Overview and Demo of RESRAD-ONSITE, RESRAD-OFFSITE, RESRAD-RDD, and RESRAD-BIOTA

Charley Yu and David LePoire
Environmental Science Division

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RESRAD Family of Codes Can be Used to Conduct Radiological Dose Assessment

More Info at RESRAD Web Site:
https://resrad.evs.anl.gov/
Email: resrad@anl.gov

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One Hundred Thirty-Three (133) Countries Downloaded RESRAD Family of Codes (twelve (12) new countries: Brunei, Central African Republic, Ecuador, El Salvador, Malta, Myanmar, Oman, Palestine, Panama, Papua New Guinea, Tonga, and Tuvalu)

Algeria	Bulgaria	Cuba	France	Italy	Malawi	Nepal	Philippines	South Africa	Tunisia	Yemen
Argentina	Burkina Faso	Cyprus	Gabon	Jamaica	Malaysia	Netherlands	Poland	South Korea	Turkey	Zambia
Armenia	Burundi	Czech Republic	Georgia	Japan	Malta	New Zealand	Portugal	Spain	Tuvalu	Zimbabwe
Australia	Cameroon	D.R. of the Congo	Germany	Jordan	Mauritius	Niger	Puerto Rico	Sudan	Uganda	
Austria	Canada	Denmark	Ghana	Kazakhstan	Mexico	Nigeria	Qatar	Sweden	Ukraine	
Azerbaijan	Central African Republic	Djibouti	Greece	Kenya	Moldova	North Korea	Romania	Switzerland	United Arab Emirates	
Bangladesh	Chad	Dominican Republic	Hungary	Kuwait	Monaco	Norway	Russia	Syria	United Kingdom	
Belarus	Chile	Ecuador	India	Latvia	Mongolia	Oman	Saudi Arabia	Taiwan	United States	
Belgium	China	Egypt	Indonesia	Lebanon	Montenegro	Pakistan	Senegal	Tajikistan	Uruguay	
Bosnia & Herzegovina	Colombia	El Salvador	Iran	Libya	Morocco	Palestine	Serbia	Tanzania	Uzbekistan	
Botswana	Congo	Estonia	Iraq	Lithuania	Mozambique	Panama	Singapore	Thailand	Vanuatu	
Brazil	Cote D'Ivoire	Fiji	Ireland	Macedonia	Myanmar	Papua New Guinea	Slovakia	Togo	Venezuela	
Brunei	Croatia	Finland	Israel	Madagascar	Namibia	Peru	Slovenia	Tonga	Vietnam	

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RESRAD Has a Strong Track Record

- RESRAD has been in existence for over 30 years
- RESRAD is the most extensively tested, benchmarked, verified and validated code in the environmental risk assessment and site cleanup field
- RESRAD has been widely used by federal and state agencies and their contractors
- Over 150 training workshops have been sponsored by DOE, NRC, EPA, DOD, IAEA, and state agencies
- Many universities have used RESRAD as a teaching and research tool
- More than 1000 journal articles, theses and other reports have been published based on RESRAD (some in foreign languages)
- RESRAD has been widely used in over 130 countries
- Comprehensive supporting documents are available for the application of RESRAD family of codes
- RESRAD is continuously maintained and improved
- RESRAD can be downloaded free of charge

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Overview of RESRAD-ONSITE

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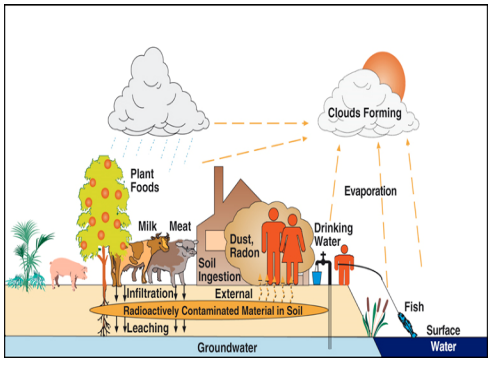
RESRAD-ONSITE – A Regulatory Tool for Determining Allowable RESidual RADioactivity in Site Cleanup

RESRAD, an internationally utilized model, successfully addresses the critical question: "How clean is clean?"



Accepted for use by government regulatory agencies

- DOE (Designated by Order 5400.5 and 458.1)
- NRC (NUREG-1757)
- EPA
- State agencies

In use for more than 30 years

- Evaluation of over 300 cleanup sites including many DOE/EM sites
- More than 150 training workshops
- International recognition (IAEA and other countries/organizations sponsored training courses)

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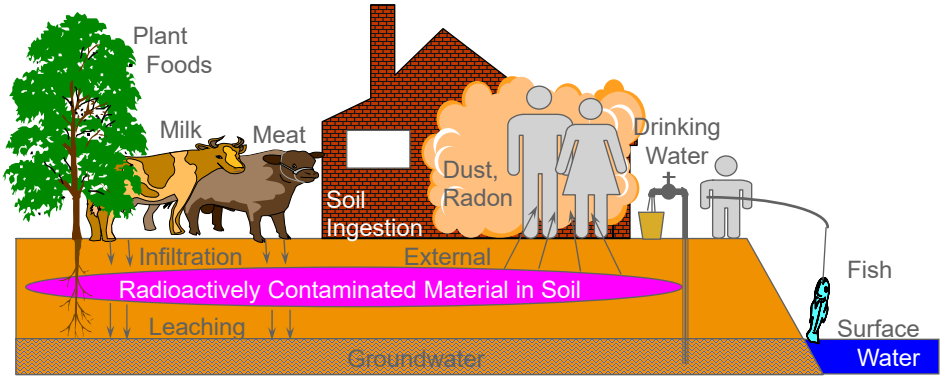
Exposure Pathways Considered in RESRAD-ONSITE: Resident Farmer Scenario



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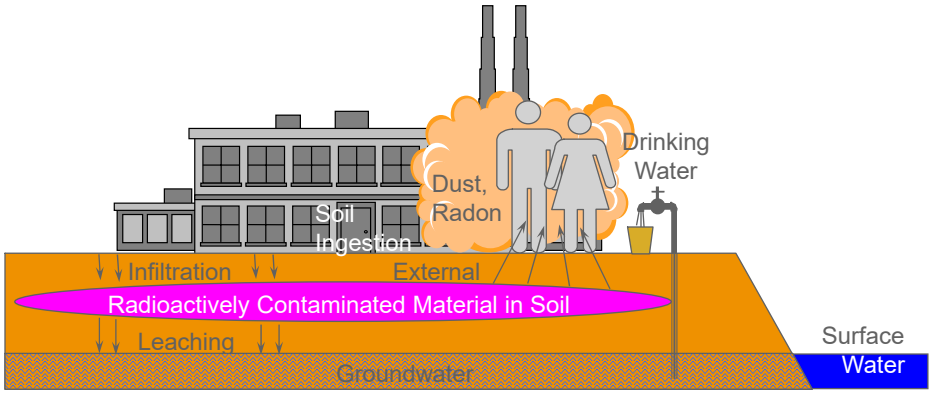
Exposure Pathways Considered in RESRAD-ONSITE: Industrial Use Scenario



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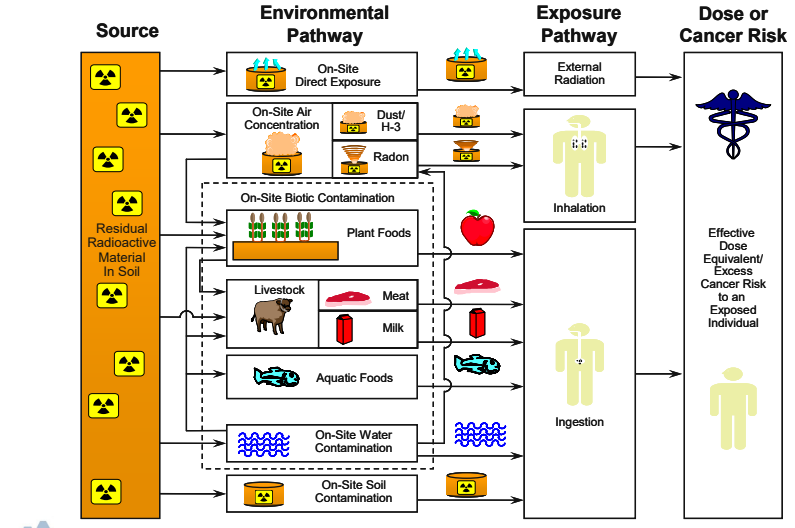
RESRAD Contains An Array of Parameters for Pathway Analysis in Performing Comprehensive Dose and Risk Assessment



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Major Categories of Input Parameters for RESRAD-ONSITE

- Contamination
  - Physical size, concentration, nuclides of concern
- Environmental Release and Transport
  - Release: leaching, particulate air release, erosion, root uptake
  - Transport: groundwater, air, radon gas, food chain
- Exposure Pathways (related to land use scenario)
  - External
  - Inhalation (particulates and radon),
  - Ingestion (plant, meat, milk, water, soil, aquatic foods)
- Consideration of Health Impacts
  - Annual dose or lifetime risk
  - Use of different coefficient to convert exposure to impact (dose, risk)

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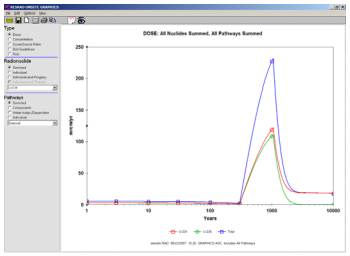
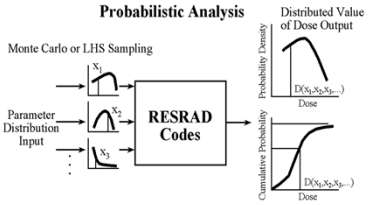
RESRAD-ONSITE Output and Analysis Tools

- Text Reports
  - Summary Dose Report (with input listing, doses, & DCGLs)
  - Concentration Report
  - Risk Report
  - Daughter Report
  - Detailed Report
- Graphics
  - Dose & Risk by Nuclide & Pathway
  - Concentration by Media
  - Dose/Source Ratios
  - Soil guidelines
- Sensitivity Analysis
  - Graphics
- Uncertainty (Probabilistic) Analysis
  - Text reports and graphics
  - Scatter plots





Demonstration of RESRAD-ONSITE

Break

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Overview of RESRAD-OFFSITE

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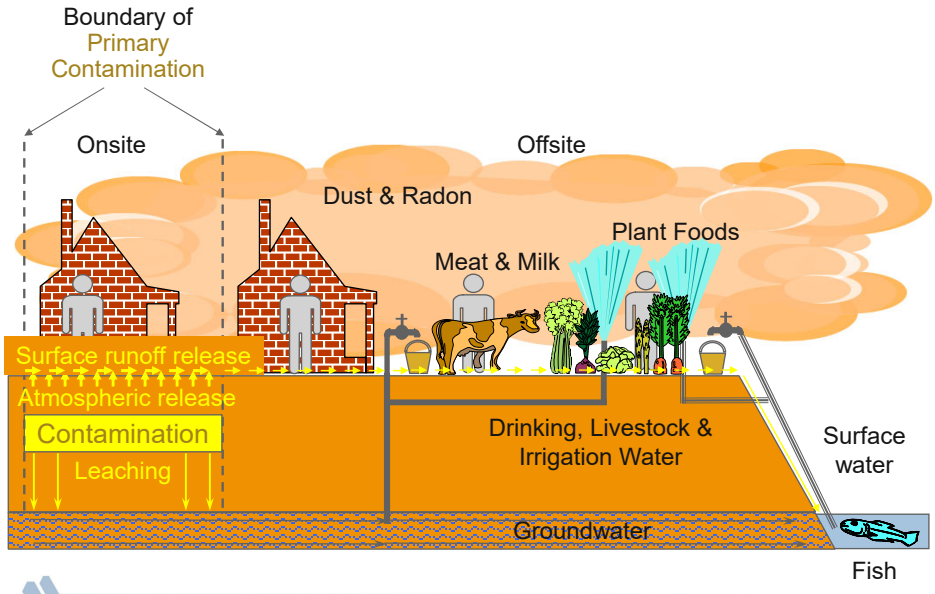
Environmental Pathways and Exposure Locations



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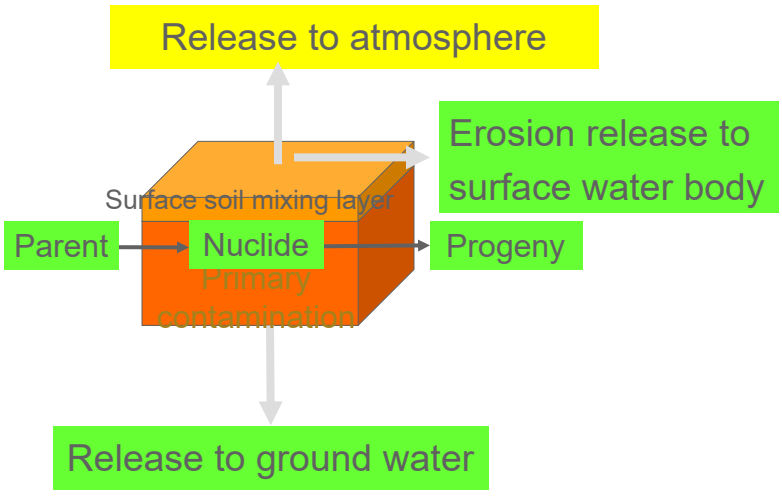
Radionuclide Balance of the Releases and the Remaining Inventory in the Primary Contamination Zone



Source balance considering radioactive transformations, leaching, and erosion

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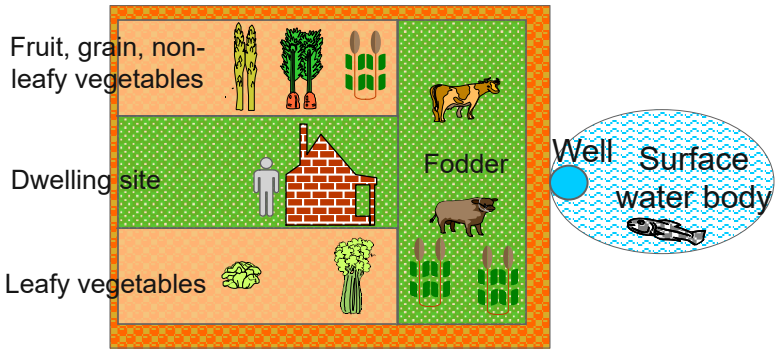
RESRAD-ONSITE Areas of Contamination

All activities occurred on top of the contaminated area



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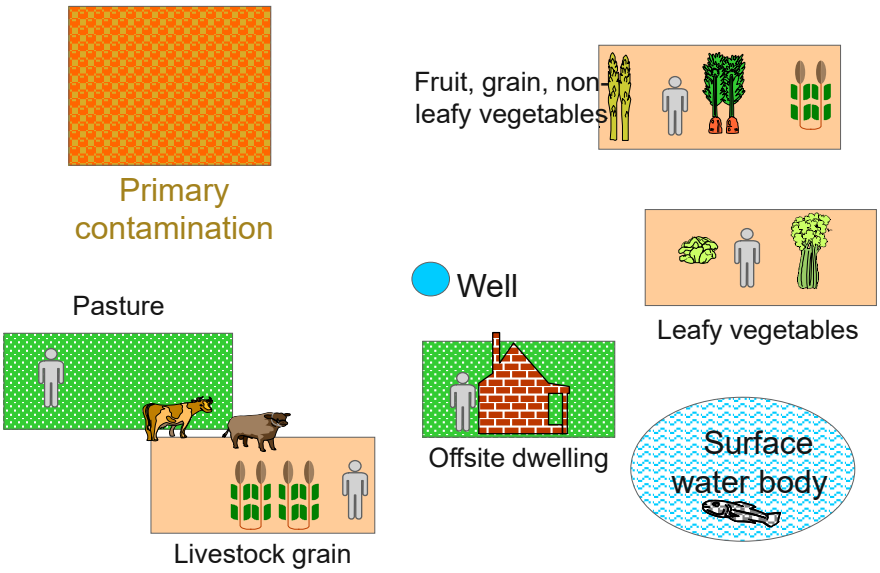
RESRAD-OFFSITE Areas of Contamination



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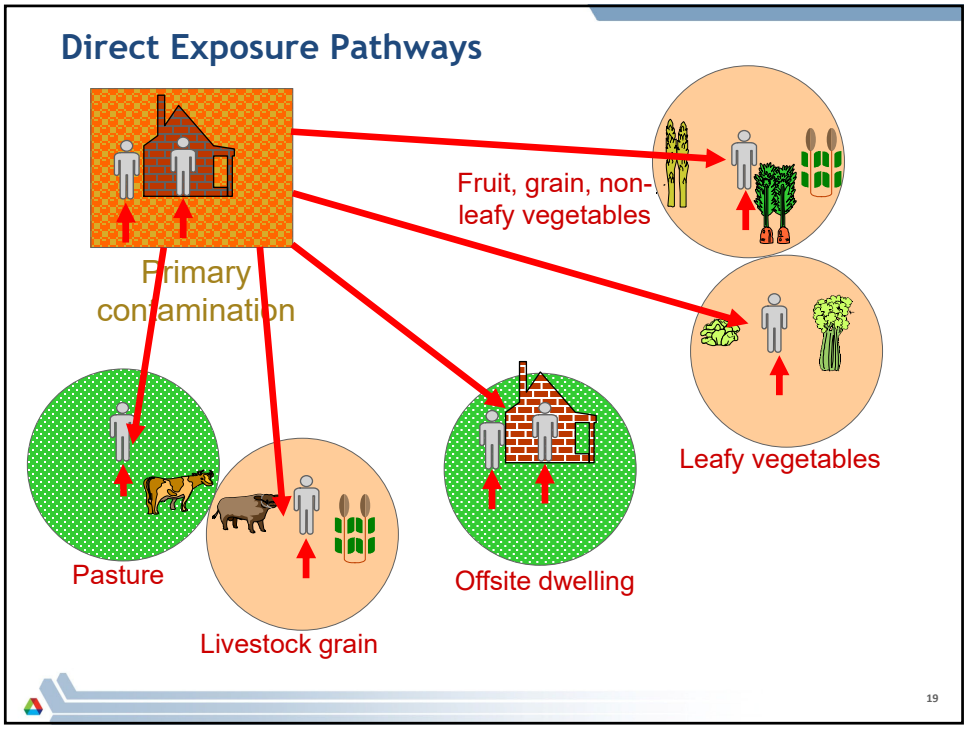
Direct Exposure Pathways
Fruit, grain, non-leafy vegetables
Primary contamination
Leafy vegetables
Pasture
Offsite dwelling
Livestock grain
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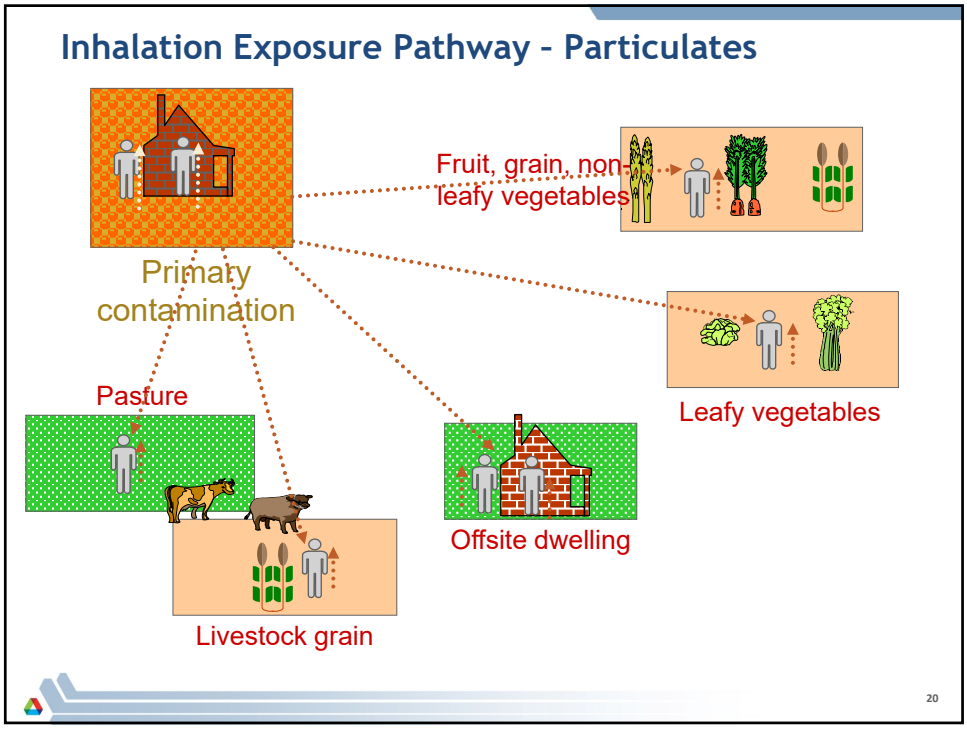
Inhalation Exposure Pathway - Particulates
Fruit, grain, non-leafy vegetables
Primary contamination
Leafy vegetables
Pasture
Offsite dwelling
Livestock grain
20

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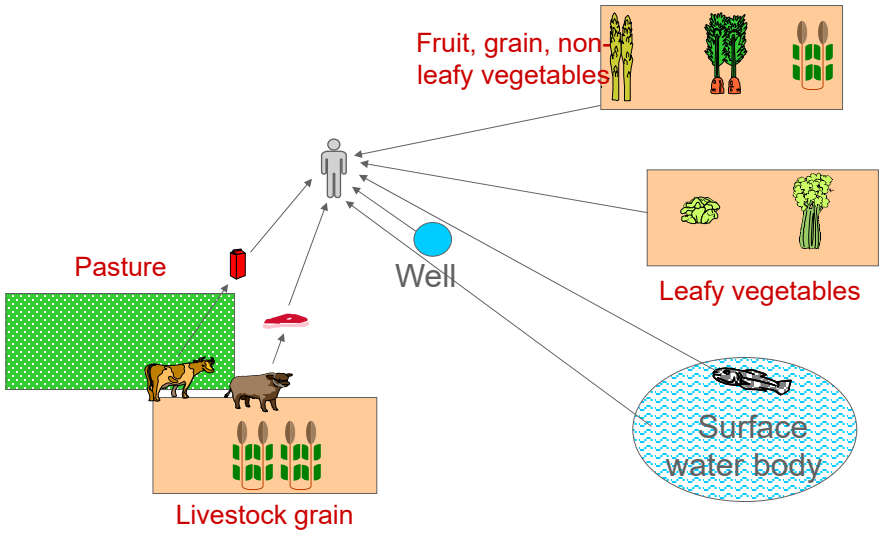
Ingestion Exposure Pathway - Food and Water



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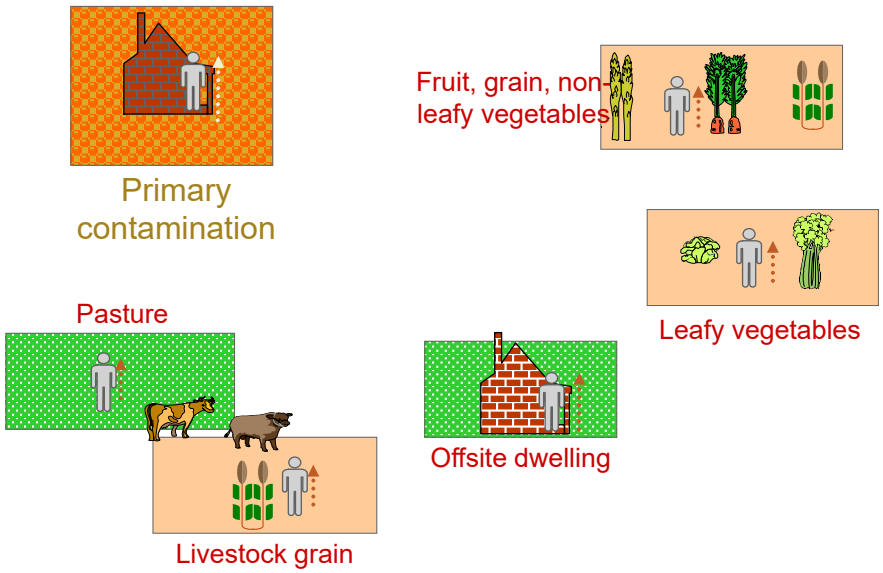
Ingestion Exposure Pathway - Soil



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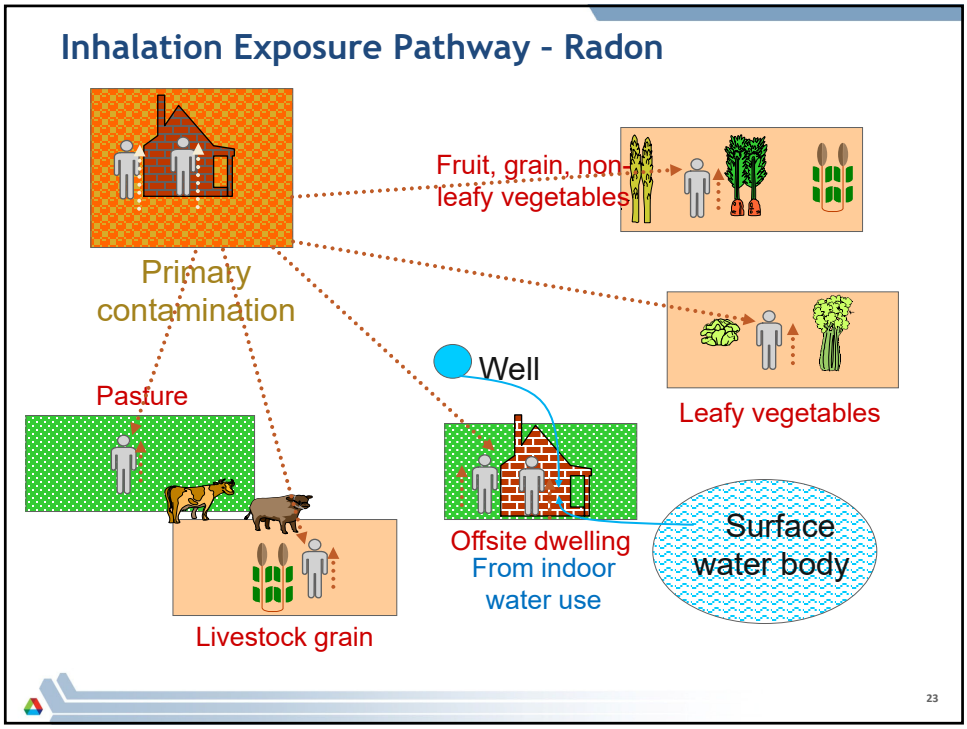
Inhalation Exposure Pathway - Radon
Fruit, grain, non-leafy vegetables
Primary contamination
Leafy vegetables
Well
Pasture
Offsite dwelling
From indoor water use
Surface water body
Livestock grain
23

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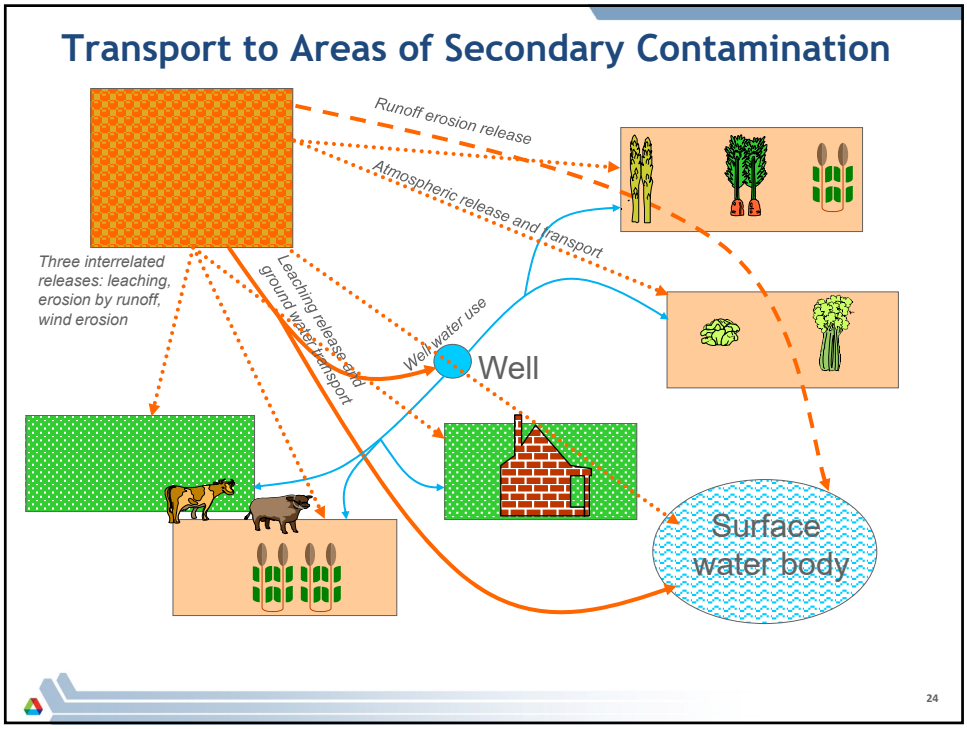
Transport to Areas of Secondary Contamination
Runoff erosion release
Atmospheric release and transport
Three interrelated releases: leaching, erosion by runoff, wind erosion
Leaching release and ground water transport
Well water use
Well
Surface water body
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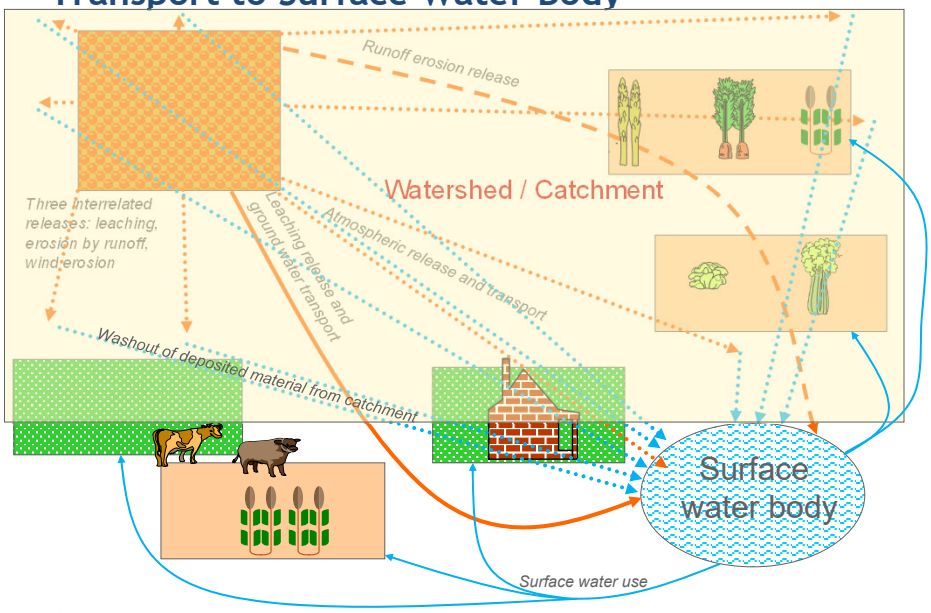
Transport to Surface Water Body



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RESRAD-OFFSITE Analysis Tools and Advanced Features

- Text reports and graphics
- Sensitivity analysis (one parameter at a time)
- Improved probabilistic analysis (multiparameter with sensitivity ranking)
- Both on-site and off-site receptors
- Air dispersion (Gaussian Plume) model
- Groundwater advection/dispersion (3-D) model
- Delayed release, time series releases, waste forms, and waste in containers, etc.
- Area factors output (for MARSSIM applications)

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Demonstration of RESRAD-OFFSITE

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Break

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Overview of RESRAD-RDD

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RESRAD-RDD Contamination Pathways and Routes of Exposure

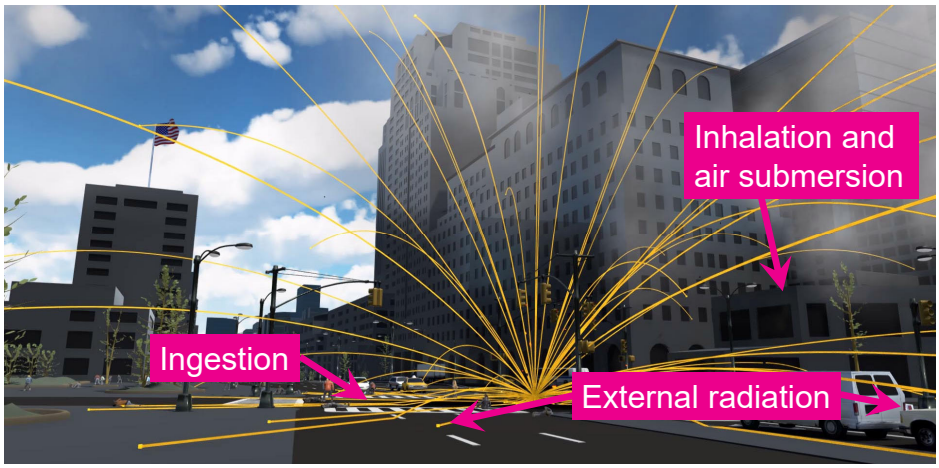

Image source: **DHS** https://www.dhs.gov/publication/st-frg-rdd-response-guidance-planning-first-100-minutes

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Role of Operational Guidelines

- **Protective Actions**
  Activities that should be conducted in response to an RDD to reduce or eliminate exposure of the public to radiation or other hazards.

- **Protective Action Guides (PAGs)**
  A projected dose to a reference individual, from an accidental or deliberate release of radioactive material, at which a specific protective action to reduce or avoid that dose is recommended.

- ***Operational Guidelines***
  Prederived levels of radiation that can be compared to field radiation measurements to quickly determine if PAGs are exceeded and actions for protection of the public need to be implemented.

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RESRAD-RDD Operational Guidelines Considerations

- Real and Personal Property:
  - buildings
  - roads and bridges
  - vehicles

- Critical Infrastructure & Resources:
  - hospitals
  - transportation
  - power & water
  - food

- Receptors-Scenarios:
  - workers and general public
  - urban, suburban, and rural environments

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RESRAD-RDD Development Approach

- Addressed 11 radionuclides (Am-241, Cf-252, Cm-244, Co-60, Cs-137, Ir-192, Po-210, Pu-238, Pu-239, Ra-226, Sr-90)
- Applied a consistent methodology & parameters across groups as appropriate
- Calculated dose to source ratios (DSR) (e.g., mSv/yr per Bq/m^2 or mrem/yr per pCi/m^2); DSRs applied to applicable Protective Action Guides (PAGs) to obtain Operational Guidelines
- Produced Guidelines in the form of look-up tables:
  - ***Stay Times*** (e.g., based on gross alpha; gamma exposure rates, etc.)
  - ***Radionuclide Concentrations*** (e.g., on surfaces and in soils)

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Operational Guideline Groups
Early Phase

Groups	***Subgroups***
A. Access Controls During Emergency Response	(1) Life- and property-saving measures (2) Emergency worker demarcation
B. Early Phase Protective Actions	(1) Evacuation (2) Sheltering

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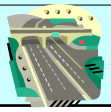
Operational Guideline Groups
Intermediate Phase

Groups	Subgroups
C. Critical Infrastructure Utilization in Relocation Areas	(1) Residential areas (2) Commercial and industrial areas (3) Other areas such as parks & monuments (4) Hospitals and health care facilities (5) Critical transport facilities (6) Water and sewer facilities (7) Power and fuel facilities
D. Temporary Access to Relocation Areas for Essential Services	(1) Worker access to businesses for essential actions (2) Public access to residences for retrieval
E. Transportation and Access Routes	(1) Bridges (2) Streets and thoroughfares (3) Sidewalks and walkways



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Operational Guideline Groups
Late (Recovery) Phase

Groups	Subgroups
F. Release of Property from Radiological Controlled Areas	(1) Personal property except wastes (2) Waste (3) Hazardous waste (4) Lands and buildings
G. Food Consumption	(1) Derived Intervention Levels (early phase) Planning Values (PVs) (2) Soil Concentrations for crops in place (3) Soil Concentrations (intermediate phase) for growing new crops (4) Soil Concentrations (recovery phase) for land use restrictions

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Demonstration of RESRAD-RDD

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Break

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Overview of RESRAD-BIOTA

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Evolution of Dose Limits for Biota

- Historical setting:
  - Human limits are dose-based
  - Protection established by examining all exposure pathways
- 1990's DOE considered parallel protection for biota
  - DOE Standard (DOE Order 5400.5):
    - 10 mGy/d (1 rad/d) for **aquatic** organisms
    - Intended to protect **natural populations** if dose to a representative exposed individual is less than the limit.
- Other standards proposed
  - 10 CFR 834, Subpart F:
    - 400 µGy/hr (1 rad/d) for aquatic animals
    - 400 µGy/hr (1 rad/d) for terrestrial plants
    - 40 µGy/hr (0.1 rad/d) for terrestrial animals

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ICRP Derived Consideration Reference Levels (DCRLs)

- DCRL bands for Reference Animals and Plants (RAPs) (ICRP 2014)

DOE Category & Criteria	Reference Organism	DCRL mGy/d	DCRL rad/d
Aquatic Animals 10 mGy/d 1 rad/d	Crab	10 to 100	1 to 10
	Trout	1 to 10	0.1 to 1
	Flatfish	1 to 10	0.1 to 1
Riparian Animals 1 mGy /d 0.1 rad/d	Frog	1 to 10	0.1 to 1
	Duck	0.1 to 1	0.01 to 0.1
Terrestrial Plant 10 mGy/d 1 rad/d	Pine tree	0.1 to 1	0.01 to 0.1
	Wild grass	1 to 10	0.1 to 1
Terrestrial Animals 1 mGy/d 0.1 rad/day	Deer	0.1 to 1	0.01 to 0.1
	Bee	10 to 100	1 to 10
	Earthworm	10 to 100	1 to 10
	Rat	0.1 to 1	0.01 to 0.1
None	Brown seaweed	10 to 100	1 to 10

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DOE's Graded Approach

1. **Data Assembly**
2. **General Screening**
3. **Analysis**
   - **Site Specific Screening**
   - **Site Specific Analysis**
   - **Site Specific Biota Dose Assessment**

Compare media concentrations with Biota Concentration Guides (BCGs) *(RESRAD-BIOTA Level 1)*

Site-representative parameters *(RESRAD-BIOTA Level 2)*

Kinetic/allometric modeling tool *(RESRAD-BIOTA Level 3)*

Collection of biota using eco-risk protocols

DOE Standard-A Graded approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota (DOE-STD-1153-2019)

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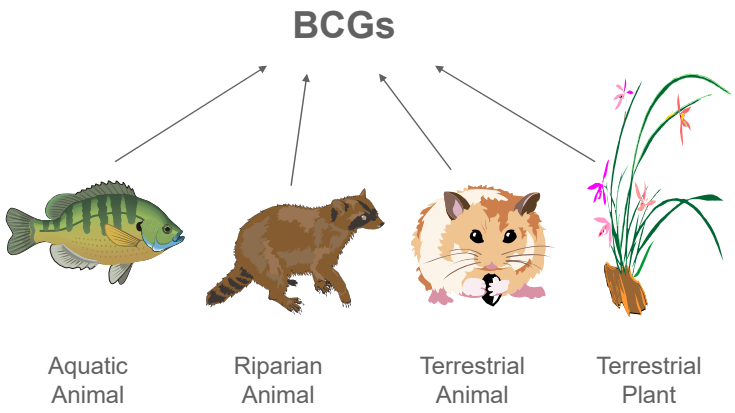
Receptors Used in Deriving the Screening Methodology



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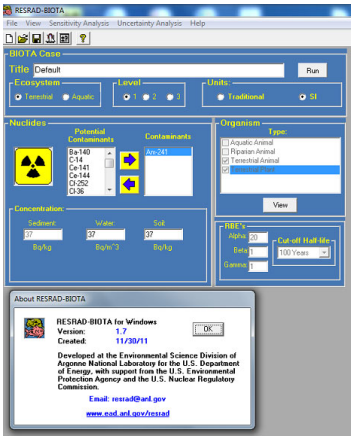
RESRAD-BIOTA: Key Features

- Duplicates DOE Graded Approach process & BCGs
- Retains flexibility to modify organism exposure profile, parameters, dose limits, allometric relationships
- Like the Graded Approach, the code implements primary and secondary reference organism concepts
- Organism Wizard allows users to configure their own "secondary" organisms
- Includes DCFs for 8 specific geometries covering a wide range of organisms
- Sensitivity analysis
- Probabilistic analysis
- Import and export data
- Food chain model



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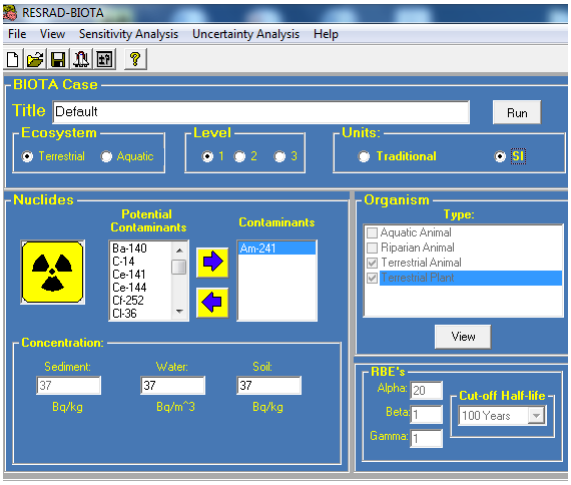
RESRAD-BIOTA Main Window



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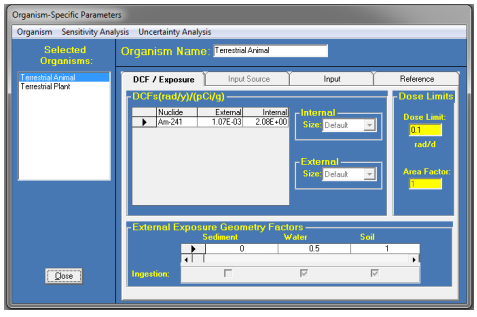
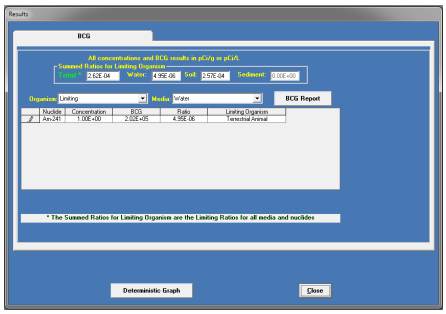
Level 1 Windows





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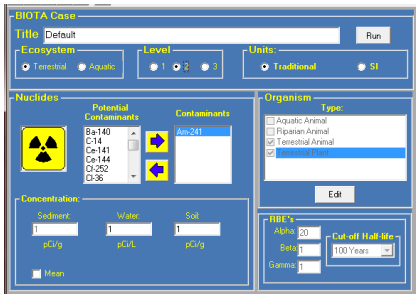
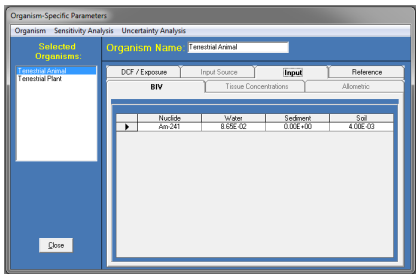
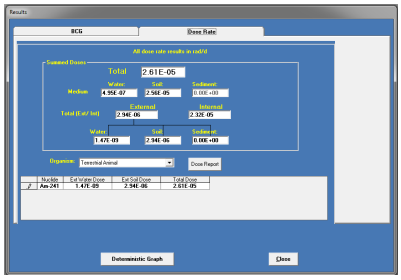
Level 2 Windows







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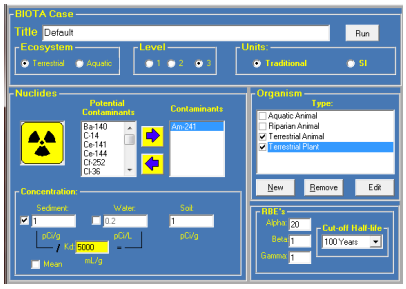
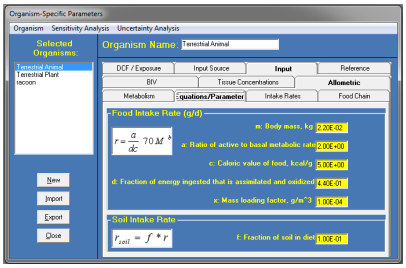
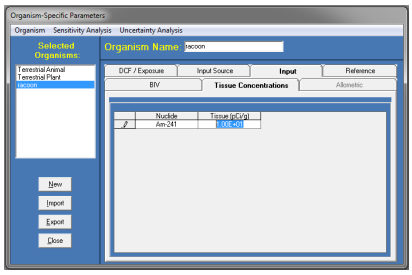
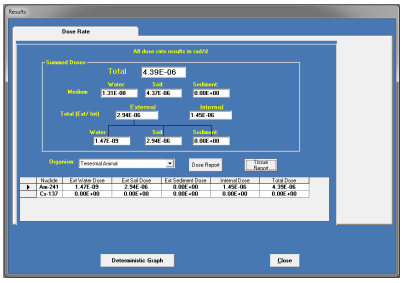
Level 3 Windows









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Parameter Access vs Level

Parameter	Level		
	1	2	3
Units	x	x	x
Concentration, K_d Option, Dose Limit	x	x	x
View BCG results	x	x	x
View dose results		x	x
Sensitivity		x	x
K_d Modification, Mean Conc. Setting		x	x
BIV		x	x
CF,T,f			x
DCF options (RBE, T_{cut})			x
Organism selection			x
Organism addition (W, shape, base)			x
Organism allometric parameters			x
Allometric option (org, nuc)			x

Text Results

Terrestrial BCG Report for Level 2

Title: Default

(Summed) Total Ratio for Limiting Organism: 1.34E-03

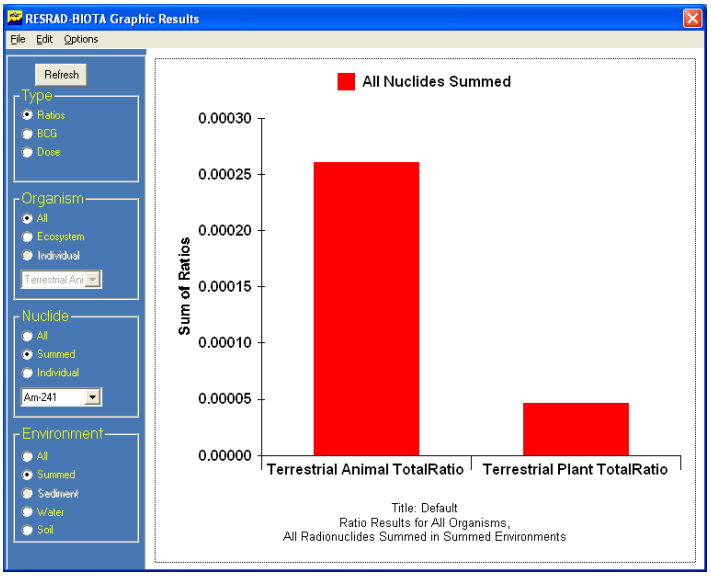
(Summed) Water Ratio for Limiting Organism: 2.94E-07

(Summed) Soil Ratio for limiting Organism: 1.34E-03

	Terrestrial Animal								
	Water				Soil				TOTAL
Nuclide	Concentration (Bq/m^3)	BCG (Bq/m^3)	Ratio	Limiting Organism	Concentration (Bq/kg)	BCG (Bq/kg)	Ratio	Limiting Organism	Ratio
Co-60	11	4.42E+07	2.49E-07	Yes	1	2.56E+04	3.91E-05	Yes	3.93E-05
Cs-137	1	2.22E+07	4.51E-08	Yes	1	7.69E+02	1.30E-03	Yes	1.30E-03
Summed	-	-	2.94E-07	-	-	-	1.34E-03	-	1.34E-03

	Terrestrial Plant								
	Water				Soil				TOTAL
Nuclide	Concentration (Bq/m^3)	BCG (Bq/m^3)	Ratio	Limiting Organism	Concentration (Bq/kg)	BCG (Bq/kg)	Ratio	Limiting Organism	Ratio
Co-60	11	5.52E+08	1.99E-08	No	1	2.27E+05	4.41E-06	No	4.43E-06
Cs-137	1	1.83E+09	5.48E-10	No	1	8.17E+04	1.22E-05	No	1.22E-05
Summed	-	-	2.05E-08	-	-	-	1.66E-05	-	1.67E-05

Graphic Results



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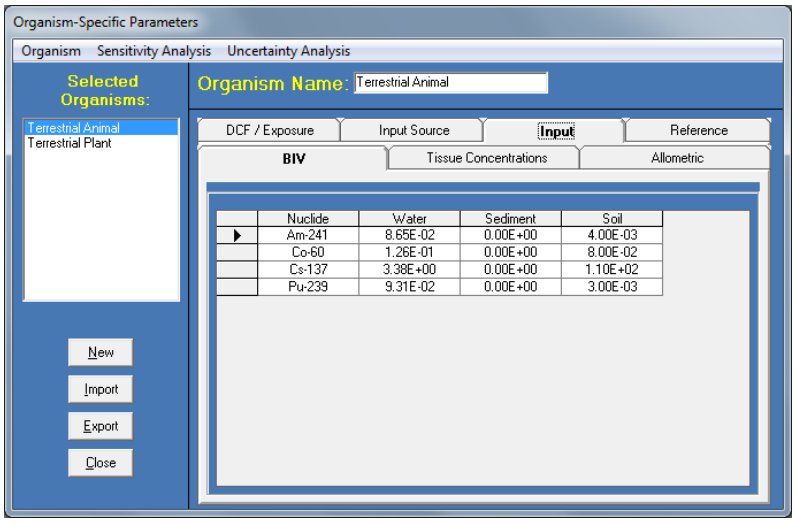
Organism- Biv's



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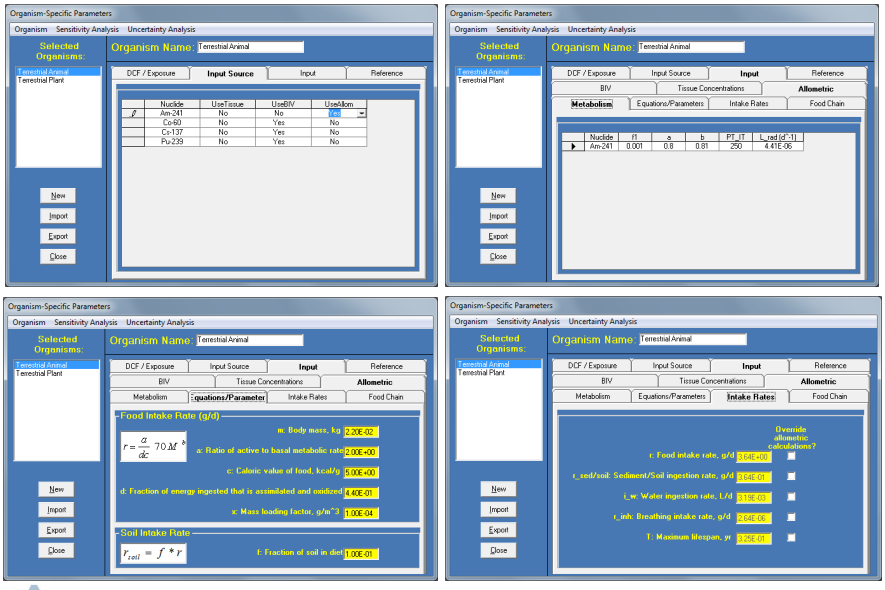
Organism - Allometric



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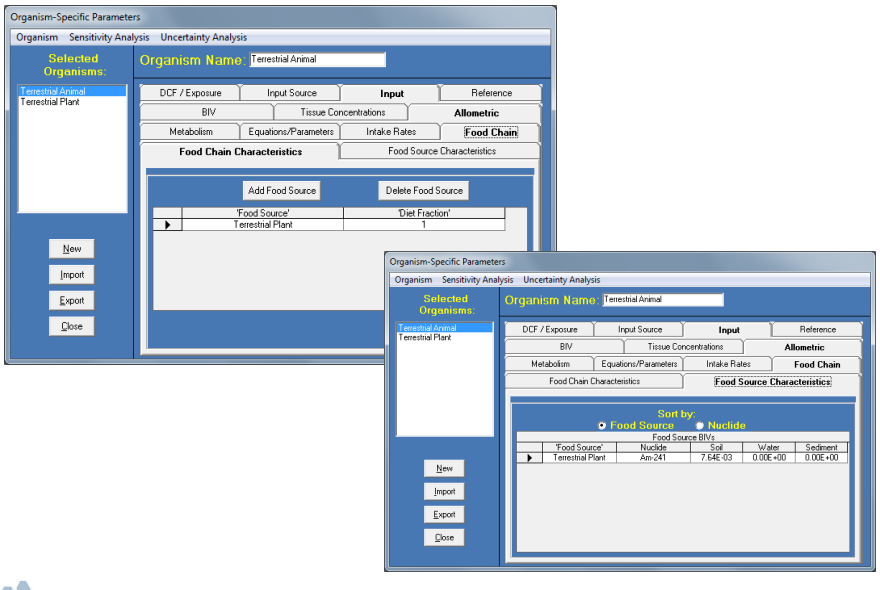
Organism - Allometric - Food Chain



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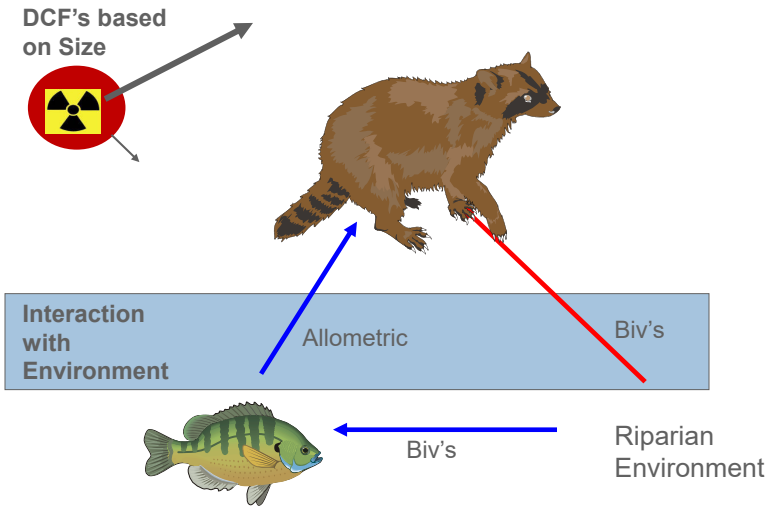
Organism Specification



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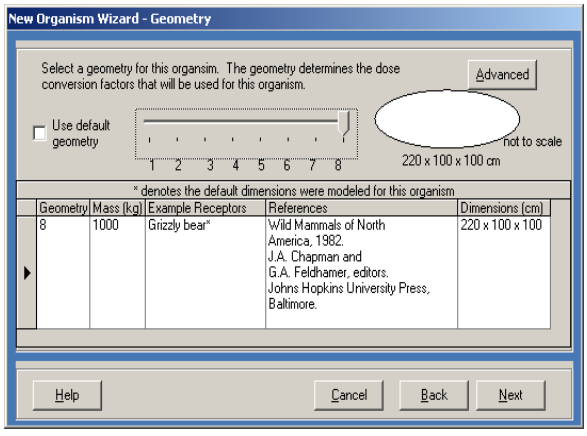
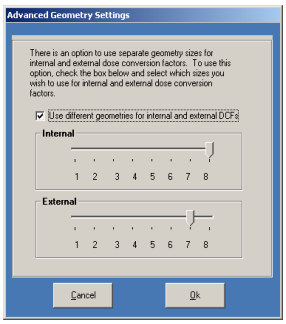
Organism Wizard (to Create an Organism)





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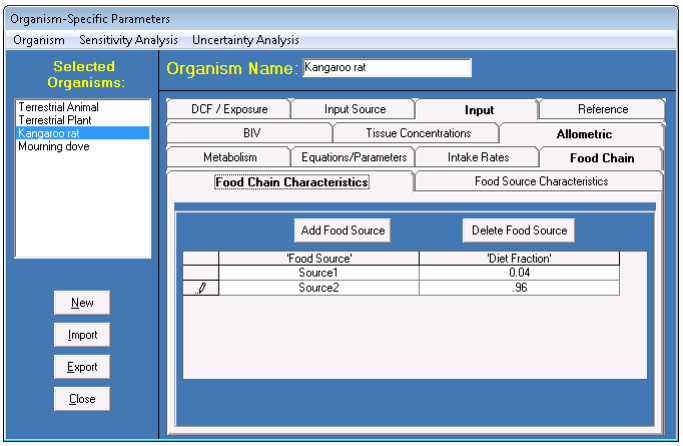
Food Chain Model in RESRAD-BIOTA

- The user has the option of adding multiple food sources
- The user provides the diet fraction of the food source



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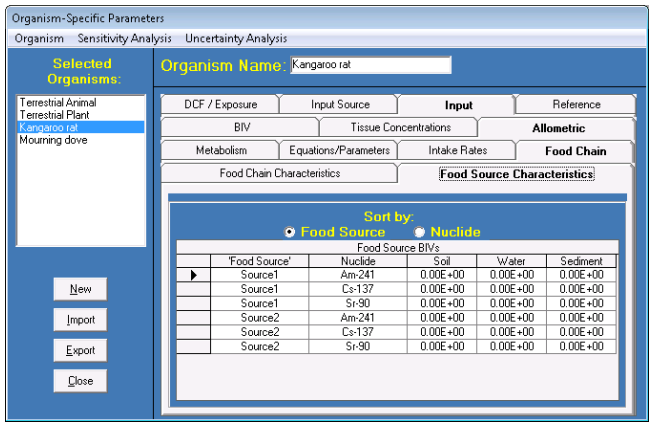
Food Chain Model in RESRAD-BIOTA (Cont.)

- The user provides the bioaccumulation factors (Bivs) for all food sources
- If Biv of a food source is not known, use RESRAD-BIOTA in a separate run to calculate Biv values



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Demonstration of RESRAD-BIOTA

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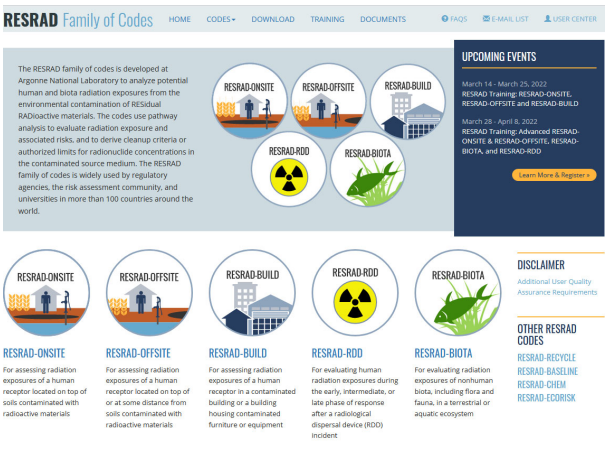
Thank you!



More Info at RESRAD Web Site:

https://resrad.evs.anl.gov/

Email: resrad@anl.gov

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