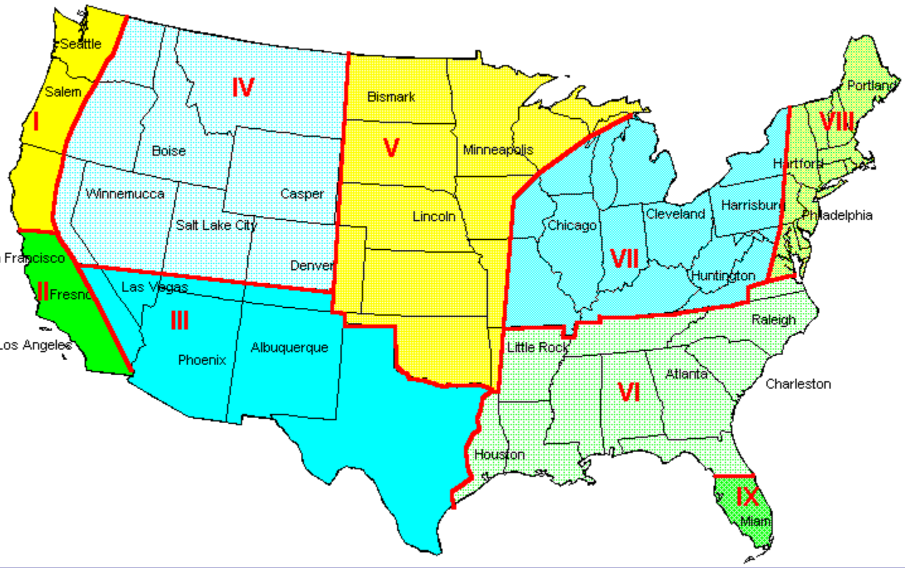
$$PEF = Q/C * \frac{3,600}{0.036 * (1 - V) * (U_m / U_t)^3 * F(x)}$$

- ❑ City (Climatic Zone)
- ❑ Surface (acres)
- ❑ Q/C (inverse of the mean conc. at the center of a 0.5-acre-square source) g/m^2-s per k g/m^3
- ❑ V (fraction of vegetative cover) unitless
- ❑ U_m (mean annual windspeed) m/s
- ❑ U_t (equivalent threshold value of windspeed at 7 m) m/s
- ❑ F(x) (function dependent on U_m/U_t) unitless

If in Step 4, you choose to calculate PRGs using site-specific parameters, the first screen you will see when you go in site-specific is the calculation of Particulate Emission Factor (PEF). PEF is required for calculations in the soil scenarios for residential, agricultural, outdoor and indoor worker.

PEF is dependent on the weather conditions in specific cities and the following map provides the climatic zone conditions for the US states/cities.

U.S. Climatic Zones: For Calculating Particulate Emission Factor



No associated notes.

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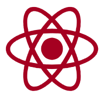
Residential Soil PRG Calculation

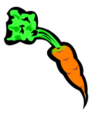
Total Risk from Residential Soil

= Risk from Direct Ingestion of radionuclides in soil – adult/child
(SFo X intake from direct ingestion of soil)

+ Risk from Wind Blown Dust Inhalation
(SFi X inhalation of volatiles and suspended particulates)



+ Risk from External Radiation from gamma-emitting of radionuclides in soil
(SFe X concentration of gamma-emitting radionuclides in soil)



+ Risk from Ingestion of Home-grown Produce
(SFp X intake of home-grown produce)

The scenario specific calculations for PRGs are built in the calculator and the following set of slides will show you some of the major scenario calculations of risk and PRG. First, we are calculating scenario specific risk and then the relative PRG. The risk calculated for the specific scenario is then plugged into the equation for PRG as shown in the following slide.

What is built into the residential scenario – types of exposures added to make the residential soil total risk are shown on this slide.

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Residential Soil PRG Equation:

$$C(pCi/g) = \frac{TR \times t \times \lambda}{ED \times (1 - e^{-\lambda t}) \times \left[\begin{array}{l} \left(SF_s \times IR_s \times 10^{-3}(g/mg) \times EF\right) + \left(SF_i \times IR_i \times \frac{10^3(g/kg)}{PEF} \times EF \times \left[ET_o + (ET_i \times DF_i)\right]\right) + \\ \left(SF_e \times \frac{EF}{365\,(d/yr)} \times ACF \times \left[ET_o + (ET_i \times GSF)\right]\right) + \left(SF_p \times (CR_f + CR_v) \times 10^3(g/kg) \times TF_p \times CPF\right) \end{array} \right]}$$

Where:

TR - target risk level (unitless)

t - time/duration over which the radionuclide decays (years)

Lambda (λ) - defined as 0.693/radionuclide half life

ED - exposure duration (years)

The calculation for specific PRG -- i.e. concentrations of soil based on specific target risk, exposure duration and total risk from soil – is shown in this slide. The numerator is the unitless target risk that factors in the duration (in years) and radionuclide half-life, both for accommodating the fate and decay of radionuclides over time. The denominator is the Total Risk, calculated for scenarios shown in the last slide, adjusted for exposure duration.

The Total Risk calculations show the input parameters for the four the sub-scenarios for residential soil: 1)incidental ingestion of soil, 2)inhalation of windblown dust, 3) external radiation, and 4) ingestion of home-grown produce.

PRG Parameters That May be Modified:

- **TR** – target excess individual lifetime cancer risk (unitless)
- **ED** – exposure duration (yr)
- **t** – duration of radionuclide decay (yr)
- **$IF_{soil/adj}$** - age-adjusted soil ingestion factor (mg-yr/day)
- **EF** - exposure frequency (days per 365 days) (unitless)
- **ET_o** - fraction of time the receptor spends outdoors (unitless)
- **ET_i** - fraction of time the receptor spends indoors (unitless)

The previous equation for calculating PRG can use the defaults for the various input parameters or one can put in site-specific values for the parameters shown in this and the next slide.

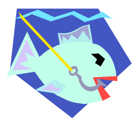
PRG Parameters That May be Modified (cont.):

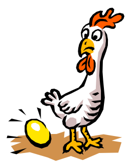
- **GSF** - gamma shielding factor (unitless)
- **IR** – rate of incidental soil ingestion (mg/day)
- **IRA** – inhalation rate (m^3/day)
- **ACF** – area correction factor of small lot size (unitless)
- **DFi** – indoor dilution factor (unitless)
- **CPF** – contaminated plant fraction (unitless)
- **CRf** – consumption rate – fruits
- **CRv** – consumption rate - vegetables

Additional examples of input parameters where either the defaults or site-specific values may be used.

Agricultural Soil PRG Calculation

Total Risk from Agricultural Soil





= **Residential Risks**

+ **Risk from Fish Intake** (SFf X Intake of fish from waters that get agricultural runoff pollution)

+ **Risk from Beef Intake** (SFf X Intake of beef that gets radionuclides partitioned from cows grazing on plants from contaminated farms)

+ **Risk from Swine Intake** (SFf X Intake of meat from contaminated farms)

+ **Risk from Poultry Intake** (SFf X Intake of poultry from contaminated farms)

+ **Risk from Eggs Intake** (SFf X Intake of eggs from contaminated poultry)

+ **Risk from Milk Intake** (SFf X Intake of milk where radionuclides are partitioned from contaminated grass to cow milk)

Similar to the Soil Scenario, the total risk from Agricultural soil exposures are shown on this slide. The total agricultural soil risk adds up risk of the residents from soil exposures to the risk of ingesting contaminated fish and eggs etc. on the farm.

Agricultural Soil Equation:

$$C(pCi/g) = \frac{TR \times t \times \lambda}{ED_r \times \left(1 - e^{-\lambda t}\right) \times \left[ING_s + INH_s + EXT_s + PROD + FISH + BEEF + MILK + SWINE + EGGS + POULTRY\right]}$$

$$ING_{s(g/pCi\text{-}yr)} = IR_s \times EF \times SF_s \times 10^{-3}(g/mg)$$

$$INH_{s(g/pCi\text{-}yr)} = IR_i \times EF \times \left[ET_o + \left(ET_i \times DF_i\right)\right] \times SF_i \times \frac{10^3(g/kg)}{PEF}$$

$$EXT_{s(g/pCi\text{-}yr)} = \frac{EF}{365\ d/yr} \times ACF \times \left[ET_o + \left(ET_i \times GSF\right)\right] \times SF_e$$

$$PROD_{(g/pCi\text{-}yr)} = \left(CR_f + CR_v\right) \times TF_p \times CPF \times SF_f \times 10^3(g/kg)$$

$$FISH_{(g/pCi\text{-}yr)} = SF_f \times IR_f \times 10^3(g/kg) \times \frac{1}{\left(K_d + \sigma \times \left(\frac{S}{\rho}\right)\right)} \times TF_f \times \frac{A_s}{A_w}$$

$$MILK_{(g/pCi\text{-}yr)} = IR_m \times \left(\left(TF_m \times FI_m \times TF_p\right) + \left(TF_m \times FI_{sm}\right) + \left(TF_m \times FI_{wm} \times \frac{1}{\left(K_d + \sigma \times \left(\frac{S}{\rho}\right)\right)} \times \frac{1}{DF_w}\right)\right) \times SF_f \times 10^3(g/kg)$$

$$MEAT_{(g/pCi\text{-}yr)} = \left(IR_b + IR_p\right) \times \left(\left(TF_b \times FI_b \times TF_p\right) + \left(TF_b \times FI_{sb}\right) + \left(TF_b \times FI_{wb} \times \frac{1}{\left(K_d + \sigma \times \left(\frac{S}{\rho}\right)\right)} \times \frac{1}{DF_w}\right)\right) \times SF_f \times 10^3(g/kg)$$

Again, similar to the Soil scenario, this slide shows the calculation of PRG or concentration of soil relative to the total risk calculated for scenarios shown in the previous slide. The Agricultural soil risk includes inhalation, ingestion, external, produce, fish, beef, milk, swine, poultry and eggs intake exposures. The specific calculation of each of these is shown in separate boxes following the main equation.

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Commercial / Industrial Land Use – Soil

Total risk from Industrial Soil

= Risk from direct ingestion of radionuclides in soil by a worker
(SFo X Intake from direct ingestion of soil)

\+ Risk from inhalation of resuspended radioactive particulates by a worker
(SFi X Intake from inhalation)

\+ Risk from external radiation from gamma-emitting radionuclides by a worker
(SFe X Concentration of gamma-emitting radionuclides in soil)

Similarly, the total risk from Industrial soil is calculated for workers using the risk from direct ingestion of soil, inhalation of soil vapor and particulates, and external exposures. The Slope factors for calculation are specific to ingestion, inhalation and external.

For SF, we start using unit risk for inhalation, in chemical risk but for rad risk, we will still continue to use slope factors.

Outdoor Worker Equation:

$$C(\mathrm{pCi/g}) = \frac{TR \times t \times \lambda}{ED \times EF \times (1 - e^{-\lambda t}) \times \left[\left(SF_s \times IR_s \times 10^{-3}(\mathrm{g/mg})\right) + \left(SF_i \times IR_i \times \frac{10^3(\mathrm{g/kg})}{PEF} \times \left[ET_o + (ET_i \times DF_i)\right]\right) + \left(SF_e \times \frac{1}{365(\mathrm{d/yr})} \times ACF \times \left[ET_o + (ET_i \times GSF)\right]\right) \right]}$$

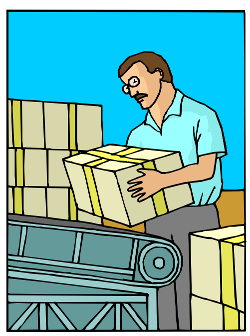
Following the previous risk calculation, the PRG for outdoor worker is calculated using the equation shown here. Once again, the denominator is where the four sub-scenarios risk are calculated, adjusted by exposure duration and exposure frequency. The Exposure Time (ET) used in the risk calculations accommodate for exposure time spent indoors vs. outdoors.

Here PEF is the Particulate Emission Factor and the GSF is the Gamma Shielding Factor, both can be input for site-specific conditions.

The outdoor worker is a long-term receptor exposed during the work day who is a full time employee of the company operating on-site and who spends most of the workday conducting maintenance activities outdoors. The activities for this receptor (e.g., moderate digging, landscaping) typically involve on-site exposures to surface and shallow subsurface soils (at depths of zero to two feet).

Indoor Worker Equation:

$$C(pCi/g) = \frac{TR \times t \times \lambda}{ED \times EF \times (1 - e^{-\lambda t}) \times \left[\left(SF_s \times IR_s \times 10^{-3}(g/mg) \right) + \left(SF_i \times IR_i \times \frac{10^3 (g/kg)}{PEF} \times \left[ET_o + (ET_i \times DF_i) \right] \right) + \left(SF_e \times \frac{1}{365(d/yr)} \times ACF \times \left[ET_o + (ET_i \times GSF) \right] \right) \right]}$$



Similar to the Outdoor worker, the indoor worker equation for risk and PRG are shown here. It is very similar to the outdoor worker, except it uses different Exposure Times for indoor vs. outdoor than the previous equation. In both of the equations, DF is the dilution factor for indoor air.

This receptor spends most, if not all, of the workday indoors. Thus, an indoor worker has no direct contact with outdoor soils.

Residential use – Tap Water

Total risk from water

= Risk from ingestion of radionuclides in water by an adult

(SFo X Intake from ingestion)

+ Risk from indoor inhalation of volatile radionuclides released from water by an adult

(SFi X Intake from inhalation)

For total risk from exposure to contaminated water, the risk is calculated for ingestion of radionulides and inhalation of volatile radionuclides (radium, radon, tritium, etc.)

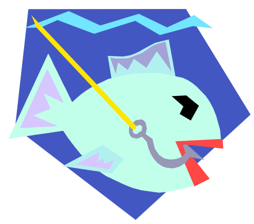
Tap Water Equation:

$$C(pCi/g) = \frac{TR}{ED \times EF \times \left[\left(SF_w \times IR_w\right) + \left(SF_i \times IR_i \times K\right)\right]}$$

Tap Water specific PRG is shown here as explained in the previous slide.

Fish Ingestion Equation:

$$C(pCi/g) = \frac{TR}{ED \times EF \times SF_f \times IR_f}$$



Similar to others, Fish ingestion specific PRG is calculated using the above equation.

Soil to Groundwater Equations:

Partitioning:

$$SSL_{DC} = C_w * 10^{-3} * \left(K_d + \frac{\theta_w}{\rho_b}\right) * \frac{t * \lambda}{(1 - e^{-\lambda t})}$$

Mass Loading:

$$SSL_{DC} = \frac{C_w * I * ED * 10^{-3} * t * \lambda}{\rho_b * d_s * (1 - e^{-\lambda t})}$$

$$DAF = 1 + \left(\frac{K * i * d}{I * L}\right)$$

$$d = (0.0112 * L^2)^{0.5} + d_a * \{1 - e^{[(-L*I)/(K*i*d_a)]}\}$$

To account for the soil to groundwater movement of the radionuclides, the Soil Screening Levels (same as PRGs) use the equations that accommodate partitioning between soil and water, by using the specific Kd, partition coefficient, and mass loading. Here, the DAF is the Dilution-Attenuation Factor to accommodate fate of radionuclides.

Part 3 of Technical Background Document (TBD) for the Soil Screening Guidance for Radionuclides contains an evaluation of five detailed soil to groundwater vadose zone models (HYDRUS, MULTIMED-DP, FECTUZ, CHAIN, CHAIN 2D) for more complete site conditions. The report "Simulating Radionuclide Fate and Transport in the Unsaturated Zone: Evaluation and Sensitivity Analyses of Select Computer Models" provides a more detailed technical analysis of these five models. This report supports the information provided in the TSD on determining the general applicability of the models to subsurface conditions, and an assessment of each model's potential applicability to the soil screening process.

Please note that the simple relationship between soil organic carbon content and sorption observed for organic chemicals does not apply to inorganics (including radionuclides). The number of significant influencing parameters, their variability in the field, and differences in experimental methods result in as much as seven orders of magnitude variability in measured metal K_d values reported in the literature. This variability makes it much more difficult to derive generic K_d values for metals (including radionuclides) than for organics. Therefore, it is recommended that K_d values be measured for site-specific conditions. If the K_d is not measured site-specifically, then a conservative K_d should be used in calculating PRGs. The PRG calculator defaults to a conservative K_d value where one could be obtained from the literature, then one must be measured site-specifically. See part C.2 of the Soil Screening Guidance for Radionuclides: User's Guide for guidance on developing site-specific K_d values

PRG Calculator Tables

Plutonium-239 default values

- Excel or PDF formats
- Units of activity (pCi/g) or mass (mg/kg)

Toxicity					
Soil Ingestion Slope Factor (risk/pCi)	Soil Ingestion Slope Factor-Adult (risk/pCi)	Water Ingestion Slope Factor (risk/pCi)	Food Ingestion Slope Factor (risk/pCi)	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/y per pCi/g)
2.76E-10	1.21E-10	1.35E-10	1.74E-10	3.33E-08	2.00E-10

Preliminary Remediation Goals (PRG)					
Residential Soil (pCi/g)	Agricultural Soil (pCi/g)	Outdoor Worker Soil (pCi/g)	Indoor Worker Soil (pCi/g)	Tap Water (pCi/L)	Fish Ingestion (pCi/g)
2.59E+00	6.09E-03	1.43E+01	2.59E+01	3.53E-01	1.01E-02

The slide shows the screen of output tables for calculated "Generic" PRGs for plutonium-239, using default parameters and the latest toxicity values

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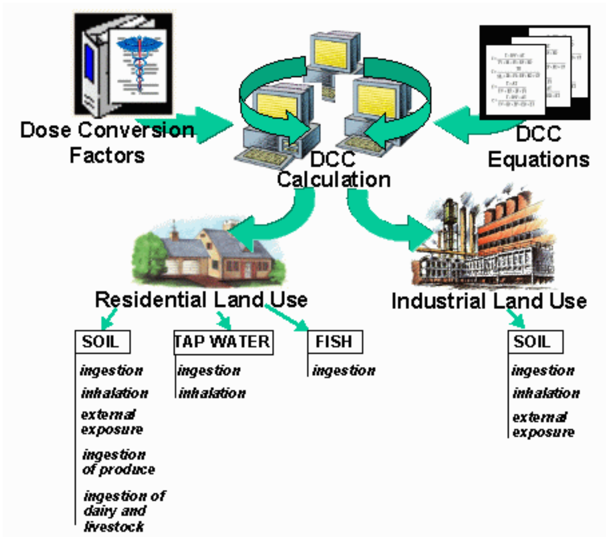
Radionuclide ARAR Dose Compliance Concentrations (DCCs) for Superfund



The purpose of this is to provide a radioactive dose compliance concentrations (DCC) calculation tool to assist risk assessors, remedial project managers, and others involved with risk assessment and decision-making at CERCLA sites in developing DCCs. It is EPA's recommendation that dose assessments should only be conducted under CERCLA where necessary to demonstrate ARAR compliance. Further, dose recommendations in guidance should generally not be used as to-be-considered material. Also, EPA generally does not use ARARs greater than 15 mrem/yr to establish cleanup levels at CERCLA sites. Cleanup levels not based on an ARAR should be based on the carcinogenic risk range (generally 10^{-4} to $10^{-6)}$, with 10^{-6} as the point of departure and 1 x 10^{-6} used for PRGs.

For further information regarding EPA's policy to not establish CERCLA cleanup levels based on dose (mrem/yr) except to comply with ARARs, please see page 2 of December 17, 1999 memo to EPA Regions from Stephen D. Luftig, Director Office of Emergency and Remedial Response and Stephen D. Page Director Office of Radiation and Indoor Air entitled "Distribution of OSWER Radiation Risk Assessment Q & A's Final Guidance", which states "Two issues addressed in this Risk Q & A should be noted here. First, the answer to question 32 in the Risk Q & A is intended to further clarify that **15 millirem per year is not a presumptive cleanup level under CERCLA, but rather site decision-makers should continue to use the risk range when ARARs are not used to set cleanup levels**. [emphasis added] There has been some confusion among stakeholders regarding this point because of language in the 1997 guidance. EPA is issuing further guidance today to site decision makers on this topic. This Risk Q&A clarifies that, in general, **dose assessments should only be conducted under CERCLA where necessary to demonstrate ARAR compliance. Further, dose recommendations (e.g., guidance such as DOE Orders and NRC Regulatory Guides) should generally not be used as to-be-considered material (TBCs)**. [emphasis added] Although in other statutes EPA has used dose as a surrogate for risk, the selection of cleanup levels for carcinogens for a CERCLA remedy is based on the risk range when ARARs are not available or are not sufficiently protective. Thus, in general, site decision-makers should not use dose-based guidance rather than the CERCLA risk range in developing cleanup levels. This is because for several reasons, **using dose-based guidance would result in unnecessary inconsistency regarding how radiological and non-radiological (chemical) contaminants are addressed at CERCLA sites** [emphasis added]. These reasons include: (1) estimates of risk from a given dose estimate may vary by an order of magnitude or more for a particular radionuclide, and; (2) dose based guidance generally begins an analysis for determining a site-specific cleanup level at a minimally acceptable risk level rather than the 10-6 point of departure set out in the NCP.

Variations between ARAR Dose Calculator and Risk Calculator

1. ARAR Dose Calculator computes a Target Dose Limit using Dose Conversion Factors (DCFs) instead of Slope Factors; e.g. in inhalation scenario:

<u>Dose</u> = (DCF) X (radionuclide concentration in air) X (breathing rate) X (exposure duration)

2. ARAR Dose Calculator uses same basic equations for back-calculating a PRG from an ARAR dose limit:

<u>Dose limit</u> = DCF X Concentration of Radionuclides in media (PRG) X Exposure

<u>PRG</u> = Dose limit / (DCF X Exposure)

An approach similar to that taken for calculation of PRGs may also be used to calculate soil "**<u>compliance concentrations</u>**" based upon various methods of dose calculation. A set of simple equations for target dose rate (e.g., either critical organ dose or single limits), radionuclide dose conversion factor (DCF), and intake/exposure parameters will be presented for use in calculating soil cleanup concentrations. These equations will be identical to those in the PRG for Radionuclides, except that the target dose rate (ARAR based) will be substituted for the target cancer risk (1×10^{-6}), and a DCF will be used in place of the slope factor. Please note that the target dose rate is generally a cleanup level when a dose standard is an ARAR (other than single dose limits greater than 15 mrem/yr such as NRC's 25/100 mrem/yr decommissioning rule), while the target risk number of 10^{-6} is a preliminary number.

Site decision-makers should choose the DCFs (ICRP 2, 30, or 60) required by the ARAR. Note that this calculator does not address ICRP 2. If DCFs are not specified within the regulation (for example, specifically required for compliance within the Code of Federal Regulations for a federal standard that is being complied with as an ARAR), then site decision-makers should generally use ICRP 2 DCFs for whole body and critical organ dose limits (e.g., 25/75/25 and 25/75 mrem/yr dose limits), and generally use ICRP 60 DCFs for single limit standards (e.g., 10 mrem/yr).

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Radiation Risk / Dose Assessment: Updates and Tools

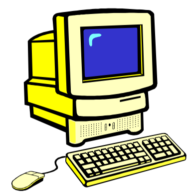
Module 4:

Application of the EPA Radionuclide PRG Calculator

The Case-study application described in this module for the participants to understand the challenges of applying the PRG Risk Calculator, and apply the tools described in Module 3

Application of PRG Calculator

Three approaches used for PRG for comparison:

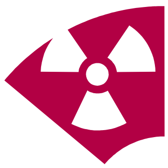


1) EPA RAGS Part B (1992)
2) EPA PRG Calculator (default inputs)
3) EPA PRG Calculator (site-specific inputs)

No associated notes

Application of PRG Calculator

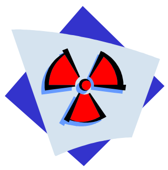
Screening levels were calculated for the following isotopes:



- Ac-228
- Ba-133
- Cm-242
- Cs-137+D
- Eu-154
- I-129
- Pb-212
- Pu-239
- Ra-226+D
- Sr-90
- U-235

No associated notes

Comparison Table of Residential Soil PRGs (10^{-6})



Isotope	RAGS B pCi/g	Rad PRG (default) pCi/g
Ac-228	1.28E-02	*7.32E+02*
Ba-133	4.02E-02	*1.75E-01*
Cm-242	7.48E+00	*3.22E+02*
Cs-137 +D	2.27E-02	*5.97E-02*
Eu-154	9.92E-03	*4.99E-02*
I-129	*2.24E+00*	5.96E-01
Pb-212	1.13E-01	*3.64E+03*
Pu-239	*2.85E+00*	2.59E+00
Ra-226 +D	6.77E-03	*1.24E-02*
Sr-90	*8.06E+00*	3.31E-01
U-235	1.09E-01	*2.05E-01*

Larger PRG values indicated in *red italics*

•Differences between RAGS Part B values and Rad PRG Calculator values are largely due to radioactive decay.

PRG Calculator Assumptions that are different than RAGS Part B

1. Use of an Area Correction Factor (ACF) of 0.9 to correct for small lot size

2. Change the assumption of indoor time spent by the resident from 15 hours to 16.4 hours, and the addition of 1.75 hours of outdoor time

3. Change of the default gamma shielding factor from 0.8 to 0.4

4. Use of the adult-only slope factor for soil ingestion for the industrial worker

Changes per the new EPA Rad PRGs guidance include:

1. For the estimate of external radiation, an individual is considered exposed to a source geometry that is effectively an infinite slab. The concept of an “infinite slab” means that the thickness of the contaminated zone and its aerial extent are so large that it behaves as if it were infinite in its physical dimensions. In practice, soil contaminated to a depth greater than about 15 cm and with an aerial extent greater than about 1,000 m2 (approximately one-quarter acre) will create a radiation field approaching that of an infinite slab. For very small areas of contamination, this will result in overly conservative estimates of risk. For calculation of PRGs, an adjustment for source area is considered to be an important modification for Superfund sites. Thus, an area correction factor, ACF, has been added.

2. EPA determined that a default gamma shielding factor of 0.4 based solely on the contribution of terrestrial radiation would be a more appropriate value to use at sites with soil contaminated with radionuclides than the previous EPA default of 0.8 which also included the effects of cosmic radiation and the inherent radioactivity in structure materials.

3. Use of the adult-only slope factor for soil ingestion for the industrial worker and modification of the Site scenario to make it consistent with the EPA indoor worker.

PRG Calculator Assumptions that are different than RAGS Part B (cont.)

5. Incorporation of a first order radioactive decay term over the exposure duration for radionuclide in soil
6. Addition of an inhalation exposure route for soils due to windblown dust with the use of an indoor air dilution factor of 0.4
7. Addition of an inhalation exposure route for H-3, C-14, Ra-224, Ra-226, and Ra-226 +D in the tapwater calculations

First order decay term = $\mathbf{(1-e^{-\lambda\, t})}$

e - natural log
t - duration of radionuclide decay (years)
Lambda (λ) - based on radionuclide half life

Example Industrial Worker Assumptions – Deviations from the PRG Defaults

1. The example Industrial Worker scenario is a blend of the EPA indoor worker and EPA outdoor worker scenarios.

2. The hypothetical industrial worker is assumed to work outdoors 65% of his time and indoors 35% of his time in an industrial type facility.

3. Change incidental soil ingestion rate to 65 mg/d (65% of the 100 mg/d default EPA outdoor worker ingestion rate).

No associated notes

Example Industrial Worker Assumptions – Deviations from PRG Defaults

4. The assumption of outdoor time spent by the outdoor worker changed from 8 hours to 5.2. Therefore, [ETo] Outdoor exposure time fraction (unitless) = 0.217 (default = 0.333).

5. The assumption of indoor time spent by the outdoor worker changed from 0 hours to 2.8. Therefore, [Eti] Indoor exposure time fraction (unitless) = 0.117 (default = 0).

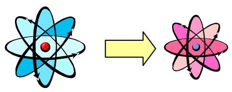
No associated notes

Comparison Table of Industrial Soil PRGs (10^{-6})

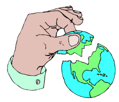
Isotope:	RAGS Part B pCi/g	Rad PRG (default outdoor worker) pCi/g	Rad PRG (site-specific industrial worker) pCi/g
Ac-228	4.80E-02	1.18E+03	1.34E+03
Ba-133	1.51E-01	3.03E-01	3.45E-01
Cm-242	3.01E+01	3.44E+03	4.87E+03
Cs-137 +D	8.52E-02	1.11E-01	1.27E-01
Eu-154	3.73E-02	8.49E-02	9.65E-02
I-129	8.87E+00	1.08E+01	1.41E+01
Pb-212	4.23E-01	6.07E+03	6.90E+03
Pu-239	1.15E+01	1.43E+01	2.00E+01
Ra-226 +D	2.55E-02	2.55E-02	2.90E-02
Sr-90	3.24E+01	4.23E+01	5.77E+01
U-235	4.11E-01	4.13E-01	4.70E-01

No associated notes

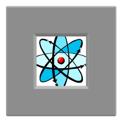
Sensitive Parameters



- Radioactive Decay



- Area Correction Factor



- Gamma Shielding Factor

- Exposure Duration

Incorporating radioactive decay into the PRG Calculator increased the resulting PRGs up to five (5) orders of magnitude above the RAGS Part B method.

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Next Steps:

- If soil measurements do not exceed the PRG, then generally no further remedial action is necessary.
- If soil measurements exceed the PRG, then it may be necessary to:
  - ✓ Evaluate the site further;
  - ✓ Determine site-specific remediation goals;
  - ✓ Remediate the site; and/or
  - ✓ Impose institutional controls.

Additional site evaluation:

- Collect additional data
- Conduct additional studies to determine site specific environmental variables
- Aggregate data over appropriate areas of concern or exposure units
- Use probabilistic methods to determine sensitive parameters
- Use geostatistical methods to show how contaminant levels are related spatially and

to determine the best spots for additional sampling.

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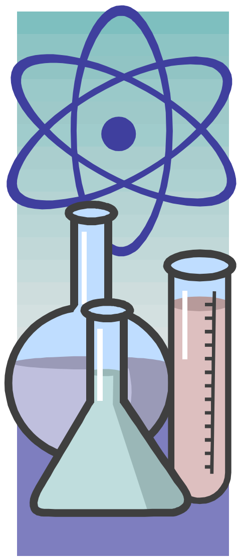
Questions and Answers



Thank you for participating in ITRC Internet-based Training. To get more information on ITRC – Go to: www.itrcweb.org

RESOURCES

***Determining Cleanup Goals at Radioactively Contaminated Sites* [ITRC, 2002]*Radionuclide Preliminary Remediation Goals (PRGs) for Superfund Electronic calculator* [EPA, 2002]**

Transmittal memo: *Distribution of Radionuclide Preliminary Remediation Goals (PRGs) for Superfund Electronic Calculator* [EPA, 2002]

***Soil Screening Guidance for Radionuclides: Users Guide and Technical Background Document* [EPA, 2000]**

***Radiation Risk Assessment At CERCLA Sites: Q & A* [EPA, 1999]**

Transmittal memo entitled *Distribution of OSWER Radiation Risk Assessment Q & A's Final Guidance* [EPA, 1999]

***Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination* (OSWER No. 9200.4-18) [EPA]**

***Simulating Radionuclide Fate and Transport in the Unsaturated Zone: Evaluation and Sensitivity Analyses of Select Computer Models* [EPA, 2002]**

EPA Superfund Radiation Risk Assessment webpage

EPA Superfund Risk Assessment webpage

EPA Superfund Radiation webpage

EPA Superfund Remedy Decisions webpage

***Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) [EPA, NRC, DOE, DOD, 2000]**

Federal Guidance Report #13

HEAST User's Guide

***Soil Screening Guidance for Radionuclides* [EPA, 1996]**

***Superfund Risk Assessment Guidance* (RAGS, Part A and B) [EPA, 1989 & 1991]**

***Supplemental Guidance for developing SSLs for Superfund Sites* (EPA, 2001)**

***Common Radionuclides Found at Superfund Sites* [EPA, 2002]**

ISCORS Report No. 1 (July 2002)

***A Guide to Selecting Superfund Remedial Actions* [EPA, 1990]**

ICRP updates on DCFs :

- *Age-Dependent Doses to Members of the Public from Intakes of Radiation, Part 5. Compilation of Ingestion and Inhalation Dose Coefficients. ICRP Publication 72* [ICRP, 1996]

- Part 3, Publication 69 [ICRP, 1995]

- Part 4, Publication 71 [ICRP, 1995]

- Publication 66 [ICRP, 1995]

Thank you for your participation

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To
Resources

http://www.clu-in.org/conf/itrc/rads/resource.cfm

Links to additional resources: http://www.clu-in.org/conf/itrc/rads/resource.cfm

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The benefits that ITRC offers to state regulators and technology developers, vendors, and consultants include:

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•helping regulators save time and money when evaluating environmental technologies

•guiding technology developers in the collection of performance data to satisfy the requirements of multiple states

•helping technology vendors avoid the time and expense of conducting duplicative and costly demonstrations

•providing a reliable network among members of the environmental community to focus on innovative environmental technologies

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•Submit proposals for new technical teams and projects

•Be part of our annual conference where you can learn the most up-to-date information about regulatory issues surrounding innovative technologies