NIMBioS Risk Analysis Tutorial

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Knoxville, Tennessee

https://rais.ornl.gov/
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Day 1 Schedule

- 8:30 a.m. Breakfast (bagels, muffins, fruit, and coffee)
- 8:45 a.m. Welcome and Introductory Remarks
- 9:00 a.m. Regional Screening Levels Background and Supporting Documentation
- 10:00 a.m. Break
- 10:15 a.m. Regional Screening Levels Calculator
- 12:00 p.m. Lunch
- 1:00 p.m. Resume Regional Screening Levels Calculator
- 2:30 p.m. Break
- 2:45 p.m. Regional Removal Management Levels
- 3:00 p.m. Practice Exercises for RSL and RML
- 4:45 p.m. Dismiss
Day 1 Outline

1. Historical Perspective of RSLs
2. Understanding RSL Changes Over time (What’s New)
3. Getting RSL Support (FAQ, Contact Information)
4. RSL Special Cases (Mutagens, TCE, Vinyl Chloride, Arsenic)
5. RSL Calculator
6. Resident, Worker, Construction, Recreator, Soil to Groundwater
7. Tapwater, Soil, Surface Water, Sediment, Air, Fish
8. Historical Perspective of RMLs
9. Understanding RML Changes over time (What’s New)
10. Getting RML Support (FAQ, Contact Information)
11. RML Calculator
12. Focus on Resident and Worker
13. Water and Soil
14. RSL and RML Practice Sessions

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RSL History

• RSL = Regional Screening Levels
• Individual tables for Regions 3, 6 and 9 with constant maintenance and differences.
• Last published region tables: Region 3 - 2004, Region 6 - 2007, Region 3 - 2006.
• Combined Headquarters (OSRTI) table in 2008.
• Website on an ORNL-UT server for the first year.
• Subsequently moved to R3 to maintain the static pages; ORNL-UT still operates the calculator page.
• 2008 to present: What’s New page provides pertinent history of the changes.
• Unified tables are shared on Region 3, 6 and 9 websites as well as other Regional websites.

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What RSLs Are and Are Not

- Default Screening levels - yes
- De facto Remediation levels- maybe. Only if your PRG equations are same as RGOs.
- Site-specific screening levels – yes. Simply use the calculator to derive appropriate numbers.
- Site-specific remediation levels – yes. Simply use the calculator to derive appropriate numbers.

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RSL Regulatory Basis

- RAGS Part A-F
- Supplemental Soil Screening Guidance and Technical Background Document
- Guidelines for Carcinogen Risk Assessment
- Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens (mutagen information)

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How Does it Work?

• ORACLE
• SAS
• Java script, PHP, Perl, etc.
• General hierarchy for toxicity and chemical parameters (see Section 2.3 and 2.4 of RSL for details)

Client

Server

HTML/CSS
Perl
SAS®
JavaScript
jQuery

Database

Oracle®

Information

Toxicity values from IRIS, PPRTV, ATSDR, OPP, CalEPA, and HEAST

Chemical Parameters from PHYSPROP, EPI Suite, CRC, Lange, Perry, Yaw, HSDB, etc.

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How Does it Work cont.

Screening Level Calculation

Toxicity Values

Screening Level Equations

Residential Land Use

Outdoor Worker

Indoor Worker

Recreational Land Use

- Soil: ingestion, inhalation, dermal
- Tap Water: ingestion, inhalation, dermal
- Fish: ingestion
- Ambient Air: ingestion, inhalation
- Air: Inhalation
- Soil to Groundwater: for protection of gw
- Soil: ingestion, inhalation, dermal
- Air: Inhalation
- Soil: ingestion, inhalation
- Soil/Sediment: ingestion, inhalation, dermal
- Surface Water: ingestion, dermal

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What is the Update Process?

- Dynamic Agenda of issues
- Conference Calls
- Toxicity Updates
- Chemical-parameter Updates
- MCL Updates
- Text updates (FAQ, What’s New)
- Freeze database
- QA check of calculations
- QA tables (by hand and with computer program)
- The RSL Checklist (around 52 steps)
- Go Live
RSL Update Checklist

**RSL Toxicity Database Check**
- Cal EPA, ATSDR and IRIS databases are checked for updates; changes are made to database and verified.
- HEAST and PPRTV updates are automatically read into database, as ORNL is hosting these databases.
- Tier 3 toxicity values selected by the RSL Workgroup are hardcoded into database (e.g., New Jersey’s oral slope factor for chromium 6).
- Confirm that all contaminants identified as carcinogenic by a mutagenic mode of action in the OSWER cancer handbook have an M in the table and use the ADAFs. Confirm that only contaminants in the handbook (and for now also Hexavalent Chromium) have an M in the tables and use the ADAFs.
- Exceptions are hardcoded (e.g., omission of lead RfD, some dioxins, furans, and TCE).
- Make sure GIABS, ABS, VOC status and mutagenic status are added for new chemicals.
- Run database search of all missing values (e.g., EPD, FA, DIA, DIW, Csat) that need to be calculated and search for new values.
- Look for Csat of 0 and missing Csat if VOC=1. Make sure the AMBIENT STATE variable is updated.
- Investigate the HLC, MW and VP of new chemicals to make sure that VOC status is assigned appropriately.
- The toxicity database is “frozen” from further updates.
- Add banner to the calculator stating that a new database in in place.
- Run a tox compare routine, which is posted in the What's New, and verify each change, subtraction and addition of toxicity values.
- Run the parameters compare for group to review.
- Run the summary table compare.

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RSL Update Checklist cont.

• **Chemical-Specific Parameters Check**
  – Chemical-specific parameters are added when a new chemical is added to the toxicity database.
  – Check the parameters table for chemicals without any values at all.
  – Added parameters are reviewed.

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RSL Update Checklist cont.

• **RSL Review**
  - The RSLs for each chemical in the Excel QA sheet are reviewed by land use and exposure route.
  - The soil to groundwater, Diffusivity in air and water, Csat, volatilization factor, and particulate emission factor calculations are reviewed.
  - Hardcoded exceptions are reviewed for chemicals that are not listed in the QA sheet. These include all of the contaminants specifically discussed in the User’s Guide (lead, manganese, vanadium, uranium, chromium, aminodinitrotoluenes, PCBs, and xylenes) as well as copper(RfD), TCE, and lead residential and industrial soil levels.
  - MCL footnotes for perchlorates and trihalomethanes are verified.
  - Make sure lead footnotes and non-RSL values are in place.
  - Make sure TCE is handled appropriately in the resident soil, air, and tapwater tables.
  - If any discrepancy is found and new tables are generated, the QA begins from the top.
  - Do all of the toxicity values have a source code to one of the 6 sources described in the user’s guide or the special cases noted in the legend of the generic tables?
  - Do the supporting tables present oral, inhalation, and dermal-based screening levels (when we have the data) for both cancer and non-cancer?
  - Are the initial cancer and non-cancer RSLs no lower than the individual oral, inhalation, and dermal screening levels?
  - Is the lower of the cancer and non-cancer RSLs for each exposure media (e.g. residential soil, industrial air) carried forward into the summary table?
  - Are the RSLs in the supporting and summary tables coded with “c” for cancer and “nc” for non-cancer?
RSL Update Checklist cont.

- Are the other codes (S to see user’s guide and M for exceeding ceiling limit) used when appropriate?
- Are all of the units in the tables correct?
- Make sure the header row texts are all visible.
- Make sure the parameters table is condensed as much as possible.
- The old hardcopy is compared to the new hardcopy to verify output is reasonable.
- Are there soil RSLs protective of the MCL for all contaminants that have an MCL?
- Are there soil RSLs protective of the tapwater RSL for all contaminants that have a tapwater RSL?
- Are there missing pages in any of the individual tables?
- Correct tables updated if necessary.
- Are all of the pages in all of the tables contained in the Composite Table?
- Tables are released to Michele for comment.
- Tables and test site are released to RSL workgroup.
- R3 begins copying changes.
- Review R3 test site.
- R3 goes live.
- Quick review of R3 live site.
- Tell the world.

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RSL Update Checklist cont.

• Miscellaneous
  – Incorporate fish table from Region 3
  – EQUIS output
  – SADA tables
  – Archive the html and pdf web pages
  – Archive the previous download tables
Spring 2019 Agenda

• Old Issues
  – Use HgCl RfD for Hg.
  – Using subchronic values more protective than chronic.
  – Where is the mutagen list website?
  – Maybe use other state tox values as tier 3.
  – DWSHA tox value use.
  – Update EQuIS format.

• New Issues
  – Endosulfan and Endrin surrogates.
  – Shorten the table and calculator key.
  – Update TPH text to clarify sources.
  – Change volatility status when groundwater temp is changed.
  – Let user enter their own PEF.
  – Fix some CAS issues.
  – All H’ values to 0 for all inorganics other than mercury (bad old idea?).
  – Change chemical names for nitrate and nitrite to include “measured as nitrogen”.

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Toxicity Sources

1. EPA Integrated Risk Information System (IRIS)
2. EPA Provisional Peer Reviewed Toxicity Values (PPRTV)
3. EPA Office of Pesticide Programs (OPP) Human Health Benchmarks for Pesticides (HHBPs)
4. Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels (MRLs)
5. California Environmental Protection Agency (CalEPA) Office of Environmental Health Hazard Assessment (OEHHA)
6. EPA PPRTV Appendix Screening Values
7. EPA Health Effects Assessment Summary Table (HEAST)

(https://semspub.epa.gov/work/03/2218797.pdf)

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Chemical-specific Parameter Sources

- PHYSPROP
- EPA SuiteTM
- EPA Soil Screening Level (SSL)
- WATER9
- CHEMFATE
- Yaws' Handbook of Thermodynamic and Physical Properties of Chemical Compounds
- Baes, C.F (SCDM)
- NIOSH Pocket Guide to Chemical Hazards (NPG)
- CRC Handbook of Chemistry and Physics
- Perry's Chemical Engineers' Handbook
- Lange's Handbook of Chemistry
- RAGS Part E, Supplemental Guidance for Dermal Risk Assessment
- ARS Pesticide Properties Database
- OTHER
Chemical-specific Parameters

- Organic Carbon Partition Coefficient (Koc)
- Dermal Permeability Coefficient (Kp)
- Effective Predictive Domain (EPD)
- Fraction Absorbed (FA)
- Molecular Weight (MW)
- Water Solubility (S)
- Unitless Henry's Law Constant (H')
- Henry's Law Constant
- Diffusivity in Air (Dia)
- Diffusivity in Water (Diw)
- Fish Bioconcentration Factor (BCF)
- Soil-Water Partition Coefficient (Kd)
- Density
- Melting Point (MP)
- log Octanol-Water Partition Coefficient (logKow)
- Vapor Pressure (VP)
- Critical Temperature (Tc)
- Enthalpy of vaporization at the normal boiling point

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Generic Tables

- Landuses
- Resident – child
- Why 3 workers?
- SSL (soil2gw)
- Media (Fish and Region 3 are exception)
- Targets (TR, THQ)
- Csat, max
- Key symbols (e.g., I = IRIS; P = PPRTV; F = See FAQ; M = mutagen; c = cancer; n = noncancer; s = concentration may exceed Csat)
- What’s New
  - Tox compare
  - Params compare
  - RAGS E compare (EPD, FA, Kow)
- Chemical Groups

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### Generic Tables cont.

#### Toxicity and Chemical-specific Information

<table>
<thead>
<tr>
<th>SFO (mg/kg-day)^{-1}</th>
<th>key</th>
<th>IUR (ug/m^3)^{-1}</th>
<th>key</th>
<th>RfD_o (mg/kg-day)</th>
<th>key</th>
<th>RfC_i (mg/m^3)</th>
<th>key</th>
<th>mutagen</th>
<th>GIABS</th>
<th>ABS</th>
<th>C_{sat} (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.8E-02</td>
<td>C</td>
<td>5.1E-06</td>
<td>C</td>
<td>1.5E-01</td>
<td>I</td>
<td>1</td>
<td>0.1</td>
<td></td>
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<td></td>
</tr>
<tr>
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<td>4.0E-03</td>
<td>l</td>
<td>9.0E-03</td>
<td>l V</td>
<td>1</td>
<td>1.1E+05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2E-06</td>
<td>l</td>
<td>1.7E-02</td>
<td>l</td>
<td>3.1E+01</td>
<td>A V</td>
<td>1</td>
<td>1.1E+05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0E-02</td>
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<td>9.0E-01</td>
<td>l</td>
<td>2.0E-03</td>
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<td>1</td>
<td>1.1E+05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Screening Levels

<table>
<thead>
<tr>
<th>Resident Soil (mg/kg)</th>
<th>key</th>
<th>Industrial Soil (mg/kg)</th>
<th>key</th>
<th>Resident Air (ug/m^3)</th>
<th>key</th>
<th>Industrial Air (ug/m^3)</th>
<th>key</th>
<th>Tapwater (ug/L)</th>
<th>key</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.7E+01</td>
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<td>9.6E+01</td>
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<td>2.4E+00</td>
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<td>3.7E+00</td>
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</tr>
<tr>
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<td>2.0E+02</td>
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<td>1.1E+00</td>
<td>c**</td>
<td>5.6E+00</td>
<td>c**</td>
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<td>c**</td>
</tr>
<tr>
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<td>c**</td>
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<tr>
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<td>nms</td>
<td>9.4E+03</td>
<td>c</td>
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<td>1.3E+02</td>
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<tr>
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<td>4.5E-01</td>
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<td>1.9E-03</td>
<td>c</td>
<td>9.4E-03</td>
<td>c</td>
<td>1.3E+02</td>
<td>c</td>
</tr>
</tbody>
</table>

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Landuses

Conceptual Site Model of Quantified Exposure Pathways for Regional Screening Levels. Black lines are direct exposure routes. Dashed black lines are indirect exposure routes.

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Calculator

- What’s not in the table
- Recreator
  - Sediment
  - Surface water
- Indoor worker
- Outdoor worker
- Construction worker
- Fish

https://rais.ornl.gov/
• Site-specific
  – Exposure parameters
  – Toxicity and chem-specific parameters
  – Age cohorts
  – New Chemical

• Chronic vs. Subchronic

• New features (Csat and max)
Calculator cont.

- Metadata
- EQuIS format
- Changing target risk or HQ
- VF changes
- PEF changes
- SSL changes
Confusing Chemicals

- **Lead** (why not use the Cal EPA tox values?)
- **Benzene** (Slope factors for benzene are actually ranges, yet the SL table shows a single number. The upper end of the range was chosen, because the SL Table is a screening tool. The consequences of screening out a chemical that could pose a significant risk are more serious than carrying the chemical through the risk assessment process.)
- **Cadmium and Manganese** ("Food" is for food and soil use; "water" is for water only. Cadmium RfDs on IRIS are based on the same study. The food RfD incorporates a 2.5% absorption adjustment while the water RfD incorporates a 5% absorption adjustment. For another medium (e.g., soil), choose the value with an absorption factor that most closely matches the expected site conditions. In most cases, the expected absorption is unknown and the RfD for food should be used. Manganese IRIS RfD is for all sources, including diet. IRIS recommends using a modifying factor of 3 when calculating risks associated with non-food sources. IRIS also recommends subtracting dietary exposure (default assumption in this case is 5 mg). Thus, the IRIS RfD has been lowered by a factor of 2 x 3, or 6. The table now reflects manganese for "non-food" sources.)

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• **Copper** (Currently, the RfD is 0.04 mg/kg-day with a reference of HEAST. Actually, HEAST presents a drinking water screening level of 1.3 mg/L. In order to use the value to assess oral exposures to other media, we "back out" the adult exposure assumptions (e.g., body weight of 70 kg, ingestion rate of 2 L/day) that go into the calculation of a drinking water screening level.)

• **Chromium** (In the RSL Table, the Cr(VI) specific value (assuming 100% Cr(VI)) is derived by multiplying the IRIS Cr(VI) Inhalation Unit Risk value by 7. This is considered to be a health-protective assumption and is also consistent with the State of California's interpretation of the Mancuso study that forms the basis of Cr(VI)'s estimated cancer potency. It’s a mutagen but controversial.)

• **Mercury** (Where is the oral RfD from Cal EPA? The EPA RSL group removed it. Not standard practice to pick apart the individual tox values.)
• **Vinyl chloride** (unique set of equations that combine the prorated cancer with non-prorated child)

• **Dioxins and Furans** (TEFs; however if IRIS has a value, we present the RSL based on that value)

• **PAHs** and RPFs based on BaP

• **TCE** (Uses a CAF and MAF so one tox value can be used)

• **TPHs** (Noncancer only)

https://rais.ornl.gov/
RSL Website Pages

Regional Screening Levels (RSLs)

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

https://rais.ornl.gov/
RSL Calculator in Default Mode

• Chronic
• Subchronic
• Metadata
• Site-specific options
• Selecting landuses
• Output data
  – View
  – Cut and paste
  – XLS
  – PDF

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Master the Pick List

- Clicking
- Typing
- Select All

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Site-specific Mode

- Exposure parameters
- Cohorts (pink and blue cells) for resident and recreator
- Toxicity values
- Chemical-specific parameters
- PEF and VF
- SSL protective of groundwater
Questions?

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RML History

- RML = Regional Removal Management Level
- Assist On Scene Coordinators (OSC’s) and others involved in decision-making concerning Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) removal actions
- Used to support the decision for EPA to undertake a removal action. Although they are not necessarily health protective concentrations for chronic exposure, exceedance of an RML by itself does not imply that adverse health effects will occur.
- 1998 was the latest release prior to our website.
- 2008 to present: What’s New page portrays change history
- Unified tables are shared on Region 3, 6 and 9 websites as well as other Regional websites.
- Note: At this time, RMLs for air are not provided or addressed on this website. (Formerly called RALs.)

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What RMLs Are and Are Not

- Not protective for long term exposures
- Not provided for air (other tables exist)
- Site-specific screening levels – yes
- Site-specific remediation levels – no
RML Website Pages

Regional Removal Management Levels

- Homepage
- Frequent Questions
- User's Guide
- RML calculator

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Questions?

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March 7-9, 2019
RSL/RML Practice Sessions
Day 2 Schedule

- 8:30 a.m.  Breakfast (bagels, muffins, fruit, and coffee)
- 8:45 a.m.  Vapor Intrusion Screening Levels (VISL) Background and Supporting Documentation
- 9:15 a.m.  VISL Calculator
- 10:00 a.m. Break
- 10:15 a.m. Practice Sessions for VISL
- 11:15 a.m. Risk Assessment Information System (RAIS) Overview
- 12:00 p.m. Lunch
- 1:00 p.m.  RAIS Calculators
- 2:30 p.m.  Break
- 2:45 p.m.  Practice Sessions for RAIS Calculators
- 4:45 p.m.  Dismiss

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Day 2 Outline

1. Historical Perspective of VISLs
2. Understanding Changes Over time (What’s New)
3. Getting Support (FAQ, Contact Information)
4. VISL User Guide Special Cases (Mutagens, TCE, Vinyl Chloride, Arsenic)
5. VISL Calculator
6. Resident, Worker
7. Water, Soil, Air
8. RAIS Calculators
9. PRGs
10. Risk Calculators
11. Toxicity Search Tools
12. Chemical Parameter Search Tools
13. Adult Lead Model
14. Applicable or Relevant and Appropriate Requirements (ARARs)
15. VISL and RAIS Practice Sessions
VISL History

- 2002: OSWER released DRAFT guidance
- 2013: DRAFT available for public comment
- 2015: Technical guide released, spreadsheet provided
- Spring 2018: VISL calculator made public
What VISLs Are and Are not

- VISLs are screening level concentrations for groundwater, soil gas (target sub-slab and near-source), and indoor air.
- VISLs assist Agency staff with making a vapor intrusion determination based on limited, initial data.
- VISLs are NOT cleanup levels.

[https://rais.ornl.gov/](https://rais.ornl.gov/)
VISL Website Pages

Contents

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

https://rais.ornl.gov/
VISL Practice Sessions
RAIS History

• 1980s: Oak Ridge Reservation was busy cleaning up the Manhattan Project Facilities, as were other DOE sites like gaseous diffusion plants in Ohio and Kentucky.

• Risk Assessment Council was developed to standardize the toxicity values, exposure equations, and essentially the entire remediation process.

• 1996: RAIS went live.
How Does the RAIS Differ from RSL?

- Greater number of chemicals
  - All of OPP
  - All of CalEPA (including lead toxicity values)

- Expanded toxicity sources
  - Draft MRLs
  - Addendum MRLs
  - All of OPP
  - Retired PPRTVs
  - Drinking Water Standards
  - Archived HEAST
  - Withdrawn from IRIS

- More land uses
  - Excavation Worker
  - Farmer
  - More Soil to Groundwater

- More Defaults
  - Farmer
  - Recreator
  - Fish
How Does the RAIS Differ from RSL? Cont.

• More Tools
  – Chemical Data Profile Tool (Shows all of the data available from the toxicity hierarchy)
  – Metadata Tool (demo)
  – Toxicity Value Tool (demo)
  – ARAR Tool (demo)
  – Ecological Benchmarks
  – Tutorials
  – Background Values
  – Media Transport

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RAIS Website Pages

Chemical Tools
- Chemical Toxicity
- Chemical Parameters
- PRG Calculator & User's Guide
- Risk Calculator & User's Guide
- ARAR Search
- Ecological Benchmarks
- Adult Lead Model
- Media Transport Tools
- Soil Background Values

Radionuclide Tools

Tutorials
- Radionuclide Toxicity
- Radionuclide Parameters
- PRG Calculator & User's Guide
- Risk Calculator & User's Guide
- Gamma Radiation Instrument Response Calculator
- Radionuclide Decay Chain Tool
- Media Transport Tools

Guidance
- ORO Risk Assessment Guidance
- EPA Regulatory Guidance
- State Guidance
Supporting Pages

- Training
- Contact
- Report an Issue
- Document Search
- Glossary
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Questions?

https://rais.ornl.gov/
RAIS Practice Sessions
Day 3 Schedule

- 8:30 a.m. Breakfast (bagels, muffins, fruit, and coffee)
- 8:45 a.m. Introduction to Radiation
- 9:00 a.m. PRG Calculator
- 10:00 a.m. Break
- 10:15 a.m. DCC Calculator
- 11:00 a.m. BRG/BDCC Calculator
- 12:00 p.m. Lunch
- 1:00 p.m. SPRG/SDCC
- 1:45 p.m. RAIS Radiation Calculators
- 2:30 p.m. Break
- 2:45 p.m. Practice Sessions for Radiation Calculators
- 4:30 p.m. Dismiss
Day 3 Outline

1. Radiation Risk Assessment Introduction Video
2. EPA PRG Calculator
   • Resident, Worker, Construction, Recreator, Farmer
   • Air, Water, Soil, Food
3. EPA DCC Calculator
4. EPA Building PRG and Building DCC Calculators
   • Dust, Air, Indoor Building
5. EPA Surfaces PRG and Surfaces DCC Calculators
   • Dust, Air, Outdoor Surfaces
6. RAIS Radiation Tools
   • PRG
   • Risk
   • Decay

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Radiation Risk Assessment

- Review of how radiation fits in Superfund
- Quick review of EPA RSL calculator
- Step by step comparison to the EPA PRG calculator
- Identification of pitfalls
- Quick look at EPA DCC calculator
- Questions

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Superfund Sites

• 1,337 NPL sites
  – 66 are radiation sites
  – 53 more sites proposed for NPL
    • 1 is a radiation site
• 1,189 NPL sites are “construction completion”
  – 38 are radiation sites
• 392 Sites have been deleted from NPL
  – 9 are radiation sites

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How to Address Radiation in a Chemical Program?

• With only 66 radioactively contaminated sites out of 1,337 total, the focus of the Superfund program has been on chemicals.

• **Question:** How best to address radiation?

• **Answer:** Address radiation in a consistent manner with chemicals, except to account for the technical differences posed by radiation
  
  – Radiation easily fits within Superfund framework
  
  – Improves public confidence by taking mystery out of radiation

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Why Does Radiation Easily Fit within the Superfund Framework?

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

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CERCLA Cleanup Levels **NOT** Based On

- DOSE (mrem/year)

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Consistency (Rad & Chem)

- Reiterate more strongly that risk assessments (e.g., models used) should be consistent with chemicals at site and with other regional sites.
- Don’t use a steady state model for chemical and a transfer/dynamic model for radionuclides.
  - Using RSL calculator for chemicals then RESRAD defaults for radionuclides is inconsistent.
Consistency on Surveys (Rad & Chem)

- Reiterate more strongly that site surveys (e.g., characterization and confirmation) should be consistent with chemicals at the site and with other regional sites.
- Don’t use not-to-exceed (NTE) for chemicals and area averaging (AA) for radionuclides for residential.
  - NTE for residential cleanup of chemicals but AA approach like MARSIMM for the radionuclides.
RSL vs PRG (1)

RSL Calculator

Hover over any form section for instructions about the individual selection and requirements.

Select Screening Level Type
- Regional Screening Levels (RSLs)
- Regional Removal Management Levels (RMLs)

Select Hazard Quotient
- 0.1
- 1
- Other: [input field]

Select Target Risk
- $10^{-8}$
- $10^{-5}$
- $10^{-4}$
- Other: [input field]

Select Scenario
- Resident
- Indoor Worker
- Outdoor Worker
- Composite Worker (presented in Generic Tables)
- Construction Worker (Site-specific only)
- Fish (Site Specific Only)
- Soil to Groundwater
- Recreator (Site-specific only)

Select Media:
- Soil
- Air
- Tap Water
- 2-D External Exposure
- Fish

Preliminary Remediation Goals for Radionuclides (PRG)

Hover over any form section for instructions about the individual selection and requirements.

Select Target Risk
- $10^{-6}$
- $10^{-5}$
- $10^{-4}$
- Other: [input field]

Select Scenario
- Resident
- Indoor Worker
- Outdoor Worker
- Composite Worker
- Construction Worker (Site-specific only)
- Recreator (Site-specific only)
- Farmer
- Soil to Groundwater

Select Media:
- Soil
- Air
- Tap Water
- 2-D External Exposure
- Fish

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External Exposure

Kevin Bacon getting his bacon fried in X-men.

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## Select Screening Level Choice

- Defaults
- Site Specific

## Select Risk Output

- No
- Yes

## Select RfD/RfC Choice

- Chronic
- Subchronic

*Chronic selection will retrieve Chronic-only RfDs/RfCs; Subchronic selection will retrieve subchronic values where possible.*

## Select Site Info Type

- Defaults
- Site-specific

## Select Risk Output

- No
- Yes

## Show Individual Produce Output

- No
- Yes

## Select Units

- pCi
- Bq
RSL vs PRG (3)
<table>
<thead>
<tr>
<th>Variable</th>
<th>Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>THQ (target hazard quotient) unitless</td>
<td>TR (target cancer risk) unitless</td>
</tr>
<tr>
<td>TR (target risk) unitless</td>
<td>t\textsubscript{res} (time - resident) yr</td>
</tr>
<tr>
<td>LT (lifetime) years</td>
<td>ED\textsubscript{res} (exposure duration - resident) yr</td>
</tr>
<tr>
<td>ET\textsubscript{res} (exposure time) hours/day</td>
<td>ET\textsubscript{res} (exposure time - resident) hr/day</td>
</tr>
<tr>
<td>ET\textsubscript{res-c} (child exposure time) hours/day</td>
<td>ET\textsubscript{res-c} (exposure time - resident child) hr/day</td>
</tr>
<tr>
<td>ET\textsubscript{res-a} (adult exposure time) hours/day</td>
<td>ET\textsubscript{res-a} (exposure time - resident adult) hr/day</td>
</tr>
<tr>
<td>ET\textsubscript{0-2} (mutagenic exposure time) hours/day</td>
<td>ET\textsubscript{res-i} (exposure time - indoor resident) hr/day</td>
</tr>
<tr>
<td>ET\textsubscript{2-6} (mutagenic exposure time) hours/day</td>
<td>ET\textsubscript{res-o} (exposure time - outdoor resident) hr/day</td>
</tr>
<tr>
<td>ET\textsubscript{6-16} (mutagenic exposure time) hours/day</td>
<td>ED\textsubscript{res} (exposure duration - resident child) yr</td>
</tr>
<tr>
<td>ET\textsubscript{16-26} (mutagenic exposure time) hours/day</td>
<td>ED\textsubscript{res-a} (exposure duration - resident adult) yr</td>
</tr>
<tr>
<td>ED\textsubscript{res} (exposure duration) years</td>
<td>EF\textsubscript{res} (exposure frequency - resident) day/yr</td>
</tr>
<tr>
<td>ED\textsubscript{res-c} (exposure duration - child) years</td>
<td>EF\textsubscript{res-c} (exposure frequency - resident child) day/yr</td>
</tr>
<tr>
<td>ED\textsubscript{res-a} (exposure duration - adult) years</td>
<td>EF\textsubscript{res-a} (exposure frequency - resident adult) day/yr</td>
</tr>
<tr>
<td>ED\textsubscript{0-2} (mutagenic exposure duration) years</td>
<td>IRS\textsubscript{res-a} (soil intake rate - resident adult) mg/day</td>
</tr>
</tbody>
</table>
# RSL vs PRG (5)

<table>
<thead>
<tr>
<th>Chemical</th>
<th>SL</th>
<th>Inhalation SL Child THQ=0.1 (mg/kg)</th>
<th>Noncarcinogenic SL Child THI=0.1 (mg/kg)</th>
<th>Ingestion SL Adult THQ=0.1 (mg/kg)</th>
<th>Dermal SL Adult THQ=0.1 (mg/kg)</th>
<th>Inhalation SL Adult THQ=0.1 (mg/kg)</th>
<th>Noncarcinogenic SL Adult THI=0.1 (mg/kg)</th>
<th>Screening Level (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acephate</td>
<td>7.59E+00</td>
<td>7.59E+00</td>
<td>1.00E+02</td>
<td>2.37E+02</td>
<td>-</td>
<td>7.04E+01</td>
<td>7.59E+00 nc</td>
<td></td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>8.18E+00</td>
<td>8.18E+00</td>
<td>-</td>
<td>-</td>
<td>8.18E+00</td>
<td>8.18E+00</td>
<td>8.18E+00 nc</td>
<td></td>
</tr>
<tr>
<td>Acetochlor</td>
<td>1.26E+02</td>
<td>1.26E+02</td>
<td>1.67E+03</td>
<td>3.95E+03</td>
<td>-</td>
<td>1.17E+03</td>
<td>1.26E+02 nc</td>
<td></td>
</tr>
<tr>
<td>Acetone</td>
<td>4.40E+04</td>
<td>6.07E+03</td>
<td>7.51E+04</td>
<td>-</td>
<td>4.40E+04</td>
<td>2.77E+04</td>
<td>6.07E+03 nc</td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Ingestion PRG TR=1E-06 (pCi/g)</th>
<th>Inhalation PRG TR=1E-06 (pCi/g)</th>
<th>External Exposure PRG TR=1E-06 (pCi/g)</th>
<th>Produce Consumption PRG TR=1E-06 (pCi/g)</th>
<th>Total PRG TR=1E-06 (pCi/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Secular Equilibrium PRG for Am-241</td>
<td>5.80E-01</td>
<td>2.60E+01</td>
<td>5.73E-02</td>
<td>1.31E-02</td>
<td>1.04E-02</td>
</tr>
<tr>
<td>*Secular Equilibrium PRG for Co-60</td>
<td>2.34E+01</td>
<td>8.39E+04</td>
<td>9.35E-03</td>
<td>5.87E-02</td>
<td>8.06E-03</td>
</tr>
<tr>
<td>*Secular Equilibrium PRG for Cs-137</td>
<td>2.10E+01</td>
<td>7.51E+04</td>
<td>4.56E-02</td>
<td>9.04E-02</td>
<td>3.03E-02</td>
</tr>
<tr>
<td>*Secular Equilibrium PRG for H-3</td>
<td>9.93E+03</td>
<td>1.25E-01</td>
<td>-</td>
<td>1.20E-01</td>
<td>6.12E-02</td>
</tr>
</tbody>
</table>
## RSL vs PRG (6)

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Halflife</th>
<th>Mode</th>
<th>Mass</th>
<th>Branching Fraction</th>
<th>Daughter</th>
<th>Branching Fraction</th>
<th>Daughter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Am-241</td>
<td>432.2y</td>
<td>A</td>
<td>241.056829</td>
<td>1.00e+0</td>
<td>Np-237</td>
<td>1.00e+0</td>
<td></td>
</tr>
<tr>
<td>Np-237</td>
<td>2.144E+6y</td>
<td>A</td>
<td>237.048173</td>
<td>1.00e+0</td>
<td>Pa-233</td>
<td>1.00e+0</td>
<td></td>
</tr>
<tr>
<td>Pa-233</td>
<td>26.967d</td>
<td>B-</td>
<td>233.040247</td>
<td>1.00e+0</td>
<td>U-233</td>
<td>1.00e+0</td>
<td></td>
</tr>
<tr>
<td>U-233</td>
<td>1.592E+5y</td>
<td>A</td>
<td>233.039635</td>
<td>1.00e+0</td>
<td>Th-229</td>
<td>1.00e+0</td>
<td></td>
</tr>
<tr>
<td>Th-229</td>
<td>7.34E+3y</td>
<td>A</td>
<td>229.031762</td>
<td>1.00e+0</td>
<td>Ra-225</td>
<td>1.00e+0</td>
<td></td>
</tr>
<tr>
<td>Ra-225</td>
<td>14.9d</td>
<td>B-</td>
<td>225.023611</td>
<td>1.00e+0</td>
<td>Ac-225</td>
<td>1.00e+0</td>
<td></td>
</tr>
<tr>
<td>Ac-225</td>
<td>10.0d</td>
<td>A</td>
<td>225.023229</td>
<td>1.00e+0</td>
<td>Fr-221</td>
<td>1.00e+0</td>
<td></td>
</tr>
<tr>
<td>Fr-221</td>
<td>4.9m</td>
<td>A</td>
<td>221.014254</td>
<td>1.00e+0</td>
<td>At-217</td>
<td>1.00e+0</td>
<td></td>
</tr>
<tr>
<td>At-217</td>
<td>3.23E-2s</td>
<td>A</td>
<td>217.004718</td>
<td>1.00e+0</td>
<td>Bi-213</td>
<td>1.00e+0</td>
<td></td>
</tr>
<tr>
<td>Bi-213</td>
<td>45.59m</td>
<td>B-, A</td>
<td>212.994384</td>
<td>9.79e-1</td>
<td>Po-213</td>
<td>2.09e-2</td>
<td>TI-209</td>
</tr>
<tr>
<td>Po-213</td>
<td>4.2E-6s</td>
<td>A</td>
<td>212.992857</td>
<td>1.00e+0</td>
<td>Pb-209</td>
<td>1.00e+0</td>
<td></td>
</tr>
<tr>
<td>TI-209</td>
<td>2.161m</td>
<td>B-</td>
<td>208.985358</td>
<td>1.00e+0</td>
<td>Pb-209</td>
<td>1.00e+0</td>
<td></td>
</tr>
<tr>
<td>Pb-209</td>
<td>3.253h</td>
<td>B-</td>
<td>208.981090</td>
<td>1.00e+0</td>
<td>Stable Bi-209</td>
<td>1.00e+0</td>
<td></td>
</tr>
</tbody>
</table>
### Carcinogenic

- **Ingestion**

\[
SL_{\text{res-soil-ca-ing}}(\text{mg/kg}) = \frac{\text{CSF}_0\left(\frac{\text{mg}}{\text{kpg-day}}\right)^{-1} \times \text{RBA} \times \text{IFS}_{\text{res-adj}}(36,750 \text{ mg/kg})}{365 \text{ days/year} \times \text{LT} (70 \text{ years})}
\]

where:

\[
\text{IFS}_{\text{res-adj}}(36,750 \text{ mg/kg}) = \frac{\text{EF}_{\text{res-c}}(350 \text{ days/year}) \times \text{ED}_{\text{res-c}}(6 \text{ years}) \times \text{IRS}_{\text{res-c}}(200 \text{ mg/day})}{\text{BW}_{\text{res-a}}(80 \text{ kg})}
\]

### Resident Soil PRGs

- **Incidental ingestion of soil**

\[
\text{PRG}_{\text{res-soil-ing}}(\text{pCi/g}) = \frac{\text{TR}}{\text{SF}_{\text{risk}}(\text{pCi}) \times \text{IFS}_{\text{res-adj}}(1,120,000 \text{ mg}) \times \left(\frac{g}{1000 \text{ mg}}\right)}
\]

where:

\[
\text{IFS}_{\text{res-adj}}(1,120,000 \text{ mg}) = \left(\frac{\text{EF}_{\text{res-c}}(350 \text{ days/year}) \times \text{ED}_{\text{res-c}}(6 \text{ years}) \times \text{IRS}_{\text{res-c}}(200 \text{ mg/day})}{\text{EF}_{\text{res-a}}(350 \text{ days/year}) \times \text{ED}_{\text{res-a}}(20 \text{ years}) \times \text{IRS}_{\text{res-a}}(100 \text{ mg/day})}\right)
\]

- **The following half-life should be multiplied by CDI equations:**

\[
\text{CDI}_{\text{decay}} = \frac{(1-e^{-\lambda t})}{t(\text{year}) \times \lambda (\frac{1}{\text{year}})}
\]

- **The following half-life should be multiplied by PRG equations:**

\[
\text{PRG}_{\text{decay}} = \frac{t(\text{year}) \times \lambda (\frac{1}{\text{year}})}{(1-e^{-\lambda t})}
\]
# Exposure Assessment Details

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

## Parameters Common to all Exposure Routes

- **ED<sub>res</sub>** (exposure duration - resident) yr
- **ED<sub>res-a</sub>** (exposure duration - resident adult) yr
- **ED<sub>res-c</sub>** (exposure duration - resident child) yr
- **EF<sub>res</sub>** (exposure frequency - resident) day/yr
- **EF<sub>res-a</sub>** (exposure frequency - resident adult) day/yr
- **EF<sub>res-c</sub>** (exposure frequency - resident child) day/yr
- **ET<sub>res</sub>** (exposure time - resident) hr/day
- **ET<sub>res-a</sub>** (exposure time - resident adult) hr/day
- **ET<sub>res-c</sub>** (exposure time - resident child) hr/day
- **t<sub>res</sub>** (time - resident) yr
RSL vs PRG (9)

Select a cover layer

- 0 cm (No cover layer)
- 10 cm
- 20 cm
- 30 cm
- 40 cm
- 50 cm
- 60 cm
- 70 cm

Site area (m²) for ACF
Clean soil thickness for GSF₀

Exposure duration - resident) yr
Exposure duration - resident adult) yr
Exposure duration - resident child) yr
Exposure frequency - resident) day/yr
Exposure frequency - resident adult) day/yr
Exposure frequency - resident child) day/yr
Exposure time - resident) hr/day
Exposure time - resident adult) hr/day
Exposure time - resident child) hr/day
### Direct Produce Consumption PRG

<table>
<thead>
<tr>
<th>CF&lt;sub&gt;res-produce&lt;/sub&gt; (contaminated plant fraction) unitless</th>
<th>EF&lt;sub&gt;res-c&lt;/sub&gt; (exposure frequency - resident child) day/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>1E-06</td>
</tr>
<tr>
<td>6</td>
<td>TR (target cancer risk) unitless</td>
</tr>
<tr>
<td>350</td>
<td>Climate zone</td>
</tr>
</tbody>
</table>

#### Select Produce Items to Include

- Toggle All
- Apples
- Asparagus
- Beets
- Berries
- Broccoli
- Cabbage
- Carrots
- Cereal Grains
- Citrus Fruits
- Corn
- Cucumbers
- Lettuce

Toggle intake rates: ○ Fresh weight  ○ Cooked weight

https://rais.ornl.gov/  March 7-9, 2019
### Select Animal Products to Include

- Toggle All
- Beef
- Eggs and Poultry
- Fish
- Goat
- Goat Milk
- Dairy
- Sheep
- Sheep Milk
- Swine

Toggle intake rates:  
- Fresh weight
- Cooked weight

### Eggs and Poultry

| CF_{far-adj} (egg contaminated fraction) unitless | 1 |
| CF_{far-poultry} (poultry contaminated fraction unitless) | 1 |
| IFE_{far-adj} (age-adjusted egg ingestion factor) g | 775810 |
| IFP_{far-adj} (age-adjusted poultry ingestion factor) g | 1376550 |
| IRE_{far-a} (egg ingestion rate - farmer adult) g/day | 59.6 |
| IRE_{far-c} (egg ingestion rate - farmer child) g/day | 31.7 |
| IRP_{far-a} (poultry ingestion rate - farmer adult) g/day | 107.4 |
| IRP_{far-c} (poultry ingestion rate - farmer child) g/day | 46.9 |

Toggle poultry type:  
- Chicken
- Duck
- Turkey
- Goose

### FRG Equation

\[
PRG_{soil-far-tot} (pCi/g) = \frac{1}{PRG_{soil-far-sol-ing} + \frac{1}{PRG_{soil-far-sol-hr}}} + \frac{1}{PRG_{soil-far-sol-ext} + \frac{1}{PRG_{soil-far-produce-ing-tot} + \frac{1}{PRG_{soil-far-egg-ing} + \frac{1}{PRG_{soil-far-poultry-ing} + \frac{1}{PRG_{soil-far-fish-ing} + \frac{1}{PRG_{soil-far-beef-ing} + \frac{1}{PRG_{soil-far-dairy-ing} + \frac{1}{PRG_{soil-far-swine-ing}}}}}}}}}}
\]
Radionuclides are metals-mostly!
  - Radon presents unique challenges
  - Metals don’t have a VF or Andelman’s constant
Radionuclides decay (equation difference, what was the parent?)
Dermal exposure from soil is not done for rads
Dermal contact with tapwater is done for rads but called “immersion”
In addition to inhalation, rads add “submersion”
Rad PRGs still use inhalation rate
2-D external exposure is done for rads with shielding
Produce is included in the rad resident scenario
Rad tool has a farmer
Make sure the rad and chemical risk assessors talk to each other
Make sure Kds and TFs are same for metals in chem and rad work
PRG calculator also gives results on a mass basis, careful!

https://rais.ornl.gov/
DCC

DCC Calculator

Using the DCC Calculator

Select Scenario

- Resident
- Indoor Worker
- Outdoor Worker
- Composite Worker
- Construction Worker (Site-specific only)
- Recreator (Site-specific only)
- Farmer
- Soil to Groundwater

Select Media:
- Soil
- Tap Water
- Air
- 2-D External Exposure
- Fish

https://rais.ornl.gov/
DCC

Select ICRP rule

- 107 – Center for Radiation Protection Knowledge
- 60/68/72
- 30
## Parameters Common to all Exposure Route Equations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.77$</td>
<td>$\text{AAF}_{\text{res}-a}$ (annual age fraction – resident adult)</td>
<td></td>
<td>unitless</td>
</tr>
<tr>
<td>$0.23$</td>
<td>$\text{AAF}_{\text{res-c}}$ (annual age fraction – resident child)</td>
<td></td>
<td>unitless</td>
</tr>
<tr>
<td>$1$</td>
<td>$\text{DL}$ (dose limit) mrem/yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$26$</td>
<td>$\text{ED}_{\text{res}}$ (exposure duration – resident) yr</td>
<td></td>
<td>yr</td>
</tr>
<tr>
<td>$20$</td>
<td>$\text{ED}_{\text{res}-a}$ (exposure duration – resident adult) yr</td>
<td></td>
<td>yr</td>
</tr>
<tr>
<td>$6$</td>
<td>$\text{ED}_{\text{res-c}}$ (exposure duration – resident child) yr</td>
<td></td>
<td>yr</td>
</tr>
<tr>
<td>$350$</td>
<td>$\text{EF}_{\text{res}}$ (exposure frequency – resident) day/yr</td>
<td></td>
<td>day/yr</td>
</tr>
<tr>
<td>$350$</td>
<td>$\text{EF}_{\text{res}-a}$ (exposure frequency – resident adult) day/yr</td>
<td></td>
<td>day/yr</td>
</tr>
<tr>
<td>$350$</td>
<td>$\text{EF}_{\text{res-c}}$ (exposure frequency – resident child) day/yr</td>
<td></td>
<td>day/yr</td>
</tr>
<tr>
<td>$24$</td>
<td>$\text{ET}_{\text{res}}$ (exposure time – resident) hr</td>
<td></td>
<td>hr</td>
</tr>
<tr>
<td>$24$</td>
<td>$\text{ET}_{\text{res}-a}$ (exposure time – resident adult) hr</td>
<td></td>
<td>hr</td>
</tr>
<tr>
<td>$24$</td>
<td>$\text{ET}_{\text{res-c}}$ (exposure time – resident child) hr</td>
<td></td>
<td>hr</td>
</tr>
<tr>
<td>$1$</td>
<td>$\text{t}_{\text{res}}$ (time – resident) yr</td>
<td></td>
<td>yr</td>
</tr>
</tbody>
</table>
Soil Ingestion

\[
\text{DCC}_{\text{res-soil-ing}} (\text{pCi/g}) = \frac{\text{DL} \left( \frac{\text{mrem}}{\text{year}} \right) \times t_{\text{res}} \left( \text{year} \right) \times \lambda \left( \frac{1}{\text{year}} \right)}{1 - N_{\text{res}}} \times \text{DCF} \left( \frac{\text{mrem}}{\text{pCi}} \right) \times \text{IFS}_{\text{res-adj}} \left( \frac{43,050 \text{ mg}}{\text{year}} \right) \times \left( \frac{\text{g}}{1000 \text{ mg}} \right)
\]

where:

\[
\text{IFS}_{\text{res-adj}} \left( \frac{43,050 \text{ mg}}{\text{year}} \right) = \left( \frac{\text{EF}_{\text{res-c}} \left( \frac{350 \text{ days}}{\text{year}} \right) \times \text{IRS}_{\text{res-c}} \left( \frac{200 \text{ mg}}{\text{day}} \right) \times \text{AAF}_{\text{res-c}} (0.23)}{\text{EF}_{\text{res-a}} \left( \frac{350 \text{ days}}{\text{year}} \right) \times \text{IRS}_{\text{res-a}} \left( \frac{100 \text{ mg}}{\text{day}} \right) \times \text{AAF}_{\text{res-a}} (0.77)} \right) + \left( \frac{\text{ED}_{\text{res-c}} (6 \text{ years})}{\text{ED}_{\text{res}} (26 \text{ years})} \right)
\]

where:

\[
\text{AAF}_{\text{res-c}} (0.23) = \frac{\text{ED}_{\text{res-c}} (6 \text{ years})}{\text{ED}_{\text{res}} (26 \text{ years})} \quad \text{and} \quad \text{AAF}_{\text{res-a}} (0.77) = \frac{\text{ED}_{\text{res-a}} (20 \text{ years})}{\text{ED}_{\text{res}} (26 \text{ years})}
\]
## Site-Specific

Resident DCCs for Soil - Secular Equilibrium

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Ingestion DCC DL=1 (pCi/g)</th>
<th>Inhalation DCC DL=1 (pCi/g)</th>
<th>External Exposure DCC DL=1 (pCi/g)</th>
<th>Produce Consumption DCC DL=1 (pCi/g)</th>
<th>Total DCC DL=1 (pCi/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Secular Equilibrium DCC for Am-241</td>
<td>4.74E+00</td>
<td>2.77E+02</td>
<td>1.34E+00</td>
<td>6.89E-02</td>
<td>6.46E-02</td>
</tr>
<tr>
<td>*Secular Equilibrium DCC for Co-60</td>
<td>1.14E+03</td>
<td>1.80E+06</td>
<td>2.20E-01</td>
<td>1.68E+00</td>
<td>1.94E-01</td>
</tr>
<tr>
<td>*Secular Equilibrium DCC for Cs-137</td>
<td>4.72E+02</td>
<td>1.42E+06</td>
<td>1.09E+00</td>
<td>1.78E+00</td>
<td>6.75E-01</td>
</tr>
</tbody>
</table>
# DCC

## Soil Volume Correction Factor

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Soil Volume Area Correction Factor</th>
<th>0 cm Soil Volume Gamma Shielding Factor</th>
<th>Wet Soil-to-plant transfer factor (pCi/g-fresh plant per pCi/g-wet soil)</th>
<th>Ingestion Dose (mrem/yr)</th>
<th>Inhalation Dose (mrem/yr)</th>
<th>External Exposure Dose (mrem/yr)</th>
<th>Produce Consumption Dose Back-calculated to Soil (mrem/yr)</th>
<th>Total Dose (mrem/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Am-241</td>
<td>6.91E-01</td>
<td>1.00E+00</td>
<td>2.20E-05</td>
<td>2.08E+00</td>
<td>9.09E-02</td>
<td>6.73E-01</td>
<td>2.97E+02</td>
<td>3.00E+02</td>
</tr>
<tr>
<td>Co-60</td>
<td>1.00E+00</td>
<td>1.00E+00</td>
<td>8.50E-03</td>
<td>4.51E-02</td>
<td>2.87E-05</td>
<td>2.64E+02</td>
<td>6.63E+00</td>
<td>2.70E+02</td>
</tr>
<tr>
<td>Cs-137</td>
<td>9.78E-01</td>
<td>1.00E+00</td>
<td>2.90E-02</td>
<td>1.15E-01</td>
<td>3.82E-05</td>
<td>1.38E-02</td>
<td>1.82E+01</td>
<td>1.84E+01</td>
</tr>
<tr>
<td><strong>Total Dose</strong></td>
<td>-</td>
<td>-</td>
<td><strong>2.24E+00</strong></td>
<td><strong>9.10E-02</strong></td>
<td><strong>2.64E+02</strong></td>
<td><strong>3.22E+02</strong></td>
<td><strong>5.88E+02</strong></td>
<td></td>
</tr>
</tbody>
</table>

## Resident Risk for Soil

### Chemical Concentration (mg/kg)

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Concentration (mg/kg)</th>
<th>Ingestion Risk</th>
<th>Dermal Risk</th>
<th>Inhalation Risk</th>
<th>Carcinogenic Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic, Inorganic</td>
<td>5.50E+01</td>
<td>7.12E-05</td>
<td>1.00E-05</td>
<td>6.20E-08</td>
<td>8.13E-05</td>
</tr>
<tr>
<td>Chromium(VI)</td>
<td>5.50E+01</td>
<td>1.80E-04</td>
<td>-</td>
<td>3.35E-06</td>
<td>1.83E-04</td>
</tr>
<tr>
<td>Cobalt</td>
<td>5.50E+01</td>
<td>-</td>
<td>-</td>
<td>1.30E-07</td>
<td>1.30E-07</td>
</tr>
<tr>
<td>Zirconium</td>
<td>5.50E+01</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total Risk/Hi</strong></td>
<td>-</td>
<td><strong>2.51E-04</strong></td>
<td><strong>1.00E-05</strong></td>
<td><strong>3.54E-06</strong></td>
<td><strong>2.64E-04</strong></td>
</tr>
</tbody>
</table>

https://rais.ornl.gov/
EPA Rad Tool History

- PRG – January 2001
- DCC – January 2002
- BPRG – April 2009
- BDCC – August 2010
- SPRG – August 2010
- SDCC – August 2010

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- User's Guide
- What's New
- Frequent Questions
- Equations
- PRG Calculator
- Generic Tables

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- DCC FAQ

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