# Upgrading RESRAD-RDD and Planning for Improvised Nuclear Device Incidents — The RESRAD-RDD&IND

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# RESRAD-RDD Background

- Computer model that runs on the .NET framework (4.0)
- First released in 2004
- Calculates operational guidelines for a radiological dispersal device (RDD)
- Helps decision-makers make risk-informed decisions in an RDD scenario
- Examples of calculations include:
  - Access control to contaminated zone
  - Procedures for protection (evacuation/sheltering)
  - Relocation and critical infrastructure utilization
  - Temporary access to contaminated zone for essential services
  - Transportation and access routes
  - Release of real property from controlled areas
  - Food safety
- Employed in real-world training exercises (e.g. Liberty RadEx)

# RESRAD-RDD&IND Basics

- Eleven radionuclides are currently considered in RESRAD-RDD:

| Radionuclide | Half-Life | Primary Decay Mode | Purpose |
| --- | --- | --- | --- |
| Am-241 | 4.33E+2 y | α | Smoke detectors |
| Cf-252 | 2.64E+0 y | α, S.F. | Neutron source |
| Cm-244 | 1.81E+1 y | α | Medical procedures |
| Co-60 | 5.27E+0 y | γ | Medical procedures |
| Cs-137 | 3.02E+1 y | γ | Medical procedures |
| Ir-192 | 2.02E-1 y | γ | Welding |
| Po-210 | 3.79E-1 y | α | Electrostatic brush |
| Pu-238 | 8.77E+1 y | α | Thermoelectric batteries |
| Pu-239 | 2.41E+4 y | α | Thermoelectric batteries |
| Ra-226 | 1.60E+3 y | γ | Oil-drilling byproduct |
| Sr-90 | 2.88E+1 y | β | Thermoelectric batteries |

- 44 – 60 additional radionuclides will be added for RESRAD-RDD&IND

# RESRAD-RDD Conversion (Interface)

Released
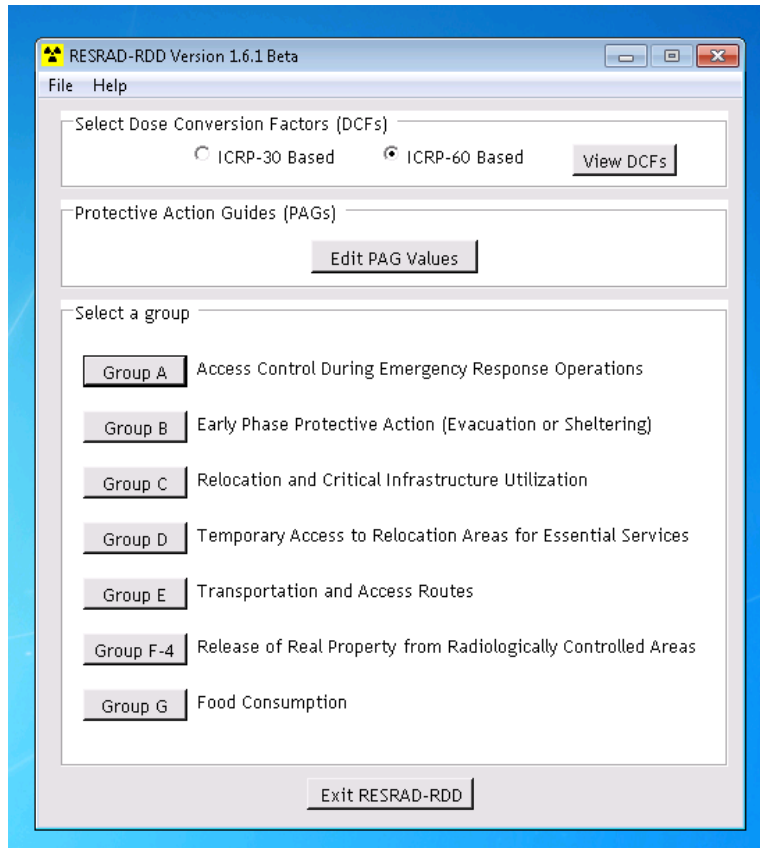
Under Development
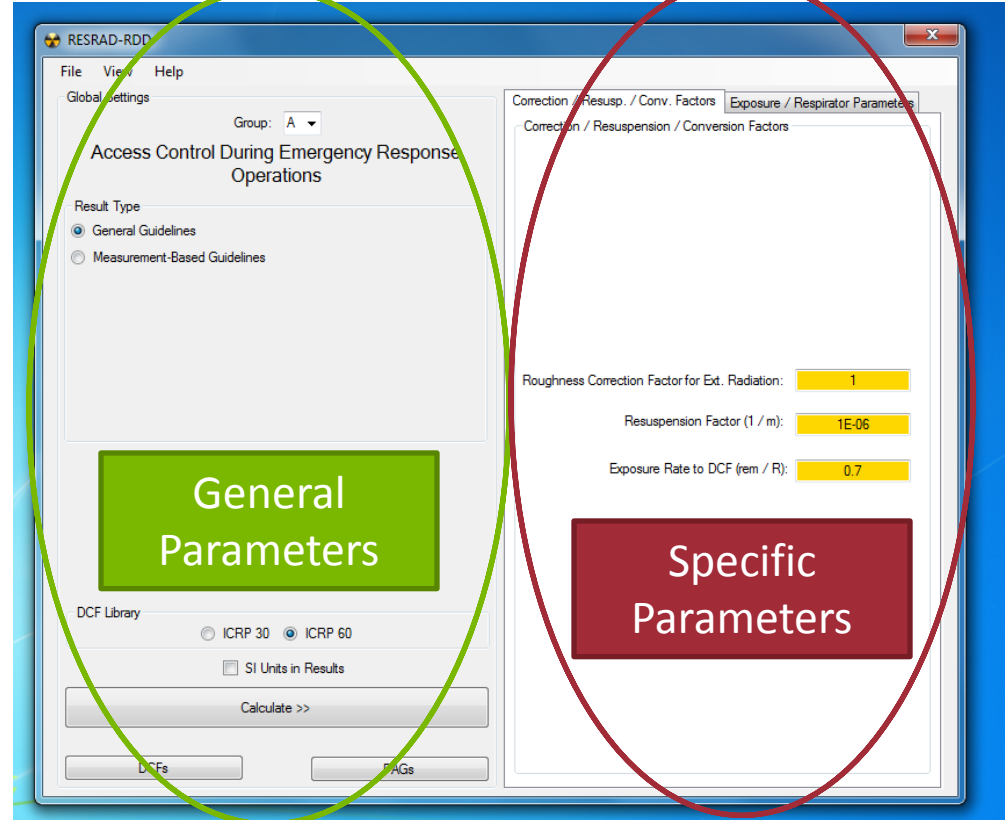


- Interface uses a combo-box for group selection and tab controls for parameters

# RESRAD-RDD Conversion (Interface)



Concentrations can be entered in units other than pCi/m²

- SI units will be available for concentration (Bq) and dose (Sv)

# RESRAD-RDD Conversion (Interface)

- More units available:
  - More units now supported for concentrations (Ci, Bq, d.p.m., d.p.s.)
  - SI units (Sv) will be supported for doses
  - Concentrations may be entered in magnitudes from pico- to giga-
- Calculations about nine times faster with the same inputs
- Fewer clicks required for the same calculations
- Reports can be written to PDFs instead of HTML

# RESRAD-RDD Conversion (Database)
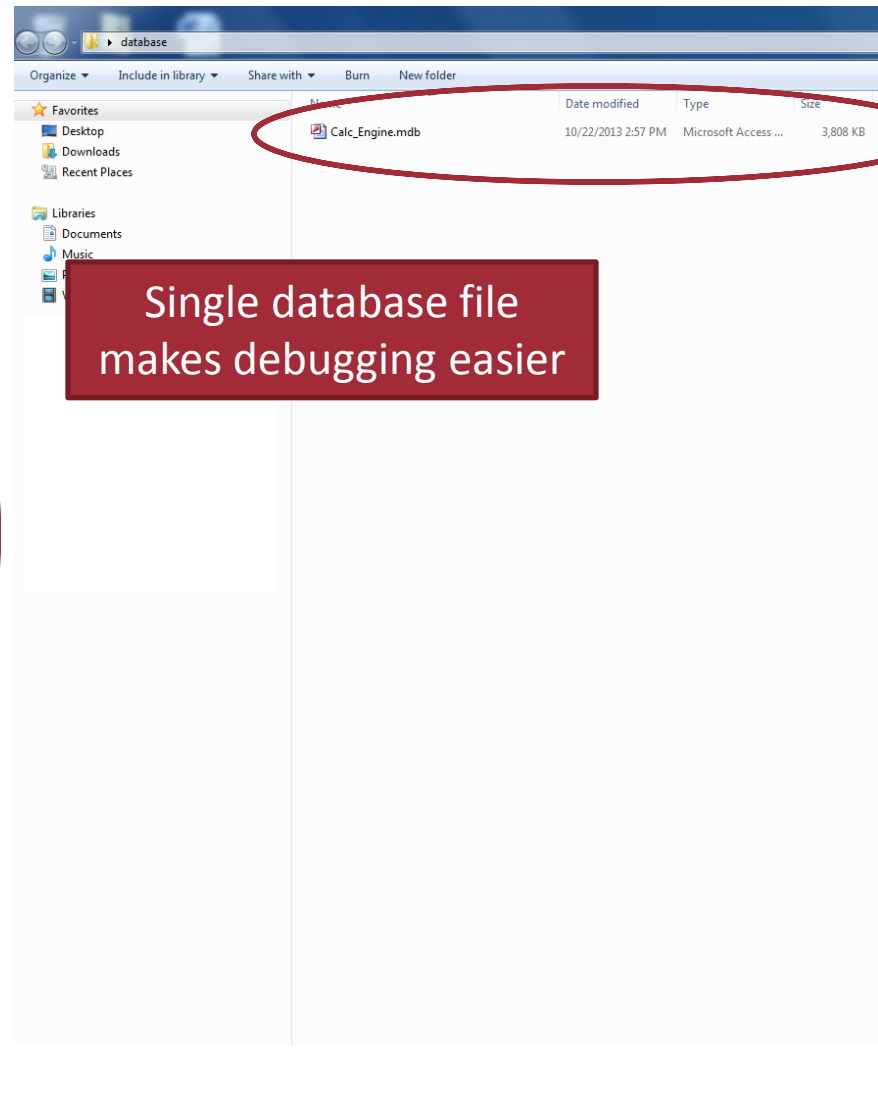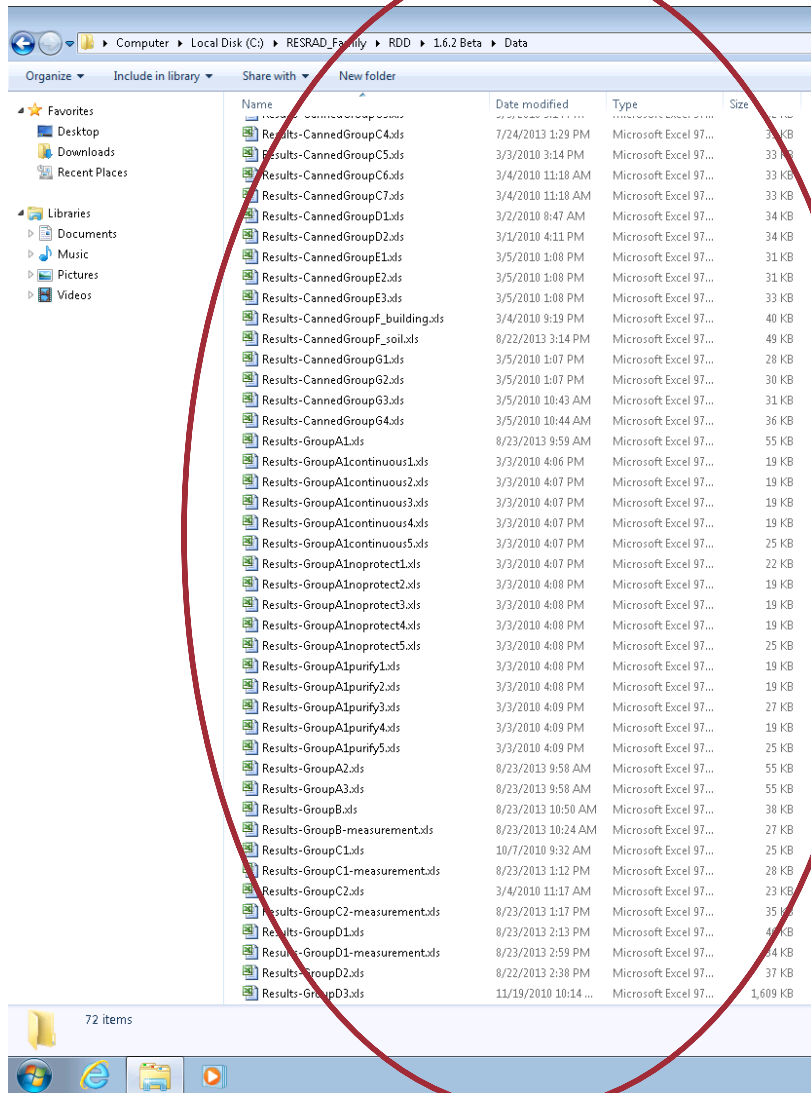


Single database file makes debugging easier

# RESRAD-RDD Conversion (Database)

- QC/QA procedures much easier to implement
- Debugging errors is faster process with fewer side-effects
- Database scalable for more radionuclides
- No special spreadsheet software required
- Validating user input simpler with a database-driven code
- The program and database communicate faster than a spreadsheet

# Future Goals

- Scale up the database by incorporating more radionuclides (such as IND [Improvised Nuclear Device] or nuclear bomb)

- Allow users to run calculations with multiple radionuclides

- Provide callback support in the case of an RDD or IND event

# RESRAD-RDD&IND Conversion (Interface)

- More units available:
  - More units now supported for concentrations (Ci, Bq, d.p.m., d.p.s.)
  - SI units (Sv) available for dose results
  - Concentrations may be entered in magnitudes from femto- to giga-
- Calculations ten times faster with the same inputs
- Fewer clicks required for the same calculations
- Reports can be written to PDFs instead of HTML

# RESRAD-RDD&IND Conversion (Calculations)

- Calculation times for all Group A general guidelines, all inputs left at default values
- Version 1.7 results: 32.8 seconds:

**TABLE 3 Stay Times$^a$ With Full Face Air Purifying Respirators based on Air Concentration Measurement**

| Air Concentration | | | Stay Time for Given Dose | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| pCi/m³ | Bq/m³ | dpm/m³ | 0.1 rem | 0.5 rem | 1 rem | 2 rem | 5 rem | 10 rem | 25 rem | 100 rem |
| 0.1 | 0.0037 | 0.222 | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | 0.037 | 2.22 | 3.26E+03 | --- | --- | --- | --- | --- | --- | --- |
| 10 | 0.37 | 22.2 | 3.26E+02 | 1.63E+03 | 3.26E+03 | 6.51E+03 | --- | --- | --- | --- |
| 100 | 3.7 | 222 | 3.26E+01 | 1.63E+02 | 3.26E+02 | 6.51E+02 | 1.63E+03 | 3.26E+03 | 8.14E+03 | --- |
| 1,000 | 37 | 2,220 | 3.26E+00 | 1.63E+01 | 3.26E+01 | 6.51E+01 | 1.63E+02 | 3.26E+02 | 8.14E+02 | 3.26E+03 |
| 10,000 | 370 | 22,200 | 3.26E-01 | 1.63E+00 | 3.26E+00 | 6.51E+00 | 1.63E+01 | 3.26E+01 | 8.14E+01 | 3.26E+02 |
| 100,000 | 3,700 | 222,000 | 3.26E-02 | 1.63E-01 | 3.26E-01 | 6.51E-01 | 1.63E+00 | 3.26E+00 | 8.14E+00 | 3.26E+01 |

a Stay times were calculated based on a reference radionuclide. If the contaminant is known, stay times listed in this table can be adjusted by multiplication with a correction factor. The correction factor was calculated as the ratio of the DSR of the reference radionuclide to the DSR of the radionuclide of concern. The correction factors for different radionuclides are different. They are listed in Table 5. When the calculated stay time is greater than 8760 h (i.e. 1 yr), "---" is displayed.

- Version 2.0 result

Group A - Results - With Full-Face Air-Purifying Respirators

Table 3 - Stay Times¹ With Full-Face Air-Purifying Respirators Based on Air Concentration Measurement

| Air Concentration | | | Stay Time¹ for Given Dose, h | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| pCi/cm³ | Bq/cm³ | dpm/100 cm³ | 0.1 rem | 0.5 rem | 1 rem | 2 rem | 5 rem | 10 rem | 25 rem | 100 rem |
| 0.1 | 0.0037 | 0.222 | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | 0.037 | 2.22 | 3.26E+3 | --- | --- | --- | --- | --- | --- | --- |
| 10 | 0.37 | 22.2 | 3.26E+2 | 1.63E+3 | 3.26E+3 | 6.51E+3 | --- | --- | --- | --- |
| 100 | 3.7 | 222 | 3.26E+1 | 1.63E+2 | 3.26E+2 | 6.51E+2 | 1.63E+3 | 3.26E+3 | --- | --- |
| 1,000 | 37 | 2,220 | 3.26E+0 | 1.63E+1 | 3.26E+1 | 6.51E+1 | 1.63E+2 | 3.26E+2 | 8.14E+2 | 3.26E+3 |
| 10,000 | 370 | 22,200 | 3.26E-1 | 1.63E+0 | 3.26E+0 | 6.51E+0 | 1.63E+1 | 3.26E+1 | 8.14E+1 | 3.26E+2 |
| 100,000 | 3,700 | 222,000 | 3.26E-2 | 1.63E-1 | 3.26E-1 | 6.51E-1 | 1.63E+0 | 3.26E+0 | 8.14E+0 | 3.26E+1 |

¹ Stay times were calculated based on a reference radionuclide. If the contaminant is known, stay times listed in this table can be adjusted by multiplication with a correction factor. The correction factor was calculated as the ratio of the DSR of the reference radionuclide to the DSR of the radionuclide of concern. The correction factors for different radionuclides are different. They are listed in Table 5. When the calculated stay time is greater than 8,760 h (i.e., 1 yr), '---' is displayed.

# RESRAD-RDD&IND Conversion (Calculations)

- Calculation times for all Group D general guidelines, all inputs left at default values
- Version 1.7 results: 64.2 seconds:

**Table 1 Stay Times for Group D1-1 Scenario: Worker Access to Business (Outdoor Exposure)**

| Radionuclide Concentration | | | | Stay Time (continuous exposure time in hours) to Receive 500 mrem | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pCi/cm² | pCi/m² | Bq/cm² | dpm/100 cm² | Am-241 | Cf-252 | Cm-244 | Co-60 | Cs-137 | Ir-192 | Po-210 | Pu-238 | Pu-239 | Ra-226 | Sr-90 |
| 1.00E+01 | 1.00E+05 | 3.70E-01 | 2.22E+03 | > 8760 | > 8760 | > 8760 | > 8760 | > 8760 | > 8760 | > 8760 | > 8760 | > 8760 | > 8760 | > 8760 |
| 1.00E+02 | 1.00E+06 | 3.70E+00 | 2.22E+04 | > 8760 | > 8760 | > 8760 | > 8760 | > 8760 | > 8760 | > 8760 | > 8760 | > 8760 | > 8760 | > 8760 |
| 1.00E+03 | 1.00E+07 | 3.70E+01 | 2.22E+05 | 3.00E+02 | 6.92E+03 | 1.99E+03 | 3.74E+03 | > 8760 | > 8760 | 1.05E+03 | 1.98E+02 | 1.55E+02 | 1.94E+03 | > 8760 |
| 1.00E+04 | 1.00E+08 | 3.70E+02 | 2.22E+06 | 8.68E+00 | 4.57E+01 | 1.46E+01 | 2.72E+02 | 1.09E+03 | 1.42E+03 | 6.89E+01 | 7.57E+00 | 6.94E+00 | 7.82E+01 | 2.71E+03 |
| 1.00E+05 | 1.00E+09 | 3.70E+03 | 2.22E+07 | 8.68E-01 | 3.94E+00 | 1.46E+00 | 2.63E+01 | 9.60E+01 | 9.86E+01 | 6.21E+00 | 7.57E-01 | 6.94E-01 | 6.03E+00 | 1.90E+02 |
| 1.00E+06 | 1.00E+10 | 3.70E+04 | 2.22E+08 | 8.68E-02 | 3.94E-01 | 1.46E-01 | 2.63E+00 | 9.36E+00 | 9.61E+00 | 6.21E-01 | 7.57E-02 | 6.94E-02 | 6.03E-01 | 1.53E+01 |
| 1.00E+07 | 1.00E+11 | 3.70E+05 | 2.22E+09 | 8.68E-03 | 3.94E-02 | 1.46E-02 | 2.63E-01 | 9.36E-01 | 9.61E-01 | 6.21E-02 | 7.57E-03 | 6.94E-03 | 6.03E-02 | 1.53E+00 |

- Version 2.0 results: 17.0 seconds:

### Group D - Results - Stay Time Tables for Group D

Table 1 - Stay Times for Worker Access to Businesses (Outdoor Exposure)

| Radionuclide Concentration | | | | Stay Time (h) for 500 mrem | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pCi/cm² | pCi/m² | Bq/cm² | dpm/100 cm² | Am-241 | Cf-252 | Cm-244 | Co-60 | Cs-137 | Ir-192 | Po-210 | Pu-238 | Pu-239 | Ra-226 | Sr-90 |
| 1.00E+1 | 1.00E+5 | 3.70E-1 | 2.22E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 |
| 1.00E+2 | 1.00E+6 | 3.70E+0 | 2.22E+4 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 |
| 1.00E+3 | 1.00E+7 | 3.70E+1 | 2.22E+5 | 3.00E+2 | 6.92E+3 | 1.99E+3 | 3.74E+3 | >8.76E+3 | >8.76E+3 | 1.05E+3 | 1.98E+2 | 1.55E+2 | 1.94E+3 | >8.76E+3 |
| 1.00E+4 | 1.00E+8 | 3.70E+2 | 2.22E+6 | 8.68E+0 | 4.57E+1 | 1.46E+1 | 2.72E+2 | 1.09E+3 | 1.42E+3 | 6.89E+1 | 7.57E+0 | 6.94E+0 | 7.82E+1 | 2.71E+3 |
| 1.00E+5 | 1.00E+9 | 3.70E+3 | 2.22E+7 | 8.68E-1 | 3.94E+0 | 1.46E+0 | 2.63E+1 | 9.60E+1 | 9.86E+1 | 6.21E+0 | 7.57E-1 | 6.94E-1 | 6.03E+0 | 1.90E+2 |
| 1.00E+6 | 1.00E+10 | 3.70E+4 | 2.22E+8 | 8.68E-2 | 3.94E-1 | 1.46E-1 | 2.63E+0 | 9.36E+0 | 9.61E+0 | 6.21E-1 | 7.57E-2 | 6.94E-2 | 6.03E-1 | 1.53E+1 |
| 1.00E+7 | 1.00E+11 | 3.70E+5 | 2.22E+9 | 8.68E-3 | 3.94E-2 | 1.46E-2 | 2.63E-1 | 9.36E-1 | 9.61E-1 | 6.21E-2 | 7.57E-3 | 6.94E-3 | 6.03E-2 | 1.53E+0 |

# RESRAD-RDD&IND Conversion (Calculations)

- Time saved by:
  - Keeping constant values within .exe file
  - Parallelizing code as appropriate
  - Preserving data that will be reusable
  - Writing tables by nuclide instead of by concentration:

Group D - Results - Stay Time Tables for Group D

Table 1 - Stay Times for Worker Access to Businesses (Outdoor Exposure)

| Radionuclide Concentration | | | | Stay Time (h) for 500 mrem | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pCi/cm² | pCi/m² | Bq/cm² | dpm/100 cm² | Am-241 | Cf-252 | Cm-244 | Co-60 | Cs-137 | Ir-192 | Po-210 | Pu-238 | Pu-239 | Ra-226 | Sr-90 |
| 1.00E+1 | 1.00E+5 | 3.70E-1 | 2.22E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 |
| 1.00E+2 | 1.00E+6 | 3.70E+0 | 2.22E+4 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 | >8.76E+3 |
| 1.00E+3 | 1.00E+7 | 3.70E+1 | 2.22E+5 | 3.00E+2 | 3.92E+3 | 1.99E+3 | 3.74E+3 | >8.76E+3 | >8.76E+3 | 1.08E+3 | 1.90E+2 | 1.56E+2 | 1.94E+3 | >8.76E+3 |
| 1.00E+4 | 1.00E+8 | 3.70E+2 | 2.22E+6 | 8.68E+0 | 4.57E+1 | 1.46E+1 | 2.72E+2 | 1.09E+3 | 1.42E+3 | 6.89E+1 | 7.57E+0 | 6.94E+0 | 7.82E+1 | 2.71E+3 |
| 1.00E+5 | 1.00E+9 | 3.70E+3 | 2.22E+7 | 8.68E-1 | 3.94E+0 | 1.46E+0 | 2.63E+1 | 9.60E+1 | 9.86E+1 | 6.21E+0 | 7.57E-1 | 6.94E-1 | 6.03E+0 | 1.90E+2 |
| 1.00E+6 | 1.00E+10 | 3.70E+4 | 2.22E+8 | 8.68E-2 | 3.94E-1 | 1.46E-1 | 2.63E+0 | 9.36E+0 | 9.61E+0 | 6.21E-1 | 7.57E-2 | 6.94E-2 | 6.03E-1 | 1.53E+1 |
| 1.00E+7 | 1.00E+11 | 3.70E+5 | 2.22E+9 | 8.68E-3 | 3.94E-2 | 1.46E-2 | 2.63E-1 | 9.36E-1 | 9.61E-1 | 6.21E-2 | 7.57E-3 | 6.94E-3 | 6.03E-2 | 1.53E+0 |

  - This order saves time since radionuclide-specific data is not reset in every cell

# Improvement of RESRAD-RDD

- Converting RESRAD-RDD from Excel Spread Sheets to a "code"

- Adopting the new Resuspension Factor formula used by TurboFRMAC

- Updating the DOE/HS-0001 (Prelim. Report on Operational Guidelines)

- Incorporating the "Additional Scenarios" to the code

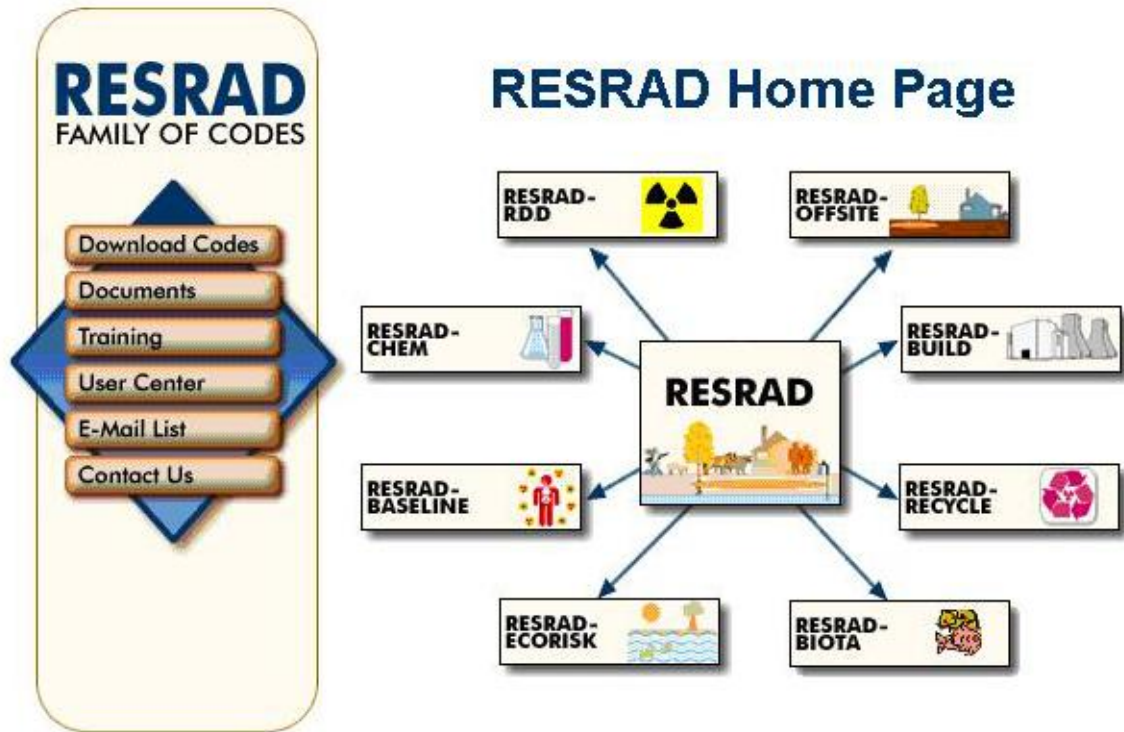- Adding Improvised Nuclear Device (IND) and reactor accident radionuclides and scenarios

# Future Plan

- Develop new risk models for Improvised Nuclear Device (IND) incidents
- Collect new data to support database and modeling parameters
- Conduct model-model comparison and model-data validation exercises

# Thank you!



**The next RESRAD training Course: Sept. 15-26, 2014 at Argonne National Lab**

More Info at RESRAD Web Site:

http://www.evs.anl.gov/resrad

Email: resrad@anl.gov