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RASCAL 4.0

Radiological Assessment System for Consequence Analysis

National Radiological Emergency Preparedness Conference

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RASCAL v4 – The New RASCAL

- What is new?
- Why is it changed?
- What are the implications of the changes?
- Are the changes reasonable?

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The Changes

- Radioactive decay scheme
- Monitored mix release type
- Atmospheric dispersion and deposition

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Radioactive Decay: What Is New?

- The decay scheme has been revised in the source term, environmental and dose calculations
- The decay scheme uses simplified chains that include short-lived daughters implicitly and are truncated at long-lived daughters
- Decay calculations are made using the Bateman Equations for 0 to 3 daughters and include branching.
- The RASCAL v4 radionuclide library is based on the radionuclide list in Appendix A of Federal Guidance Report 12
- The library lists 800 isotopes; only 15 short-lived isotopes are not Included either explicitly or implicitly.
  - The library also Includes $U_{natural}$, $U_{enriched}$, and UF_6

Radioactive Decay

- Why the Change?
  - Consistency
    - RASCAL v3.0.5 uses 3 different decay schemes
    - RASCAL v 4 uses just one
  - Traceability
    - RASCAL v4 decay schemes are documented
    - Appendices in the technical documentation will list the chains, decay parameters and implicit daughters

Radioactive Decay

- What are the Implications of the Change?
  - The changes in decay schemes should not result in any significant changes in dose estimates; however, they significantly alter DRL estimates.
  - Truncation errors have been evaluated and are generally << 1%
  - Addition of implicit daughters and simplification of chains that include branching increases doses slightly at short times

Monitored Release

- Assumptions
  - Monitored pathway
  - Monitor capable of distinguishing between particle and noble gas activity
  - Reactor is shutdown with core damage
  - Particles are CsI

Monitored Release

- Assumptions
  - RASCAL v3.0.5
    - Particle activity is 50% Cs-137 and 50% I-131
  - RASCAL v4
    - Particle activity is distributed among all radioactive and stable Cs and I isotopes based on stoichiometric proportions

Monitored Release

- Why the Change?
  - RASCAL 3.0.5 significantly overestimated the long-term consequences of a release by exaggerating the Cs-137 activity
  - RASCAL 3.0.5 significantly underestimated the short-term consequences of a release by minimizing the I-131 activity

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Monitored Release

- What are the Implications of the Change?
  - In RASCAL v4, >99.6% of the activity is in iodine isotopes; <0.4% of the activity is in Cesium Isotopes.
  - Doses are also reduced because most of the activity is in isotopes having dose factors that are lower than those for I-131 and Cs-137.

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Monitored Release

Monitored Release Particle Activity Fraction

Isotope	RASCAL v3.0.5	RASCAL v4
I-131	0.500	0.115
I-132		0.167
I-133		0.233
I-134		0.258
I-135		0.223
Cs-134		0.00193
Cs-136		0.000613
Cs-137	0.500	0.00134

Atmospheric Dispersion

- What is New?
  - RASCAL v4 has changed from distance-based dispersion parameters to time-based parameters
  - Gone are the Pasquill-Gifford parameters
  - Dispersion is now a function of:
    - time since release
    - wind speed
    - atmospheric stability
    - surface roughness

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Atmospheric Dispersion

- Why the Change?
  - The Pasquill-Gifford dispersion parameters were based on dispersion experiments in the 1950s.
  - Atmospheric experiments on dispersion and boundary layer processes in the 1960s, 1970s, and 1980s provide better methods of estimating atmospheric dispersion.

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Atmospheric Dispersion

- What are the Implications of the Changes?
  - The RASCAL v4 dispersion parameters tend to be larger than the RASCAL v3.0.5 parameters
  - X/Qs and doses for ground-level releases will tend to be lower
  - X/Qs and doses for elevated releases will tend to be higher near the release point

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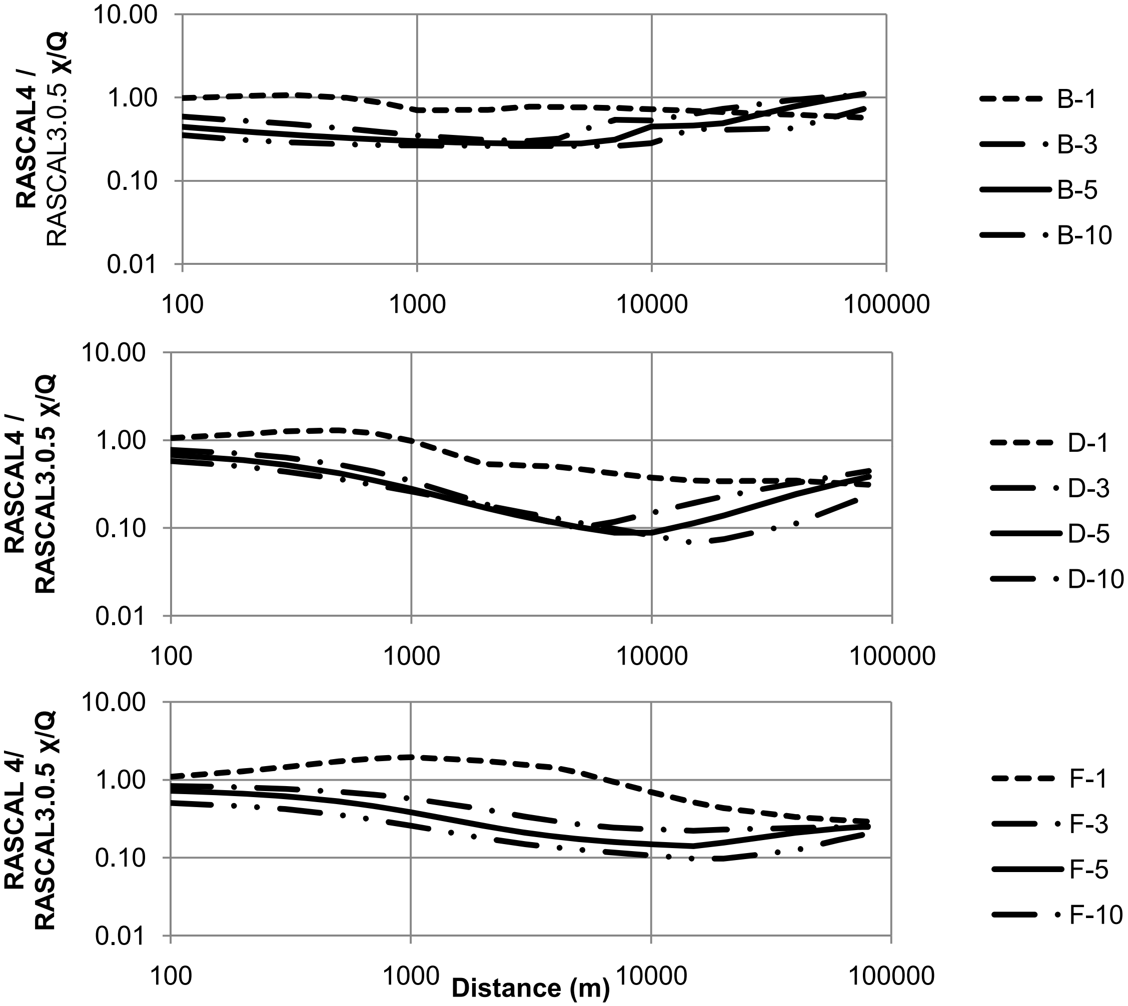
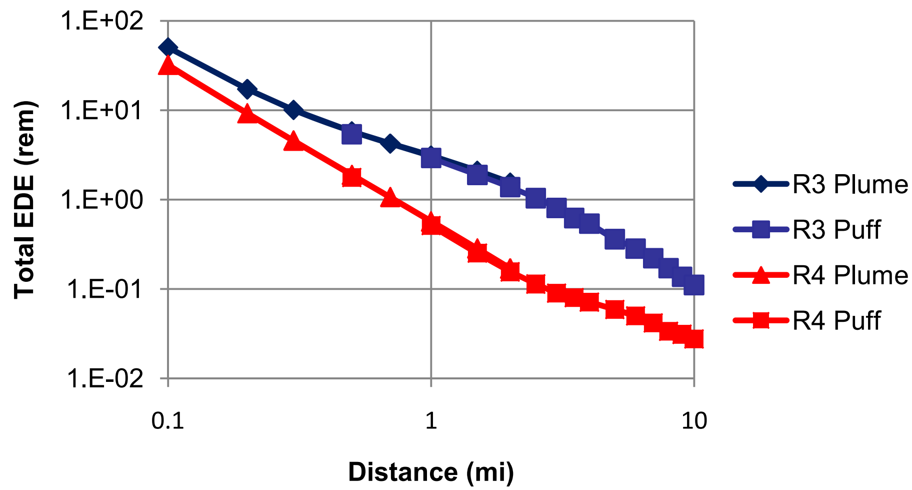
Atmospheric Dispersion

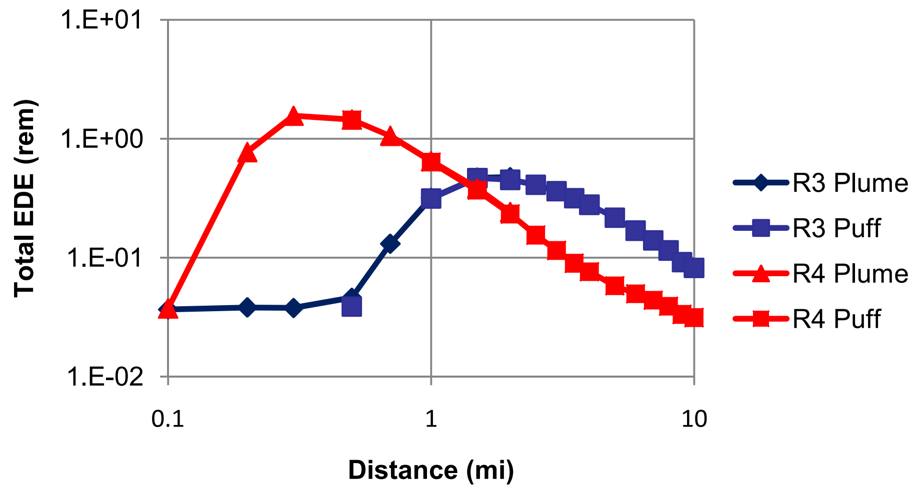


Atmospheric Dispersion

Ground Level,
D Stability, 3 m/s



Elevated,
D Stability, 3 m/s



Atmospheric Deposition

- Why the Changes?
  – The RASCAL v3.0.5 parameters were developed in the 1950s and early 1960s.
  – Research on atmospheric processes in the 1960s, 1970s, and 1980s provide better methods of estimating atmospheric deposition.

Atmospheric Dry Deposition

- What is New?
  - RASCAL v4 has changed from constant dry deposition velocities to dry deposition velocities that are a function of atmospheric conditions including wind speed, stability, and surface roughness.
  - RASCAL v4 treats iodine (halogens) as three species having different deposition characteristics for purposes of calculating deposition (I_2, particles, and CH_3I)

Atmospheric Dry and Wet Deposition

- What is New?
  - RASCAL v4 iodine speciation is 25% Particles, 30% I_2, and 45% CH_3I; CH_3I is assumed not to deposit.
  - RASCAL v4 uses a wet deposition velocity for wet deposition of gases and a washout model for wet deposition of particles. These parameters are functions of wind speed, atmospheric stability, surface roughness, and precipitation rate

Atmospheric Deposition

- What are the Implications of the Changes?
  – The RASCAL v4 deposition parameters, while not constant, tend to be within a factor of 2 of the RASCAL v3.0.5 parameters.
  – RASCAL v4 deposition velocities for iodine tend to be lower than the RASCAL 3.0.5 value in low wind speed conditions and higher in high wind speeds.
  – Deposition of iodine is generally lower in RASCAL v4 because 45% of the iodine does not deposit.

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Atmospheric Deposition

Iodine Dry Deposition Velocities (m/s)

	Wind Speed (m/s)				
Stability	1	2	3	5	10
B	0.0023	0.0035	0.0043	0.0055	0.0072
D	0.0018	0.0028	0.0035	0.0046	0.0063
F	0.0014	0.0023	0.0030	0.0039	0.0055

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Atmospheric Dispersion and Deposition

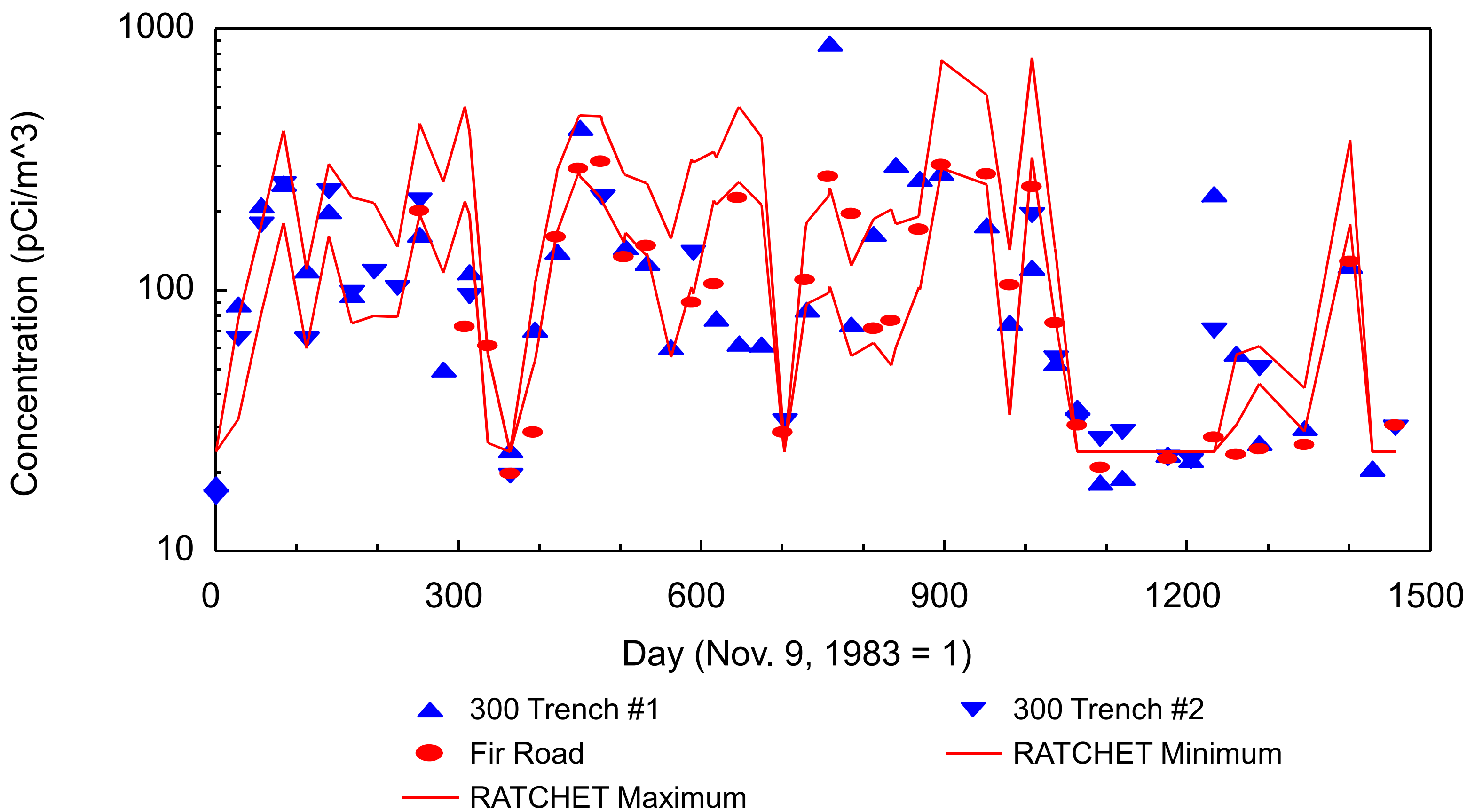
- Are the Dispersion and Deposition Changes Reasonable?
  - The new dispersion and deposition algorithms were developed for environmental dose reconstruction at Hanford in the 1990s
  - The development and application of the new algorithms were extensively reviewed by leading experts including F. Gifford and scientific organizations including the National Academy of Sciences.

Atmospheric Dispersion and Deposition

- Are the Dispersion and Deposition Changes Reasonable?
  - The Hanford Environmental Dose Reconstruction Project included an extensive validation effort
  - The dispersion and deposition algorithms have been used in subsequent dose reconstruction projects (ORNL, INEL, Rocky Flats, and Mayak, USSR)

Atmospheric Dispersion

Kr-85 Predictions for Routine Releases at Hanford



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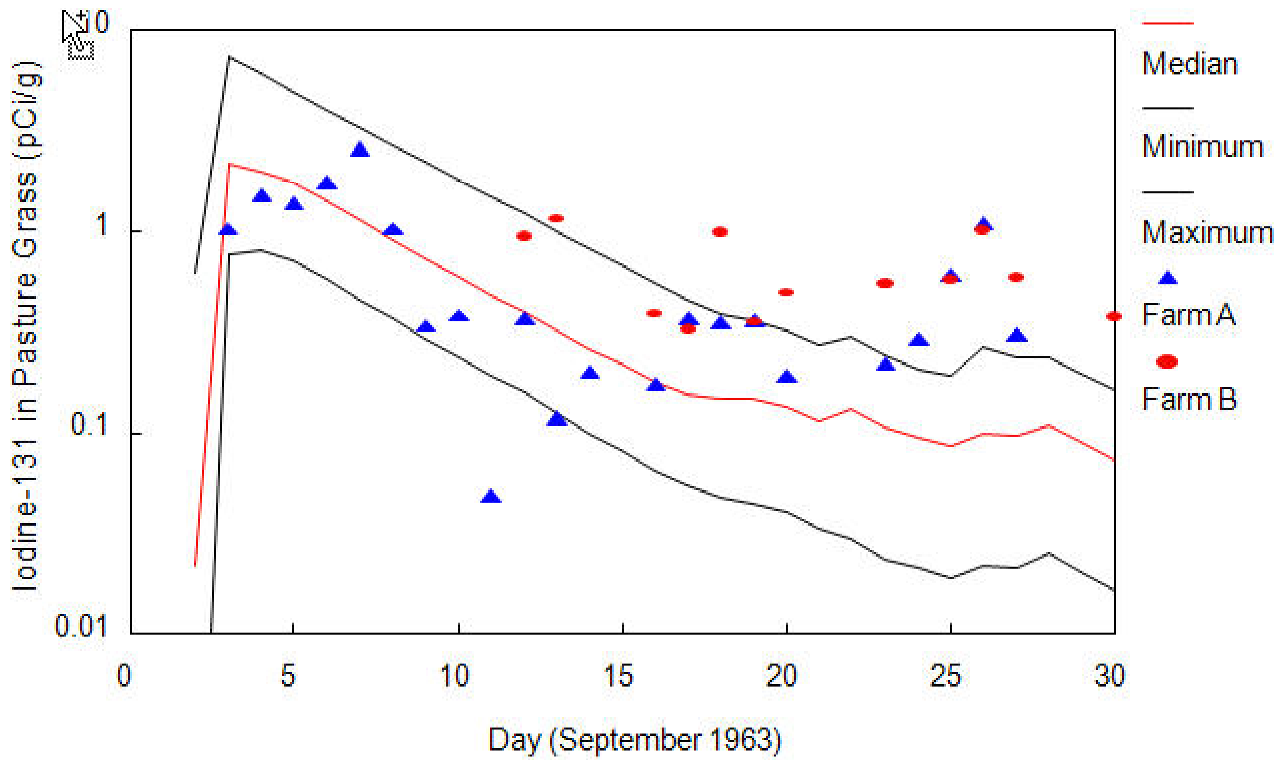
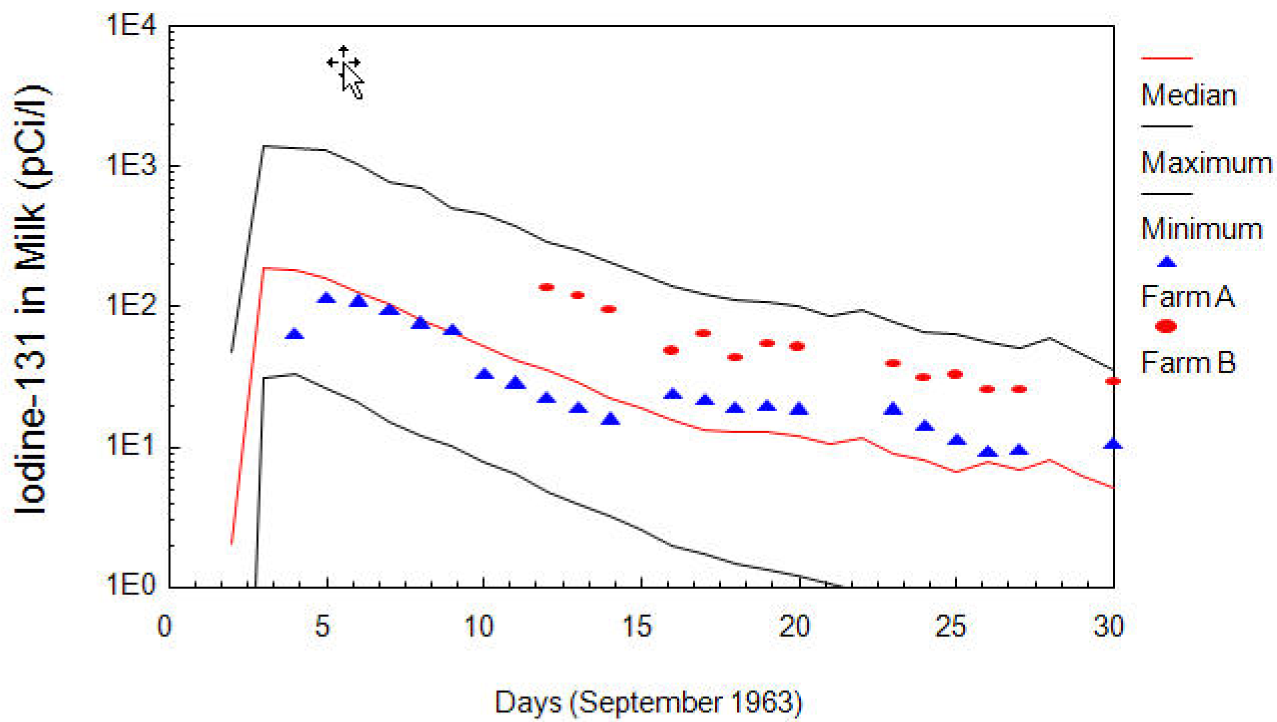
Atmospheric Dispersion and Deposition

Iodine in Grass Following Unintended Release at Hanford
(Sept. 1963)



Atmospheric Dispersion and Deposition

Iodine in Milk Following Unintended Release at Hanford (Sept. 1963)



Atmospheric Dispersion and Deposition

The Bottom Line For an Unintended Release at Hanford (Sept 1963)

	HEDR Median Thyroid Dose Estimate (mrad)	Contemporary Thyroid Burden Estimates (mrad)
Boy	45.3	35
Girl	11.3	9