U.S. EPA's Models for Establishing Cleanup Levels in Soil, Water, Buildings and Streets at Superfund Sites

Stuart Walker
U.S. Environmental Protection Agency
Office of Superfund Remediation
and Technology Innovation (OSRTI)
Science and Policy Branch

Presented to the IAEA EMRAS II Workgroup
"NORM & Legacy Sites"
in Vienna, Austria on September 23, 2009

EPA

Purpose

1. Provide ***brief*** overview of EPA Superfund approach for selecting cleanup levels and use of risk/dose assessment
2. Provide overview on new and upcoming CERCLA risk assessment calculators, guidance, and training for Radionuclides

Part 1

EPA Superfund Approach for Selecting Cleanup Levels

EPA

EPA Addresses Site Cleanup Under Several Laws, Programs

- Comprehensive Environmental Response, Compensation & Liability Act, CERCLA or "Superfund"
- National Contingency Plan (NCP) is regulation for CERCLA
- National Priorities List (NPL) guides EPA on which sites need further attention

EPA

What does a Superfund Site look like?

- There are many different types of Superfund sites.
  - » See following 4 pages for examples of radioactively contaminated sites.

EPA

Nuclear Metals Inc. - Massachusetts

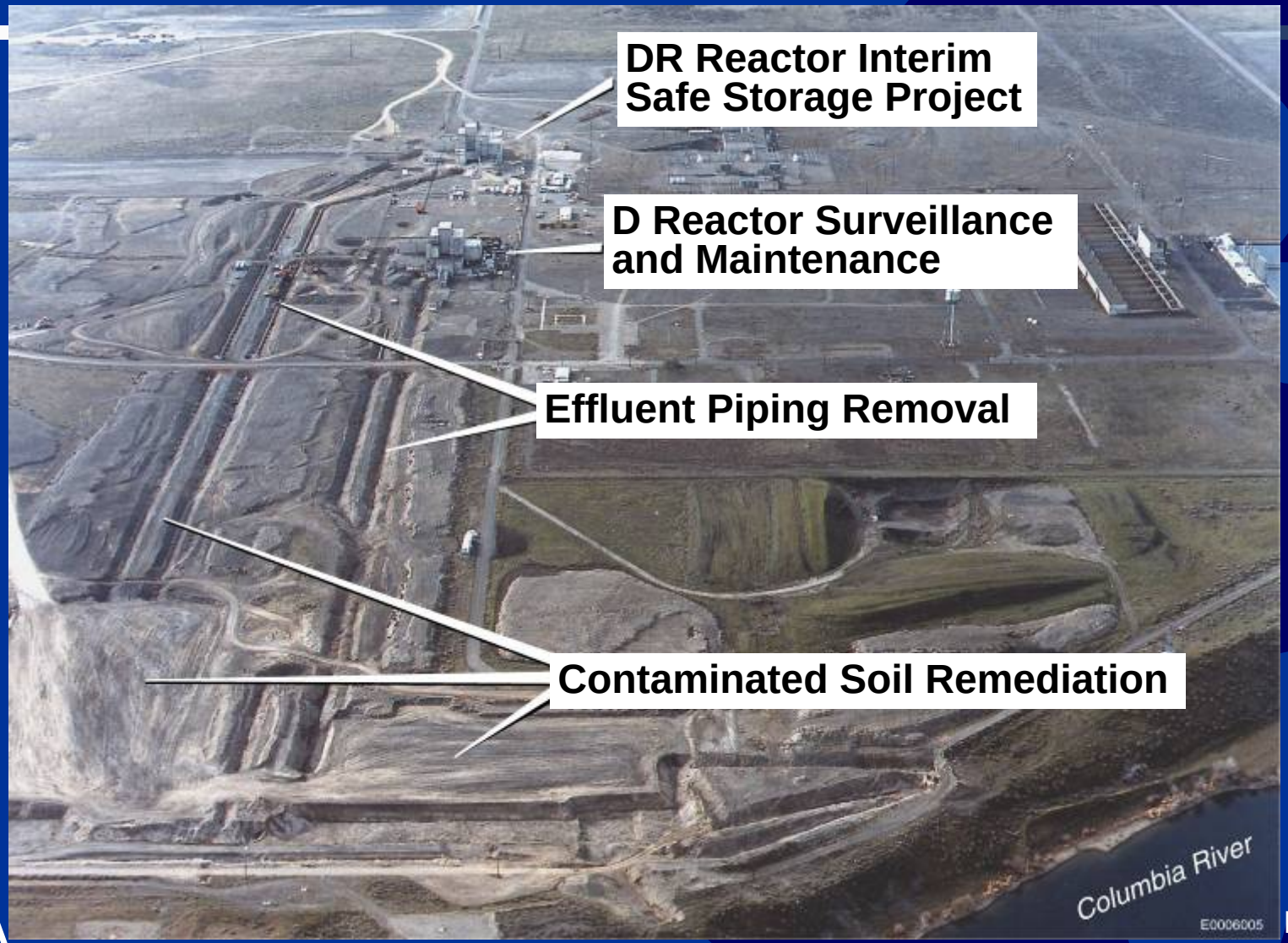
EPA

Abandoned Uranium Mines Project – Navajo Nation

Welsbach/General Gas Mantle – New Jersey

EPA

Hanford – D Reactor / DR Reactor Remediation



EPA

CERCLA Decision-making

- CERCLA cleanup decisions are made site-specifically
  - » Must comply with CERCLA and NCP
- EPA Regional site managers
  - » Removals – On Scene Coordinators (OSCs)
  - » Remedial (and NTC-removals) – Remedial Project Managers (RPMs)

Nine CERCLA Remedy Selection Criteria

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

EPA

Nine CERCLA Remedy Selection Criteria (continued)

- 6 CERCLA ARAR waivers
  1. Interim Measure
  2. Greater Risk to Health and the Environment
  3. Technical Impracticability
  4. Equivalent Standard of Performance
  5. Inconsistent Application of State Requirements
  6. Fund Balancing

EPA

Nine CERCLA Remedy Selection Criteria (continued)

- Five balancing criteria (used to evaluate between potential remedies that meet threshold criteria)
  1. Long-term effectiveness and permanence
  2. Reduction of waste toxicity, mobility, or volume
  3. Short-term effectiveness
  4. Implementability
  5. Cost

EPA

Nine CERCLA Remedy Selection Criteria (continued)

- Two modifying criteria (information from public comment period that may modify remedial action)
  1. State acceptance
  2. Community acceptance

EPA

CERCLA Cleanup Levels

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

EPA

CERCLA Cleanup Levels Are NOT Based On

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

Risk-based Cleanup Levels for Radioactive Contamination

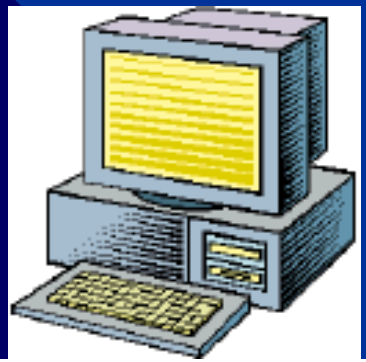
- Radiation cleanup levels expressed as risk levels, **not** mrem [mSv]
- Superfund uses “slope factors” in Health Effects Assessment Summary Tables (HEAST) instead of dose conversation tables to estimate cancer risk from radioactive contaminants
  - » HEAST has been updated with new information from Federal Guidance 13
    - —Based on information in ICRP 72

EPA/ITRC CERCLA Policy and Guidance Training

- Four modules provide:
  1. Radiation Regulatory Background and Case Studies
  2. **Overview of CERCLA Requirements**
  3. **EPA CERCLA Radiation Guidance and Tools**
  4. Challenges of Long-Term Management of Radiation Sites

EPA/ITRC CERCLA Policy and Guidance Training, cont.

- Five Live Internet rad CERCLA Policy Training sessions have been conducted
  - » 838 total participants, including 163 EPA employees
- An archived version of a live training session is available at:
  - » http://www.clu-in.org/conf/itrc/radscleanup_060507/
- Archived version was accessed by users 3,282 times between January 1, 2008 and August 26, 2009.



EPA

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.

Radiation Human Health Assessment Approaches

Risk = Exposure X Cancer Slope Factor

Dose = Exposure X Dose Conversion Factor (DCF)

EPA

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)

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

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

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

EPA

Radiation Human Health Assessment Approaches

- **Dose values may be converted into risk and vice versa using conversion factors**
- **Dose and Risk are closely related**
  - » [Risk = (total dose) X (probability coefficient in risk/unit dose)]
- **Risks converted from dose may vary as much as 10 times from risks based on slope factors for some types of exposure**

Part 2

New and Upcoming Superfund Radiation Risk Calculators and Training

Guidance: Risk Assessment Q&A

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

Guidance: Rad SSG

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

EPA

CERCLA Risk and Dose Calculators (final and *draft*)

Human Health

Cancer risk (1 x 10-6)

- PRG (soil and water)
- BPRG (inside buildings)
- SPRG (outside surfaces)

Dose (millirem per year)

- DCC (soil and water)
- *BDCC (inside buildings*
- *SDCC (outside surfaces)*

Ecological

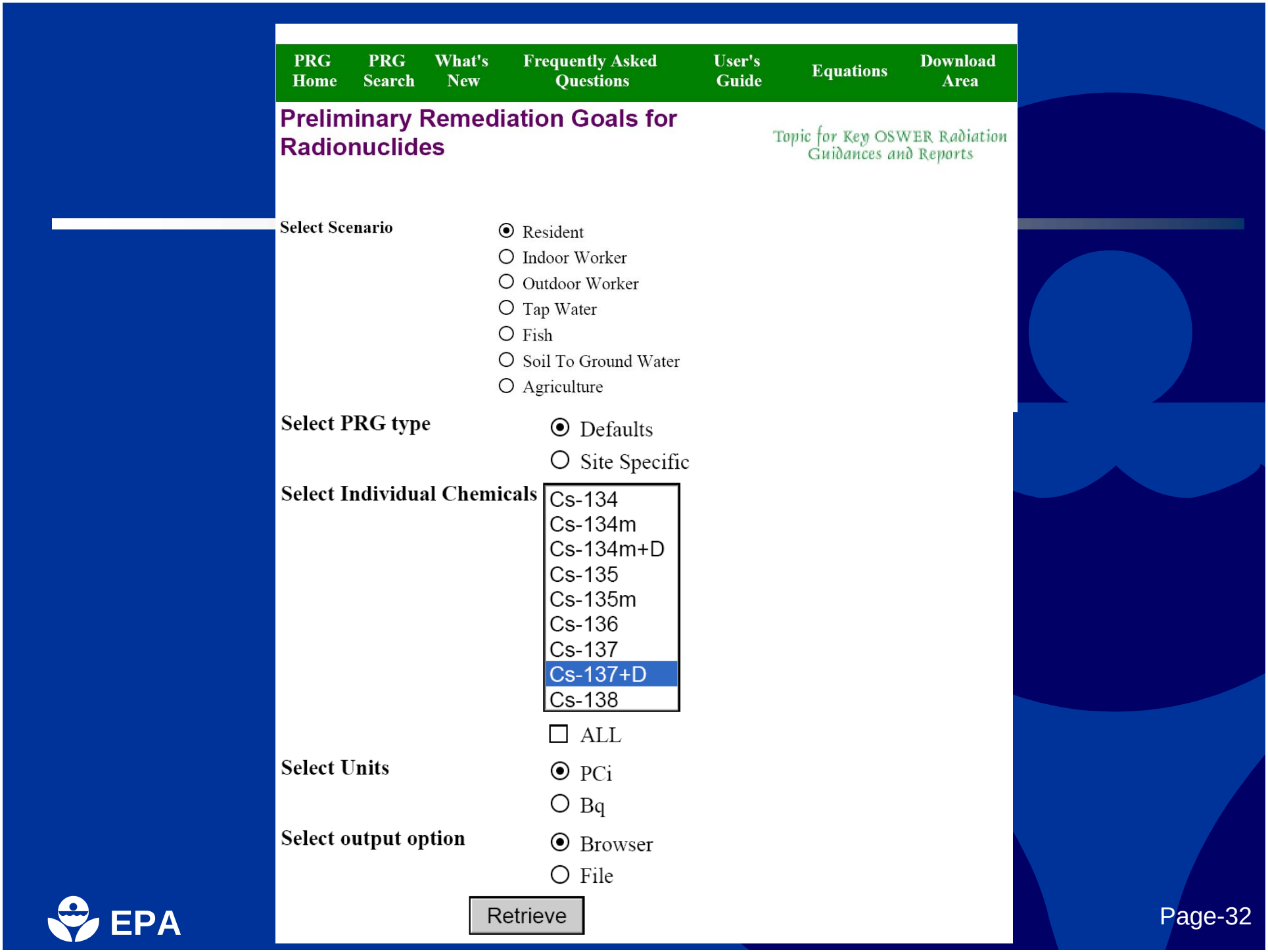
- *REB (aquatic, riparian, terresterial, plants and animals*

EPA

Default Parameters

- All CERCLA risk and dose assessment calculators for radionuclides allow default runs
  - » Default parameters already established
  - » Just select a scenario and radionuclides and click on retrieve

EPA


PRG Home
PRG Search
What's New
Frequently Asked Questions
User's Guide
Equations
Download Area
Preliminary Remediation Goals for Radionuclides
Topic for Key OSWER Radiation Guidances and Reports
Select Scenario
Resident
Indoor Worker
Outdoor Worker
Tap Water
Fish
Soil To Ground Water
Agriculture
Select PRG type
Defaults
Site Specific
Select Individual Chemicals
Cs-134
Cs-134m
Cs-134m+D
Cs-135
Cs-135m
Cs-136
Cs-137
Cs-137+D
Cs-138
ALL
Select Units
PCi
Bq
Select output option
Browser
File
Retrieve

Site-Specific Paramters

- All CERCLA risk and dose assessment calculators for radionuclides allow site-specific runs
  - » Change default parameters with defensible site-specific or regional information
  - » Still select a scenario and radionuclides, but then see each parameter

Residential Exposure to Soil

Particulate Emission Factor
Residential Exposure

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

Default	City (Climatic Zone)	0.5	Surface (acres)
93.77	Q/C_{wind}/inverse of the ratio of the geometric mean air concentration to the emission flux at center of a square source (g/m²-s per kg/m³)	4.69	U_m/mean annual wind speed (m/s)
		11.32	U_t/equivalent threshold value of windspeed at 7m (m/s)
0.5	V/fraction of vegetative cover (unitless)	0.194	F(x)/function dependenet on U_m/U_t derived using Cowherd et al. (1985) (unitless)

Ingestion, External, Inhalation, and Produce Exposure

$$C_{p(c/a)} = \frac{TR \times t_r \times \lambda}{ED_r \times \left(1-e^{-\lambda t_r}\right) \times \left[\left(SF_i \times IR_{ar} \times 10^3\,(g/mg) \times EF_r\right) + \left(SF_i \times IR_r \times \frac{10^3\,(g/kg)}{PEF} \times EF_r \times \left[ET_{ro} + (ET_{ri} \times DF_i)\right]\right) + \left(SF_e \times \frac{EF_r}{365\,(d/yr)} \times ACF \times \left[ET_o + (ET_i \times GSF)\right]\right) + \left(SF_i \times (CR_{ar} + CR_{vr}) \times 10^3\,(g/kg) \times TF_p \times CPF_r\right)\right]}$$

Where:

$$IR_{ar} = \frac{ED_{cr} \times IR_c + ED_{ar} \times IR_a}{ED_r}$$

$$IRA_{ar} = \frac{ED_{cr} \times IRA_c + ED_{ar} \times IRA_a}{ED_r}$$

$$CR_{vr} = \frac{ED_{cr} \times CR_{vc} + ED_{ar} \times CR_{va}}{ED_r}$$

$$CR_{fr} = \frac{ED_{cr} \times CR_{fc} + ED_{ar} \times CR_{fa}}{ED_r}$$

1.0E-6	TR (target risk) unitless	6	ED_{cr} (exposure duration, child) yr
30	t_r (time of exposure) yr	24	ED_{ar} (exposure duration, adult) yr
30	ED_r (exposure duration, $ED_{cr} + ED_{ar}$) yr	200	IR_c (soil intake rate, child) mg/day
350	EF_r (exposure frequency) d/yr	100	IR_a (soil intake rate, adult) mg/day
0.073	ET_{ro} (exposure time fraction, outdoor) unitless	10	IRA_c (inhalation rate, child) m³/day
0.683	ET_{ri} (exposure time fraction, indoor) unitless	20	IRA_a (inhalation rate, adult) m³/day
0.4	DF_i (indoor dilution factor) unitless	5.4	CR_{fc} (fruit consumption rate, child) kg/yr
0.9	ACF (area correction factor) unitless	20.5	CR_{fa} (fruit consumption rate, adult) kg/yr
0.4	GSF (gamma shielding factor) unitless	3.8	CR_{vc} (vegetable consumption rate, child) kg/yr
0.25	CPF_r (contaminated plant fraction) unitless	10.4	CR_{va} (vegetable consumption rate, adult) kg/yr

NOTES:

1. SF_s=soil ingestion slope factor (Risk/pCi). radionuclide-specific
2. SF_i=inhalation slope factor (Risk/pCi). radionuclide-specific
3. SF_e=external exposure slope factor (Risk/yr per pCi/g). radionuclide-specific
4. SF_p=food ingestion slope factor (Risk/pCi). radionuclide-specific
5. IR_s=age-adjusted ingestion rate (mg/day).
6. IR_i=age-adjusted inhalation rate (m³/day).
7. CR_f=age-adjusted fruit consumption rate (kg/yr).
8. CR_v=age-adjusted vegetable consumption rate (kg/yr).
9. PEF=particulate emission factor (m³/kg).
10. TF_p=soil-to-plant transfer factor. radionuclide-specific
11. λ = Decay constant (0.693/halflife) yr^{-1}. Radionuclide-specific.
12. The curie (Ci), the customary unit of activity, is equal to 3.7×10^{10} nuclear transformations per second. 1 picocurie (pCi) = 10^{-12} Ci. The International System (SI) unit of activity is the becquerel (1 Bq =1 nuclear transformation per second).

Retrieve | clear selection

1.0E-6	TR (target risk) unitless	6	ED_{cr} (exposure duration, child) yr
30	t_r (time of exposure) yr	24	ED_{ar} (exposure duration, adult) yr
30	ED_r (exposure duration, $ED_{cr} + ED_{ar}$) yr	200	IR_c (soil intake rate, child) mg/day
350	EF_r (exposure frequency) d/yr	100	IR_a (soil intake rate, adult) mg/day
0.073	ET_{ro} (exposure time fraction, outdoor) unitless	10	IRA_c (inhalation rate, child) m³/day
0.683	ET_{ri} (exposure time fraction, indoor) unitless	20	IRA_a (inhalation rate, adult) m³/day
0.4	DF_i (indoor dilution factor) unitless	5.4	CR_{fc} (fruit consumption rate, child) kg/yr
0.9	ACF (area correction factor) unitless	20.5	CR_{fa} (fruit consumption rate, adult) kg/yr
0.4	GSF (gamma shielding factor) unitless	3.8	CR_{vc} (vegetable consumption rate, child) kg/yr
0.25	CPF_r (contaminated plant fraction) unitless	10.4	CR_{va} (vegetable consumption rate, adult) kg/yr

EPA CERCLA Policy on Changing Defaults

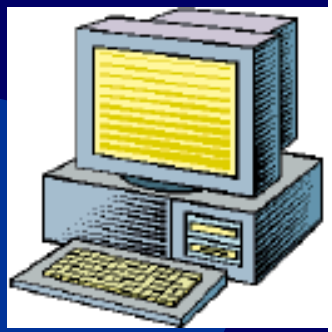
- Site managers should weigh the cost of collecting data with the potential for deriving significantly different concentrations (either PRG or DCC)
  - » Defaults are generally conservative
  - » Using site-specific data will usually result in higher allowable concentrations for same risk or dose estimate

How NOT to Change Defaults

- In general, should not replace default parameters with literature values
  - » Including defaults from other Agencies or other EPA programs
  - » Should be same values for parameters used with chemicals for the same receptor at the same site

Guidance: Rad PRG Calculator

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



Guidance: Rad PRG Calculator (continued)

- Seven scenarios/land uses available

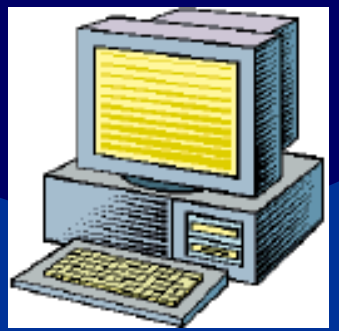
  1. Residential
  2. Agricultural
  3. Indoor workers
  4. Outdoor workers
  5. Fish ingestion
  6. Tap water
  7. Soil to groundwater

- Chemical SSL Internet equations should be used for chemical toxicity of uranium

Guidance: ARAR Dose Calculator

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

1. Residential
2. Agricultural
3. Indoor workers
4. Outdoor workers
5. Fish ingestion
6. Tap water



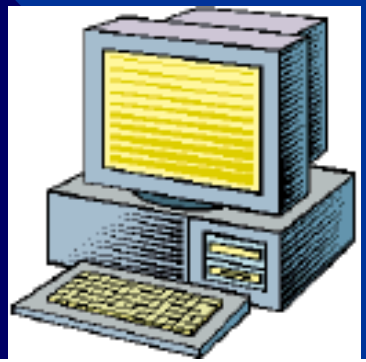
- Equations similar to those used for PRG calculator, except dose conversion factors used instead of slope factors

EPA/ITRC Radiation Risk Training

- Four modules provide:
  1. Background and Regulatory Case Studies
  2. Existing Practices in Radiation Risk Assessment
  3. **Use of Radiation PRG Calculator *(tutorial on using PRG and ARAR dose calculator)***
  4. **Case Study Application for PRG Calculator**

EPA/ITRC Radiation Risk Training, cont.

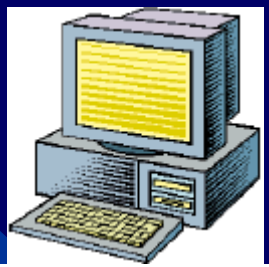
- Eight Live Internet rad CERCLA Policy Training sessions have been conducted
  - » 1,047 total participants, including 165 EPA employees
- An archived version of a live training session is available at:
  - » http://www.clu-in.org/conf/itrc/rads_051507/
- Archived version was accessed by users 1,710 times between January 1, 2008 and August 26, 2009.



EPA

Guidance: Building PRG (BPRG) Calculator

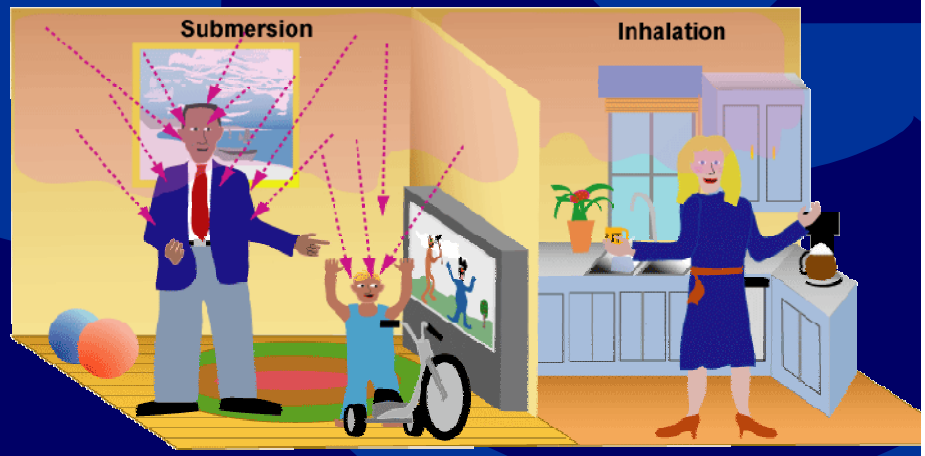
- Calculator to establish $1x10^{-6}$ risk based PRGs for the reuse of radioactively contaminated buildings.
- Equations and parameters are derived from latest EPA chemical methodology (e.g., assessment at WTC)
  - » Adjusted to account for technical differences posed by radiation



EPA

Guidance: Building PRG (BPRG) Calculator (continued)

- BPRG calculator includes 2 land use scenarios
  - » Residential
  - » Indoor worker
- Both land uses include 3 exposure routes
  - » Settled dust
  - » Ambient air
  - » Direct external exposure
    - —5 Room sizes and 4 receptor locations, both
      - –Surface
      - –Volumetric



EPA

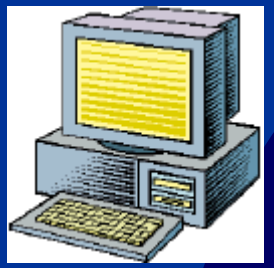
Building Dose Cleanup Concentrations (BDCC) ARAR Dose Calculator *DRAFT*

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

EPA

Surfaces PRG (SPRG) Calculator

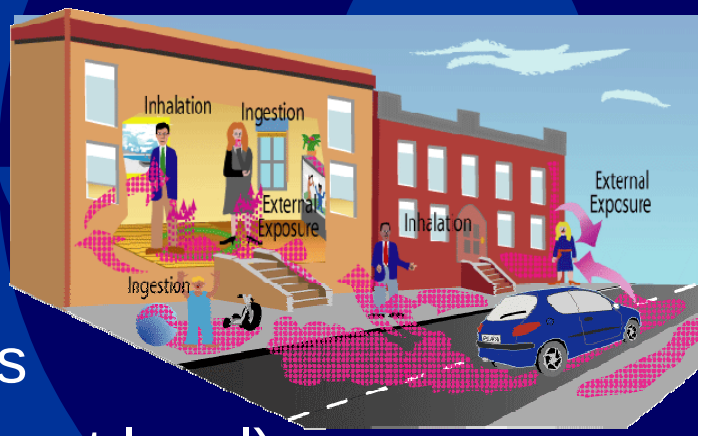
- Establish 1 x 10^{-6} risk based PRGs for radioactively contaminated ***outside*** hard surfaces (e.g., slabs, pavement, sidewalks, sides of buildings)
- Derived from rad PRG and BPRG calculators



EPA

SPRG Exposure Scenarios

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



EPA

Surface Dose Cleanup Concentrations (SDCC) ARAR Dose Calculator *DRAFT*

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

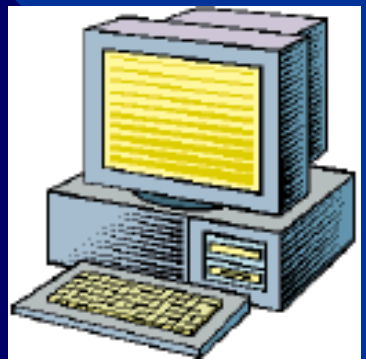
EPA

EPA/ITRC Radiation D&D Training

- Four modules provide:
  1. Introduction and Regulatory Basis for D&D
  2. Factors for Implementing D&D
  3. **Preliminary Remediation Goal (PRG) Calculators *(tutorial on using BPRG, SPRG, BDCC, and SDCC calculators)***
  4. Case Studies and Lessons Learned

Radiation D&D Training, cont.

- Five Live Internet rad CERCLA Policy Training sessions have been conducted
  - » 731 total participants, including 101 EPA employees
- An archived version of a live training session is available at:
  - » http://www.clu-in.org/conf/itrc/radsdd_040308/
- Archived version was accessed by users 2,046 times between January 1, 2008 and August 26, 2009.



EPA

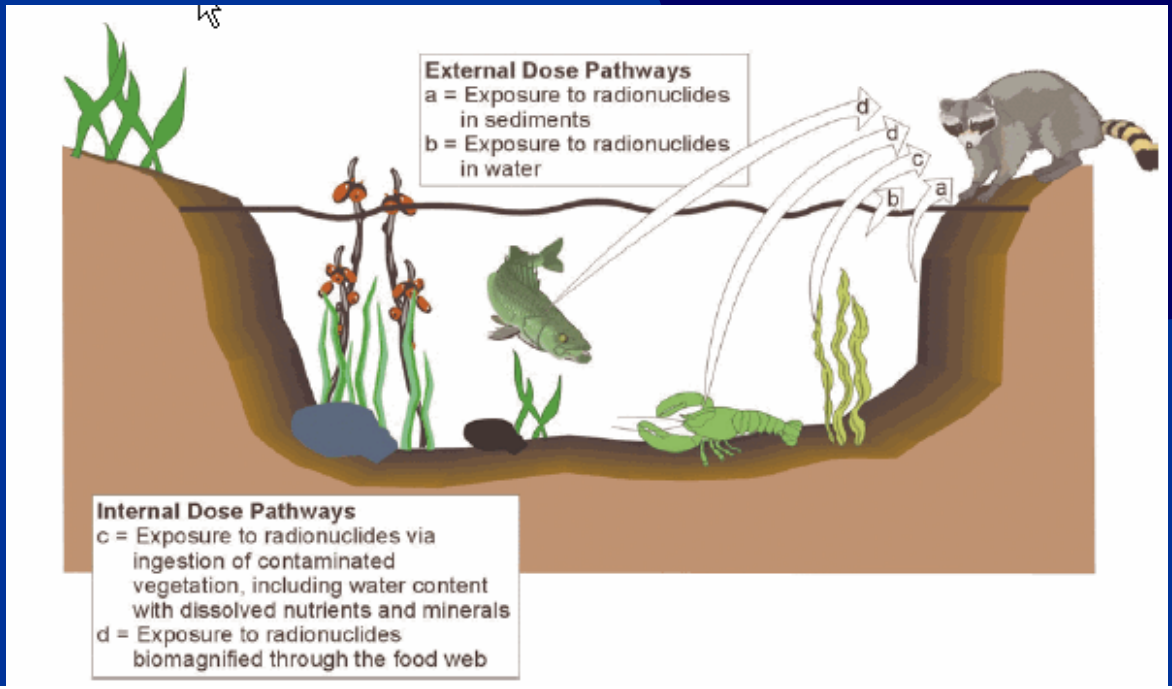
Radionuclide Ecological Benchmark (REB) Calculator *DRAFT*

- Establish risk-based Biota Concentration guides (BCGs), or ecological benchmarks, for radioactively contaminated sites
- Derived from DOE Graded Approach guidance
  - » Includes same dose levels for tissue death
  - » Strong recommendation to look at chemical eco effects

EPA

REB Exposure Scenarios

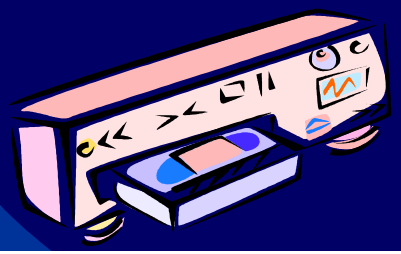
- Includes 12 animal or plant benchmark scenarios
  - »6 generic composite only
  - »6 species-specific/site-specific



EPA

Video: Radiation Risk Assessment

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



EPA

For More Copies or Information

- Guidance documents are on Superfund Radiation Webpage:
  - http://www.epa.gov/superfund/health/contaminants/radiation/index.htm
- Guidance documents for Superfund Radiation Risk Assessment
  - http://www.epa.gov/superfund/health/contaminants/radiation/radrisk.htm
- For further information or questions, Stuart Walker
  - Phone: (703) 603-8748
  - Fax: (703) 603-9133
  - Email: Walker.Stuart@epa.gov

EPA

EPA