
RESRAD-BIOTA Hands-on Problems Workbook

October 2017

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Hands-On Problem #1: Demonstration of General Screening and Site-Specific Screening Phases

A DOE site is conducting an evaluation to demonstrate protection of biota from the potential effects of ionizing radiation, for subsequent reporting in their Annual Site Environmental Monitoring Report. Measured radionuclide concentrations for Blue Falls Creek at the Poplar Springs Site were available from the site environmental monitoring and surveillance program. Maximum and mean values are summarized.

(1) Using dataset #1, conduct an aquatic system evaluation to determine if maximum measured concentrations of residual radioactivity in Blue Falls Creek are potentially providing a radiation dose to biota above DOE's biota dose limits. Use co-located data where available. Report the total sum of fractions from your evaluation, the limiting media type, the radionuclide that provides the greatest contribution to the total sum of fractions, and the limiting organism type identified for that radionuclide. Why is it recommended to use co-located data where possible?

(2) Repeat the evaluation, using the average concentrations in dataset #1. Use co-located data where available. Report the total sum of fractions from your evaluation, the limiting media type, the radionuclide that provides the greatest contribution to the total sum of fractions, and the limiting organism type identified for that radionuclide. Why is the total sum of fractions lower in this example compared to question (1)?

(3) Repeat the evaluation, using the maximum concentrations in dataset #1, and employing the Cs-137 organism-specific concentration factor (Biv) for a raccoon resident in the evaluation area. Use co-located data where available. Report the total sum of fractions from your evaluation and the limiting media type. Why is the total sum of fractions lower in this example compared to question (1)? Also indicate the potential "upper-bound" dose to an aquatic animal, and to a riparian animal, resulting from this evaluation. Why do we call these an "upper-bound" dose (at level 2 analysis)?

Dataset #1. Blue Falls Creek: Radionuclide Concentration Data

Nuclide	Water (Maximum) Bq/m ³ (pCi/L)	Water (Average) Bq/m ³ (pCi/L)	Sediment (Maximum) pCi/g	Sediment (Average) pCi/g
Co-60	144.3 (3.9)	92.5 (2.5)	N/A	N/A
Cs-137*	1480 (40)	444 (12)	N/A	N/A
H-3	5.18E+06 (140,000)	2.627E+06 (71,000)	N/A	N/A
Sr-90	5,180 (140)	3,700 (100)	N/A	N/A
U-234	303.4 (8.2)	185 (5.0)	N/A	N/A
U-235	2.405 (0.065)	1.073 (0.029)	N/A	N/A
U-238	59.2 (1.6)	35.15 (0.95)	N/A	N/A

Concentration factor for Cs-137 (organism to water value) derived using site data for a raccoon resident in the Blue Falls Creek evaluation area = 3000.

Answers:

(1) Total sum of fractions = 1.51. Water is the limiting media type in this evaluation. Cs-137 appears to be a major contributor to the total potential dose. A riparian animal is indicated as the limiting organism type for Cs-137. Co-located water and sediment data are preferred because where one media is absent the methodology uses a conservatively derived sediment Kd value to back-calculate the missing media concentration, resulting in a conservative estimate of the missing media concentration. Subsequent analysis efforts could focus on re-visiting the radionuclide concentration data for possible use of mean values, and on obtaining site-specific information on riparian animal environmental transfer parameter data for a riparian animal known to be resident in the evaluation area.

(2) Total sum of fractions = 6.79E-1. Water is the limiting media type in this evaluation. Sr-90, along with Cs-137, appear to be principal contributors to potential dose. A riparian animal is indicated as the limiting organism type for Sr-90 and Cs-137. The total sum of fractions is lower in this example because average media concentrations were used in place of maximum media concentrations.

(3) Total sum of fractions = 6.20E-1. Water is the limiting media type in this evaluation. The total sum of fractions was lower in this example compared to example (1) because a site-specific Cs-137 concentration factor was used in place of the conservatively-derived default concentration factor value provided in the methodology, employing the site-specific screening phase of the graded approach. Doses are considered “upper-bound” (in the site-specific screening phase) in that they are still largely representative of conservatively derived generic organisms.

Problem 1; Question 1: Data Input Screen

RESRAD-BIOTA

File View Sensitivity Analysis Uncertainty Analysis Help

BIOTA Case

Title: Blue Falls Creek Maximum Concentration Run

Ecosystem: ☐ Terrestrial ☒ Aquatic

Level: ☒ 1 ☐ 2 ☐ 3

Units: ☐ Traditional ☒ SI

Nuclides

Potential Contaminants: Th-229, Th-230, Th-232, Th-234, U-233, Zn-65

Contaminants: Cs-137, H-3, Sr-90, U-234, U-235, U-238

Concentration:

Sediment: ☐ 2.96 Bq/kg

Water: ☒ 59.2 Bq/m³

Soil: ☐ 0 Bq/kg

Kd: 50 L/kg

Organism

Type: ☒ Aquatic Animal, ☒ Riparian Animal, ☐ Terrestrial Animal, ☐ Terrestrial Plant

View

RBE's

Alpha: 20, Beta: 1, Gamma: 1

Cut-off Half-life: 100 Years

Problem 1, Question 1: Results

Results

BCG

All concentrations and BCG results in Bq/kg or Bq/m³

Summed Ratios for Limiting Organism: **Ground: 1.51E+00**, **Water: 1.49E+00**, **Soil: 0.00E+00**, **Sediment: 1.64E-02**

Organism: Limiting Media: Water BCG Report

Nuclide	Concentration	BCG	Ratio	Limiting Organism
Co-60	1.44E+02	1.39E+05	1.04E-03	Aquatic Animal
Cs-137	1.48E+03	1.58E+03	9.38E-01	Riparian Animal
H-3	5.18E+06	9.80E+09	5.29E-04	Riparian Animal
Sr-90	5.18E+03	1.03E+04	5.03E-01	Riparian Animal
U-234	3.03E+02	7.46E+03	4.07E-02	Aquatic Animal
U-235	2.41E+00	8.05E+03	2.99E-04	Aquatic Animal
U-238	5.92E+01	8.26E+03	7.16E-03	Aquatic Animal

* The Summed Ratios for Limiting Organism are the Limiting Ratios for all media and nuclides

Deterministic Graph Close

Problem 1; Question 2: Data Input Screen

RESRAD-BIOTA - \problem1-2.bio

File View Sensitivity Analysis Uncertainty Analysis Help

BIOTA Case

Title: Blue Falls Creek Average Concentration Run

Ecosystem: ☐ Terrestrial ☒ Aquatic

Level: ☐ 1 ☒ 2 ☐ 3

Units: ☐ Traditional ☒ SI

Nuclides

Potential Contaminants: Th-229, Th-230, Th-232, Th-234, U-233, Zn-65

Contaminants: Cs-137, H-3, Sr-90, U-234, U-235, U-238

Concentration:

Sediment: ☐ 1.7575 Bq/kg

Water: ☒ 35.15 Bq/m³

Soil: 0.0 Bq/kg

☒ Mean ☐ L/kg

Organism

Type: ☒ Aquatic Animal, ☒ Riparian Animal, ☐ Terrestrial Animal, ☐ Terrestrial Plant

Edit

RBE's

Alpha: 20, Beta: 1, Gamma: 1

Cut-off Half-life: 100 Years

Problem 1; Question 2: Results

Results

BCG Dose Rate

All concentrations and BCG results in Bq/kg or Bq/m³

Summed Ratios for Limiting Organism: Water: 6.79E-01 Water: 6.70E-01 Soil: 0.00E+00 Sediment: 8.84E-03

Organism: Limiting Media: Water BCG Report

Nuclide	Concentration	BCG	Ratio	Limiting Organism
Co-60	9.25E+01	1.39E+05	6.64E-04	Aquatic Animal
Cs-137	4.44E+02	1.58E+03	2.81E-01	Riparian Animal
H-3	2.63E+06	9.81E+09	2.68E-04	Riparian Animal
Sr-90	3.70E+03	1.03E+04	3.59E-01	Riparian Animal
U-234	1.85E+02	7.47E+03	2.48E-02	Aquatic Animal
U-235	1.07E+00	8.06E+03	1.33E-04	Aquatic Animal
U-238	3.52E+01	8.27E+03	4.25E-03	Aquatic Animal

* The Summed Ratios for Limiting Organism are the Limiting Ratios for all media and nuclides

Deterministic Graph Close

Problem 1; Question 3: Data Input Screen

RESRAD-BIOTA - \problem1-3.bio

File View Sensitivity Analysis Uncertainty Analysis Help

BIOTA Case

Title: Blue Falls Creek Maximum Concentration Run

Ecosystem: ☐ Terrestrial ☒ Aquatic

Level: ☐ 1 ☒ 2 ☐ 3

Units: ☐ Traditional ☒ SI

Nuclides

Potential Contaminants: Am-241, Ba-140, C-14, Ce-141, Ce-144, Cf-252

Contaminants: Cs-137, H-3, Sr-90, U-234, U-235, U-238

Concentration:

Sediment: ☐ 2.96 Bq/kg ☒ 59.2 Bq/m³ ☐ 0 Bq/kg

Water: ☒ 59.2 Bq/m³

Soil: ☐ 0 Bq/kg

Organism

Type: ☒ Aquatic Animal ☒ Riparian Animal ☐ Terrestrial Animal ☐ Terrestrial Plant

Edit

RBE's: Alpha: 20 Beta: 1 Gamma: 1

Cut-off Half-life: 100 Years

Problem 1; Question 3: Adding Site-Specific Biv for Cs-137, Riparian Animal

Organism-Specific Parameters

Organism Sensitivity Analysis Uncertainty Analysis

Selected Organisms: Aquatic Animal, Riparian Animal

Organism Name: Riparian Animal

DCF / Exposure **Input Source** **Input** **Reference**

BIV **Tissue Concentrations** **Allometric**

	Nuclide	Water	Sediment	Soil
	Co-60	1.57E+02	9.94E-03	0.00E+00
	Cs-137	3000	2.70E-01	0.00E+00
	H-3	8.10E-01	4.30E-01	0.00E+00
	Sr-90	6.20E+03	2.48E+00	0.00E+00
	U-234	2.95E+01	3.76E-03	0.00E+00
	U-235	2.95E+01	3.76E-03	0.00E+00
	U-238	2.95E+01	3.76E-03	0.00E+00

Close

Problem 1; Question 3: BCG Results

Results

BCG

Dose Rate

All concentrations and BCG results in Bq/kg or Bq/m³

Summed Ratios for Limiting Organism

Total* 6.20E-01 Water: 6.04E-01 Soil: 0.00E+00 Sediment: 1.64E-02

Organism: Limiting Media: Water

BCG Report

	Nuclide	Concentration	BCG	Ratio	Limiting Organism
	Co-60	1.44E+02	1.39E+05	1.04E-03	Aquatic Animal
	Cs-137	1.48E+03	2.84E+04	5.21E-02	Riparian Animal
	H-3	5.18E+06	9.81E+09	5.28E-04	Riparian Animal
	Sr-90	5.18E+03	1.03E+04	5.02E-01	Riparian Animal
	U-234	3.03E+02	7.47E+03	4.06E-02	Aquatic Animal
	U-235	2.41E+00	8.06E+03	2.99E-04	Aquatic Animal
	U-238	5.92E+01	8.27E+03	7.16E-03	Aquatic Animal

* The Summed Ratios for Limiting Organism are the Limiting Ratios for all media and nuclides

Deterministic Graph

Close

Problem 1; Question 3:(Upper-Bound) Dose Results for Aquatic Animal

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File View Sensitivity Analysis Uncertainty Analysis Help

BIOTA Case

Title: Blue Falls Creek Maximum Concentration Run

Ecosystem: ☐ Terrestrial ☒ Aquatic

Level: ☐ 1 ☒ 2 ☐ 3

Units: ☐ Traditional ☒ SI

Results

BCG Dose Rate

All dose rate results in Gy/d

Summed Doses

Total: $9.07\text{E-}04$

Medium

Water: $8.99\text{E-}04$ Soil: $0.00\text{E+}00$ Sediment: $7.88\text{E-}06$

Total (Ext/ Int)

External: $8.13\text{E-}06$ Internal: $8.99\text{E-}04$

Water: $2.50\text{E-}07$ Soil: $0.00\text{E+}00$ Sediment: $7.88\text{E-}06$

Organism: Aquatic Animal Dose Report

Nuclide	Ext Water Dose	Ext Sediment Dose	Internal Dose	Total Dose
H-3	$1.99\text{E-}07$	$1.99\text{E-}10$	$8.14\text{E-}08$	$2.80\text{E-}07$
Sr-90	$3.97\text{E-}08$	$1.19\text{E-}06$	$2.59\text{E-}05$	$2.72\text{E-}05$
U-234	$2.66\text{E-}11$	$1.33\text{E-}09$	$4.06\text{E-}04$	$4.06\text{E-}04$
U-235	$6.20\text{E-}12$	$3.10\text{E-}10$	$2.99\text{E-}06$	$2.99\text{E-}06$
U-238	$3.73\text{E-}10$	$1.87\text{E-}08$	$7.16\text{E-}05$	$7.16\text{E-}05$

Deterministic Graph Close

Problem 1; Question 3: (Upper-Bound) Dose Results for Riparian Animal

RESRAD-BIOTA - \problem1-3.bio

File View Sensitivity Analysis Uncertainty Analysis Help

BIOTA Case

Title: Blue Falls Creek Maximum Concentration Run

Ecosystem: ☐ Terrestrial ☒ Aquatic

Level: ☐ 1 ☒ 2 ☐ 3

Units: ☐ Traditional ☒ SI

Results

BCG Dose Rate

All dose rate results in Gy/d

Summed Doses

Total: 5.86E-04

Medium

Water: 5.70E-04 Soil: 0.00E+00 Sediment: 1.64E-05

Total (Ext/ Int)

External: 8.13E-06 Internal: 5.78E-04

Water: 2.50E-07 Soil: 0.00E+00 Sediment: 7.88E-06

Organism: Riparian Animal Dose Report

	Nuclide	Ext Water Dose	Ext Sediment Dose	Internal Dose	Total Dose
	Co-60	2.61E-09	2.61E-06	8.64E-07	3.48E-06
	Cs-137	8.11E-09	4.05E-06	5.44E-05	5.85E-05
	H-3	1.99E-07	1.99E-10	3.30E-07	5.28E-07
	Sr-90	3.97E-08	1.19E-06	5.08E-04	5.09E-04
	U-234	2.66E-11	1.33E-09	1.21E-05	1.21E-05
	U-235	6.20E-12	3.10E-10	8.97E-06	8.97E-06

Deterministic Graph Close

Hands-On Problem #2: North Mountain Laboratory

This hands-on problem illustrates the importance of evaluating your monitoring data for applicability to non-human pathways, the importance of establishing well thought-out evaluation areas, and the iterative process of screening.

A large DOE site, the North Mountain Laboratory (NML), conducted its first biota dose evaluation to demonstrate protection of biota from the potential effects of ionizing radiation for subsequent reporting in their Annual Site Environmental Monitoring Report. This initial biota dose evaluation was also used to provide insights on modifications that might be needed in future evaluations, to include: determining the appropriate number and delineation of evaluation areas, and the need for any refinements to the environmental monitoring and surveillance program. Maximum measured radionuclide concentrations available for soil media, and from liquid effluent data, were assembled for the evaluation.

Because of the size and complexity of the NML Site (Fig. 1) and its environs, a conceptual model was constructed (Fig. 2) to better understand the environmental exposure and transport pathways that could potentially contribute a dose to biota at NML. Next, a more detailed conceptual model was constructed that mapped the pathways of exposure from the primary sources of radioactivity, the affected media, transport mechanisms, secondary sources, direct exposure routes, and potential receptors (Fig. 3). Guidance from DOE Technical Standard DOE-STD-1153-2002 (Module 2, Chapter 1, “The Graded Approach, Ecological Risk Assessment, and Guidance on Their Implementation in Evaluating Radiation Doses to Biota,” particularly section 1.4.1.4 - “Conceptual Model,” and Chapter 2, “Guidance on Sources, Receptors, and Routes of Exposure”) was reviewed to assist in the preparation of the conceptual models.

The intersection of contaminated areas and habitats can be used to help define the areas over which concentrations can be averaged if the use of maximum radionuclide concentrations at any location does not pass the general screening phase of the graded approach methodology. In preparation for the case study biota dose evaluation, the NML site was categorized into 35 evaluation areas, defined by the isopleths of modeled air concentrations, and by land cover information that included vegetation type data (that provided an understanding of habitat types available for plants and animals). Guidance from DOE Technical Standard DOE-STD-1153-2002 (Module 2, Chapter 4, “Guidance for Defining the Evaluation Area,” and Module 2, Chapter 3, “Guidance on Spatial and Temporal Averaging Regarding Application of Biota Dose Limits and Mean Radionuclide Concentrations”) was used to assist in defining the evaluation areas. The delineation of these evaluation areas, mapped by radionuclide concentration isopleths and vegetation types, is shown in Fig. 4. Land cover information, and soil sampling locations, are also shown in Fig. 4.

Questions:

(1) Maximum concentrations of radionuclides detected in liquid effluents and available soil media are summarized in dataset #1. Using the available maximum media concentration data, conduct a terrestrial biota dose evaluation for the NML. Report the total sum of fractions, limiting media type, the radionuclide(s) that provide the greatest contribution to the total sum of fractions, and the limiting organism type for that radionuclide. Did the maximum data result in compliance with the DOE biota dose limits?

Dataset #1. Maximum Radionuclide Concentration Data Measured Across the Entire Site: Liquid Effluent & Soil Media

Nuclide	Water Bq/m ³ (pCi/L)	Soil Bq/kg (pCi/g)
Am-241		2.9711 (0.0803)
Cs-137		1073 (29)
Co-60		37.37 (1.01)
Pu-239		3.774 (0.102)
Ra-226	139.49 (3.77)	
Sr-90	298.96 (8.08)	313.39 (8.47)
U-233		19.869 (0.537)
U-234		19.869 (0.537)
U-235		1.0989 (0.0297)
U-238		21.534 (0.582)

(2) From inspection of the media concentrations across each of the 35 evaluation areas it was determined that area 6 exhibited the largest source (i.e., maximum concentration) of Cs-137 in soils from NML (see Fig. 5). Further, upon inspection of the frequency distribution for Cs-137 detected in soils, this maximum concentration represented a single occurrence at a level much higher than the remaining distribution of detected concentrations. Based on this determination, it was decided to remove area 6 from consideration and conduct another biota dose evaluation using maximum radionuclide concentrations with area 6 removed. Evaluation area 6 will be considered separately in a subsequent evaluation.

Conduct another biota dose evaluation, again using maximum concentrations for the entire NML, but with evaluation area 6 removed from consideration. Use the data in dataset #2 for your evaluation. Report the total sum of fractions, the limiting media type, the radionuclide that provides the greatest contribution to the total sum of fractions, and the limiting organism type identified for that radionuclide. Did the NML Site (not including area 6) meet the DOE biota dose limits?

Dataset #2. Maximum Radionuclide Concentration Data Measured Across the Entire Site: Liquid Effluent & Soil Media (Area 6 Removed)

Nuclide	Water Bq/m ³ (pCi/L)	Soil Bq/kg (pCi/g)
Am-241		2.9711 (0.0803)
Cs-137		341.88 (9.24)
Co-60		37.37 (1.01)
Pu-239		3.774 (0.102)
Ra-226	139.49 (3.77)	
Sr-90	298.96 (8.08)	313.39 (8.47)
U-233		19.869 (0.537)
U-234		19.869 (0.537)
U-235		1.0989 (0.0297)
U-238		21.534 (0.582)

(3) Evaluation area 6 was then considered separately. After consideration of the sampling data, it was determined to be technically appropriate to average the radionuclide concentrations for soil samples collected within area 6. Conduct another biota dose evaluation using average radionuclide concentrations in soil for area 6. Use dataset #3 for your evaluation. Report the total sum of fractions, the limiting media type, the radionuclide that provides the greatest contribution to the total sum of fractions, and the limiting organism type identified for that radionuclide. Did evaluation area 6 meet the DOE biota dose limits?

Dataset #3. Average Radionuclide Concentration Data for Area 6 Soil Media

Nuclide	Soil Bq/kg (pCi/g)
Am-241	1.258 (0.034)
Cs-137	407 (11)
Co-60	6.66 (0.18)
Pu-239	1.8315 (0.0495)
Ra-226	
Sr-90	135.79 (3.67)
U-233	1.8389 (0.0497)
U-234	1.8389 (0.0497)
U-235	1.0249 (0.0277)
U-238	19.203 (0.519)

Answers:

(1) Total sum of fractions = 1.78. Soil is the limiting media type. Cs-137 appears to be a major contributor to the total potential dose. A terrestrial animal is indicated as the limiting organism type for Cs-137. The site did not pass the screening process at level 1, the general screening phase of the DOE graded approach methodology.

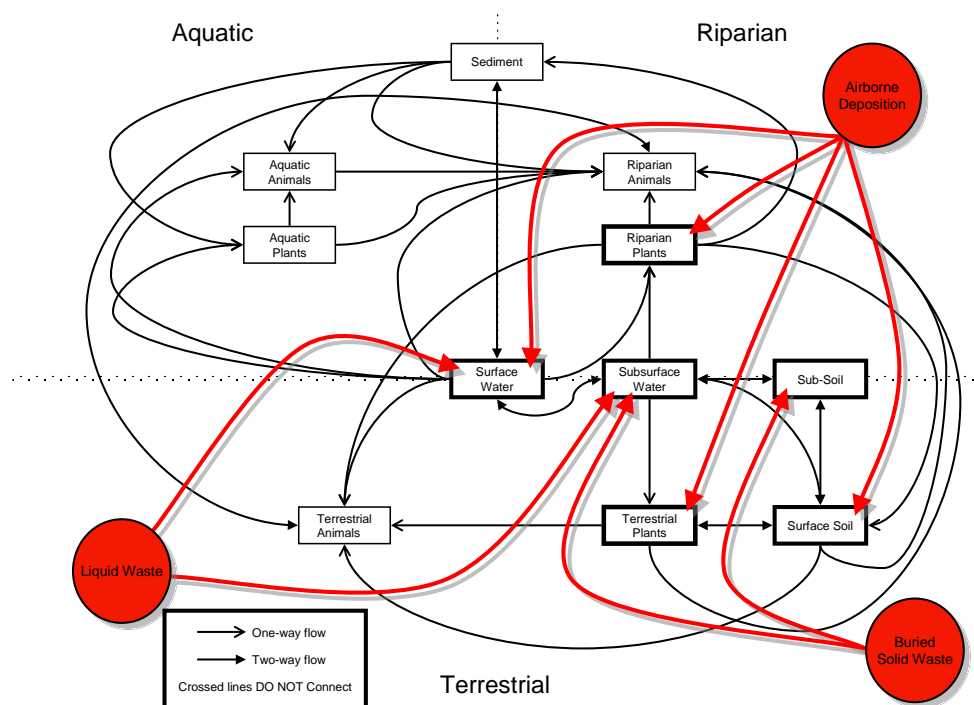
(2) Total sum of fractions = $8.24\text{E-}1$. Soil is the limiting media type. Cs-137 appears to be a major contributor to the total potential dose. A terrestrial animal is indicated as the limiting organism type for Cs-137. The site (all areas but evaluation area 6) passed the screening process at level 1, the general screening phase of the DOE graded approach methodology. Biota protection at DOE dose limits is demonstrated.

(3) Total sum of fractions = $6.93\text{E-}1$. Soil is the limiting media type. Cs-137 appears to be a major contributor to the total potential dose. A terrestrial animal is indicated as the limiting organism type for Cs-137. Evaluation area 6 passed the screening process at level 2, the site-specific screening phase of the DOE graded approach methodology. Biota protection at DOE dose limits is demonstrated.

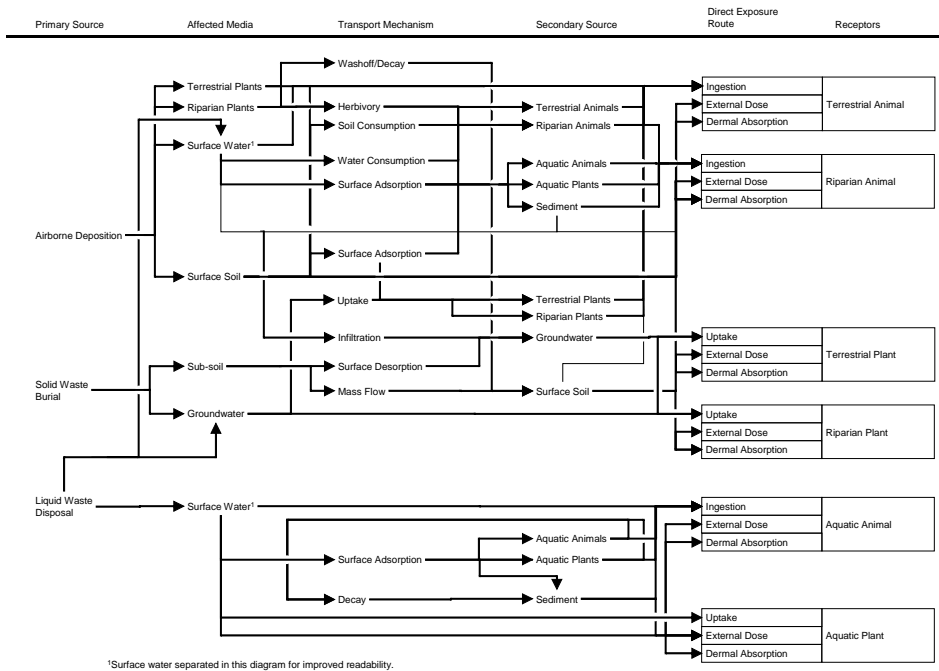
Prob. 2 (Fig. 1): NML Land Cover



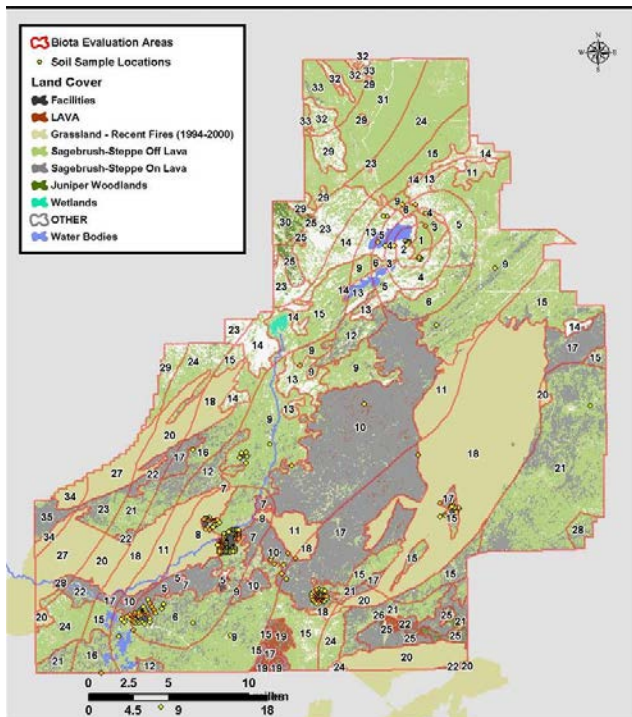
Prob. 2 (Fig. 2): Conceptual Model



Prob. 2 (Fig. 3): CM - Pathways



Prob. 2 (Fig. 4): Evaluation Areas



- Evaluation areas defined by the isopleths of air concentration and the land cover / vegetation types

Prob. 2, Q. 1: Data Input Screen

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File View Sensitivity Analysis Uncertainty Analysis Help

BIOTA Case

Title: NML-1 Run

Ecosystem: ☒ Terrestrial ☐ Aquatic

Level: ☒ 1 ☐ 2 ☐ 3

Units: ☐ Traditional ☒ SI

Nuclides

Potential Contaminants: Ba-140, C-14, Ce-141, Ce-144, Cf-252, Cl-36

Contaminants: Am-241, Co-60, Cs-137, Pu-239, Ra-226, Sr-90

Concentration: Sediment: 0 Bq/kg, Water: 0 Bq/m³, Soil: 1073 Bq/kg

Organism

Type: ☐ Aquatic Animal, ☐ Riparian Animal, ☒ Terrestrial Animal, ☒ Terrestrial Plant View

RBE's

Alpha: 20, Beta: 1, Gamma: 1

Cut-off Half-life: 100 Years

Prob. 2, Q. 1: BCG Results

Results

BCG

All concentrations and BCG results in Bq/kg or Bq/m³

Summed Ratios for Limiting Organism: **Terrestrial** 1.78E+00, Water: 6.13E-04, Soil: 1.78E+00, Sediment: 0.00E+00

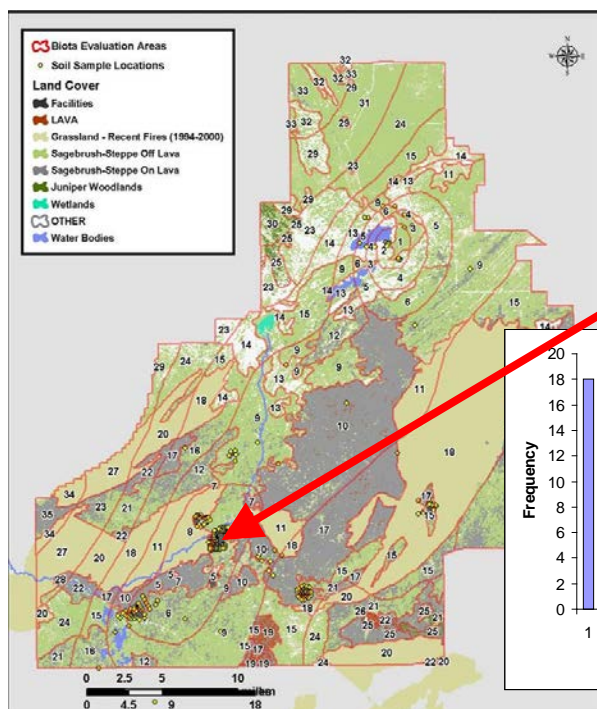
Organism: Limiting Media: Soil BCG Report

Nuclide	Concentration	BCG	Ratio	Limiting Organism
Am-241	2.97E+00	1.44E+05	2.06E-05	Terrestrial Animal
Co-60	3.74E+01	2.56E+04	1.46E-03	Terrestrial Animal
Cs-137	1.07E+03	7.68E+02	1.40E+00	Terrestrial Animal
Pu-239	3.77E+00	2.26E+05	1.67E-05	Terrestrial Animal
Ra-226	0.00E+00	1.87E+03	0.00E+00	Terrestrial Animal
Sr-90	3.13E+02	8.32E+02	3.77E-01	Terrestrial Animal
U-233	1.99E+01	1.79E+05	1.11E-04	Terrestrial Animal
U-234	1.99E+01	1.90E+05	1.05E-04	Terrestrial Animal
U-235	1.10E+00	1.03E+05	1.07E-05	Terrestrial Animal
U-238	2.15E+01	5.84E+04	3.69E-04	Terrestrial Animal

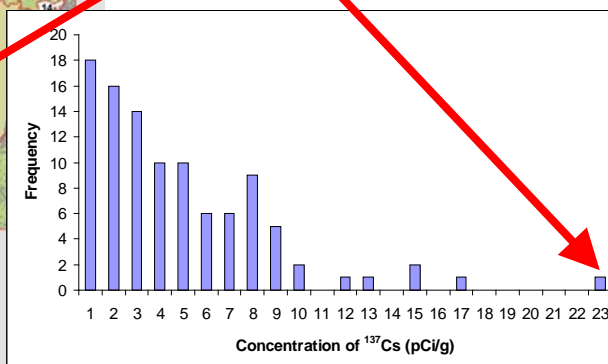
* The Summed Ratios for Limiting Organism are the Limiting Ratios for all media and nuclides

Deterministic Graph Close

Prob. 2 (Fig. 5): Cs-137 in Area 6



- Due to high ^{137}Cs concentration in area 6, near the largest source of environmental contamination



Prob. 2, Q. 2: Data Input Screen

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File View Sensitivity Analysis Uncertainty Analysis Help

BIOTA Case

Title: NML-2 (Area 6 Removed) [Run]

Ecosystem: ☒ Terrestrial ☐ Aquatic

Level: ☒ 1 ☐ 2 ☐ 3

Units: ☐ Traditional ☒ SI

Nuclides

Potential Contaminants: Ba-140, C-14, Ce-141, Ce-144, Cf-252, Cl-36

Contaminants: Am-241, Co-60, Cs-137, Pu-239, Ra-226, Sr-90

Concentration:

Sediment: 0 Bq/kg

Water: 0 Bq/m³

Soil: 341.88 Bq/kg

Organism

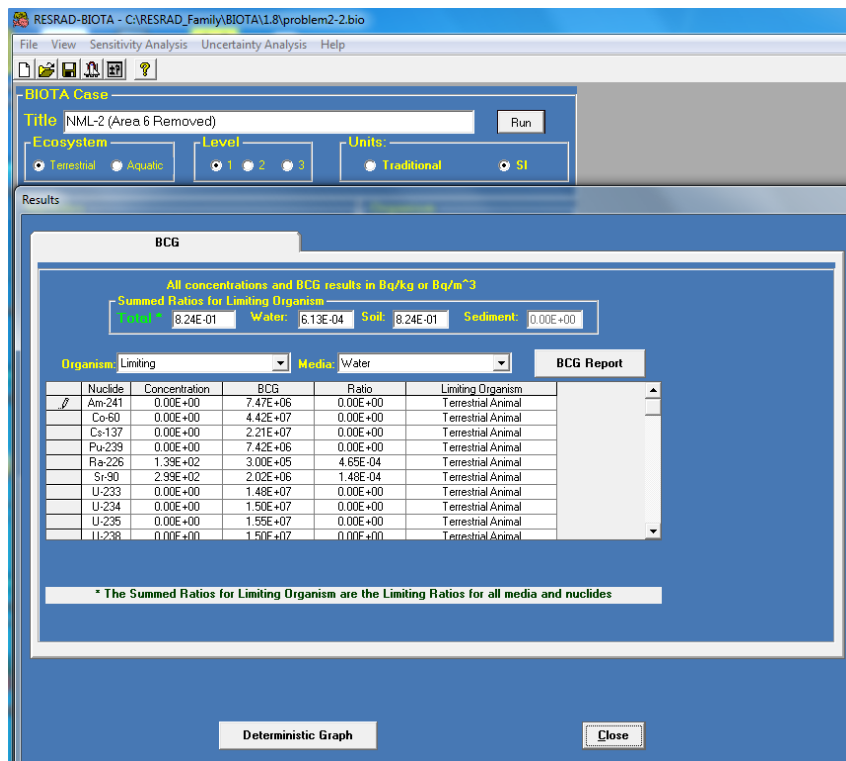
Type: ☐ Aquatic Animal, ☐ Riparian Animal, ☒ Terrestrial Animal, ☒ Terrestrial Plant [View]

RBE's

Alpha: 20, Beta: 1, Gamma: 1

Cut-off Half-life: 100 Years

Prob. 2, Q. 2: BCG Results (Area 6 Removed)



Prob. 2, Q. 3: Data Input Screen (Area 6 Mean Soil Concentrations Only)

RESRAD-BIOTA - C:\RESRAD_Family\BIOTA\1.8\problem2-3.bio

BIOTA Case

Title: NML-3 Area 6 Mean Concentration [Run]

Ecosystem: ☒ Terrestrial ☐ Aquatic

Level: ☐ 1 ☒ 2 ☐ 3

Units: ☒ Traditional ☐ SI

Nuclides

Potential Contaminants: Ba-140, C-14, Ce-141, Ce-144, Cf-252, Cl-36

Contaminants: Am-241, Co-60, Cs-137, Pu-239, Ra-226, Sr-90

Concentration:

Sediment: 37 Bq/kg

Water: 0 Bq/m³

Soil: 1.258 Bq/kg

☒ Mean

Organism

Type:

☐ Aquatic Animal

☐ Riparian Animal

☒ Terrestrial Animal

☒ Terrestrial Plant

[Edit]

RBE's

Alpha: 20

Beta: 1

Gamma: 1

Cut-off Half-life: 100 Years

Prob. 2, Q. 3: BCG Results (Area 6 Mean Soil Concentrations Only)

Results

BCG

Dose Rate

All concentrations and BCG results in Bq/kg or Bq/m³

Summed Ratios for Limiting Organism

Total: 6.93E-01 Water: 0.00E+00 Soil: 6.93E-01 Sediment: 0.00E+00

Organism: Limiting Media: Water BCG Report

	Nuclide	Concentration	BCG	Ratio	Limiting Organism
	Am-241	0.00E+00	7.48E+06	0.00E+00	Terrestrial Animal
	Co-60	0.00E+00	4.42E+07	0.00E+00	Terrestrial Animal
	Cs-137	0.00E+00	2.22E+07	0.00E+00	Terrestrial Animal
	Pu-239	0.00E+00	7.42E+06	0.00E+00	Terrestrial Animal
	Sr-90	0.00E+00	2.02E+06	0.00E+00	Terrestrial Animal
	U-233	0.00E+00	1.48E+07	0.00E+00	Terrestrial Animal
	U-234	0.00E+00	1.50E+07	0.00E+00	Terrestrial Animal
	U-235	0.00E+00	1.55E+07	0.00E+00	Terrestrial Animal
	U-238	0.00E+00	1.50E+07	0.00E+00	Terrestrial Animal

* The Summed Ratios for Limiting Organism are the Limiting Ratios for all media and nuclides

Deterministic Graph

Close

Hands-On Problem 3: Effect of Area Factor and Concentration Ratios in Site-Specific Analysis

The Little Forest Burial Ground (LFBG) site, located in New South Wales, Australia is conducting an evaluation to demonstrate protection of biota from the potential effects of ionizing radiation. From 1960 to 1968 radioactive waste from nearby reactor research facility was placed in a series of 79 shallow trenches. The LFBG is under active administrative control that includes environmental monitoring, maintenance, etc. The current site characterization identified cesium-137, cobalt-60, strontium-90, and americium-241 in surface soils. The data was collected in three different zones as described in Figure 2. Table 1 lists the measured concentrations.

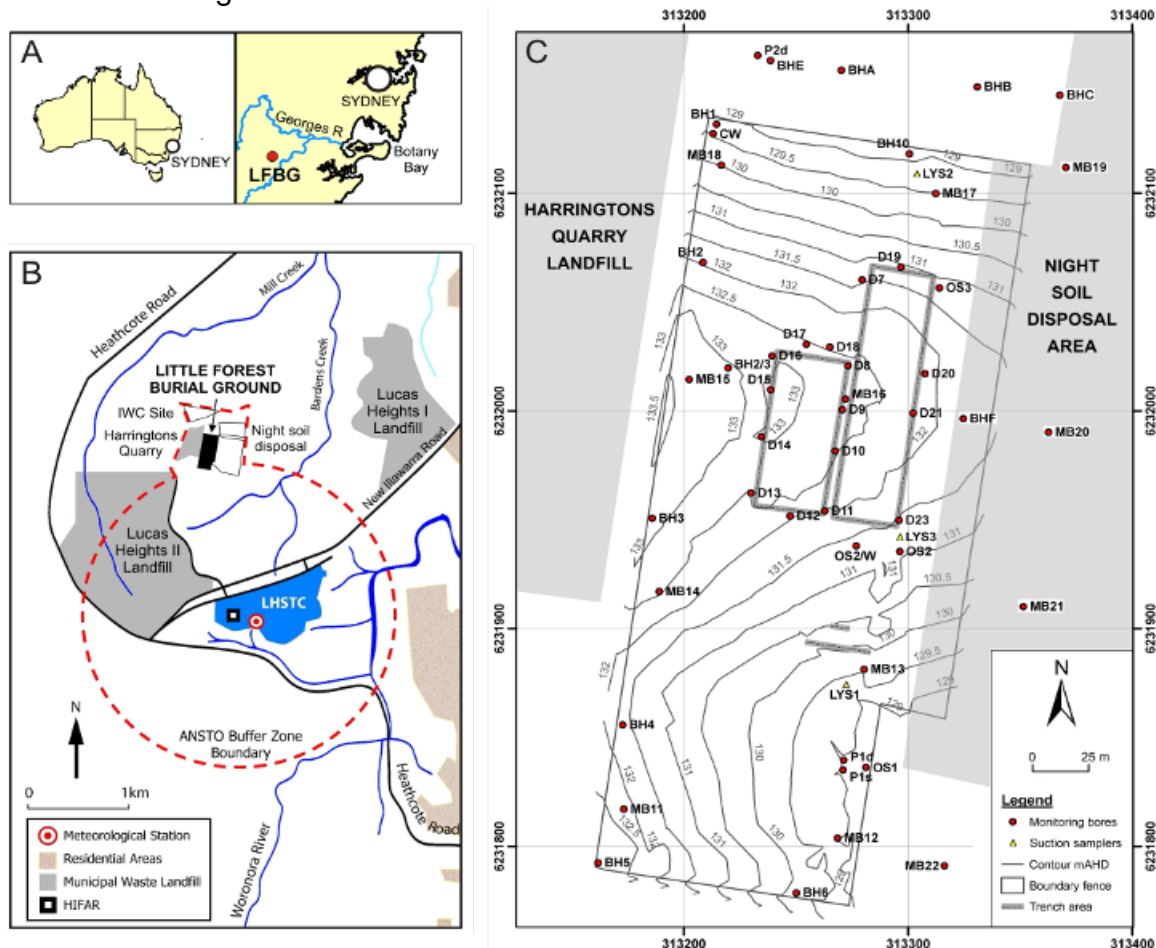


Figure 1 Location of Little Forest Burial Ground, New South Wales, Australia

The following four species, representative of site biota are to be analyzed:

- Acacia tree
- Grass
- Raven
- Red fox

Assumed Contaminant Exposure Zones

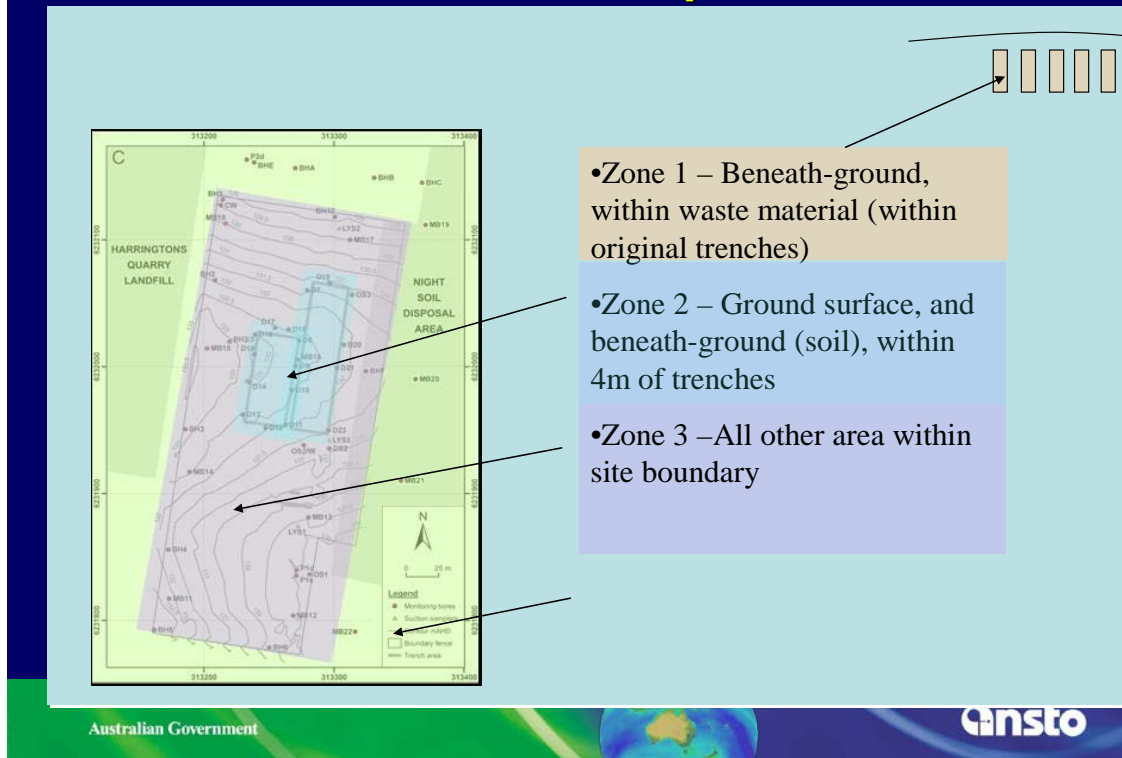


Figure 2 Contaminated Exposure Zones

Table 1 Average Radionuclide Concentrations in Three Zones

Area	Co-60 Bq/kg	Sr-90 Bq/kg	Cs-137 Bq/kg	Am-241 Bq/kg
Zone 1				
Within waste trenches	2000	1000	470	710
Zone 2				
Soil <4m from trenches	2	28	3	4
Zone 3				
Soil >4m from trenches	1	4	2	0.01

Table 2 provides the time spent by these species in different zones.

Table 2 Time Spent by Species in Different Zones

Species	Zone 1	Zone 2	Zone 3	Outside
Acacia (tree)	100%			
Grass		100%		
Raven		30%		70%
Fox			30%	70%

Problem 3 – Question 1

Using data provided in Tables 1 and 2 and default RESRAD-BIOTA Biv values calculate total, internal and external doses received by each species at the site.

Problem 3 – Question 2

The International Atomic Energy Agency (IAEA) has recently published its new Technical Report Series (TRS) handbook on radionuclide transfer to wildlife (TRS 479). Repeat the evaluation, using the Biv values from TRS 479. Explain the differences in dose results compared to question (1). Table 3 provides the Biv values from TRS 479.

Table 3 Concentration Ratios (Bq/Kg per Bq/Kg) from TRS 479

Organism	Co-60	Sr-90	Cs-137	Am-241
Acacia (tree)	8.7E-03	4.9E-01	1.4E-01	2.7E-02
Grass	4.2E-03	1.8E+00	1.8E+00	1.0E-01
Raven	NA	4.8E-01	6.7E-01	3.2E-02
Fox	3.0E-01	1.8E+00	3.2E+00	3.0E-02

Answers:

Problem 3 – Question 1

Doses are estimated at RESRAD-BIOTA level 3 by entering the soil concentration in different zones. Two types of terrestrial species (terrestrial plant and terrestrial animal) can be evaluated in a single run. Acacia tree is located in zone 1. Grass and Raven occupy zone 2, and fox occupies zone 3. Three separate run will be done. Table 4 summarizes the dose results.

Table 4 Dose Results (Gy/d) with RESRAD-BIOTA Default Biv Values

Species	External	Internal	Total
Acacia (tree)	9.26E-5	1.37E-04	2.29E-04
Grass	5.45E-07	2.08E-06	2.63E-06
Raven	1.64E-07	1.11E-05	1.13E-05
Fox	3.60E-08	2.20E-06	2.23E-06

Dose estimation for Acacia

Enter soil concentration in zone 1.

Data input and dose results for Acacia

RESRAD-BIOTA

File View Sensitivity Analysis Uncertainty Analysis Help

BIOTA Case

Title: Acacia tree [Run]

Ecosystem: ☒ Terrestrial ☐ Aquatic Level: ☒ 1 ☐ 2 ☐ 3 Units: ☒ Traditional ☐ SI

Nuclides

Potential Contaminants: Pu-239, Ra-226, Ra-228, Sb-125, Se-75, Tc-99

Contaminants: Am-241, Co-60, Cs-137, Sr-90

Concentration: Sediment: ☒ 0 Bq/kg, Water: 0 Bq/m³, Soil: 1000 Bq/kg

Organism

Type: ☐ Aquatic Animal, ☐ Riparian Animal, ☒ Terrestrial Animal, ☒ Terrestrial Plant

RBE's: Alpha: 20, Beta: 1, Gamma: 1, Cut-off Half-life: 100 Years

Results

BCG Dose Rate

All dose rate results in Gy/d

Summed Doses

Total: 2.29E-04

Medium: Water: 0.00E+00, Soil: 2.29E-04, Sediment: 0.00E+00

Total (Ext/Int): External: 9.26E-05, Internal: 1.37E-04

Water: 0.00E+00, Soil: 9.26E-05, Sediment: 0.00E+00

Organism: Terrestrial Plant [Dose Report] [Tissue Report]

Nuclide	Ext Water Dose	Ext Soil Dose	Ext Sediment Dose	Internal Dose	Total Dose
Am-241	0.00E+00	5.64E-07	0.00E+00	8.36E-06	8.92E-06
Co-60	0.00E+00	7.12E-05	0.00E+00	1.58E-05	8.70E-05
Cs-137	0.00E+00	5.15E-06	0.00E+00	5.24E-05	5.75E-05
Sr-90	0.00E+00	1.56E-05	0.00E+00	6.01E-05	7.58E-05

Dose estimation for Grass and Raven

Enter soil concentration in zone 2. Raven spends 30% time in zone 2 and is away from contamination 70% time. Change area factor for terrestrial animal.

Data Input and Dose Results for Raven

RESRAD-BIOTA

File View Sensitivity Analysis Uncertainty Analysis Help

BIOTA Case

Title: Grass and Raven Zone 2 Run

Ecosystem: ☒ Terrestrial ☐ Aquatic Level: ☐ 1 ☐ 2 ☒ 3 Units: ☒ Traditional ☐ SI

Nuclides

Potential Contaminants: Pu-239, Ra-226, Ra-228, Sb-125, Se-75, Tc-99

Contaminants: Am-241, Co-60, Cs-137, Sr-90

Organism Type: ☐ Aquatic Animal, ☐ Riparian Animal, ☒ Terrestrial Animal, ☐ Terrestrial Plant

Concentration: Sediment: ☒ 0 Bq/kg, Water: ☒ 0 Bq/m³, Soil: 28 Bq/kg

Mean: ☐ Mean

Organism-Specific Parameters

Organism: Sensitivity Analysis Uncertainty Analysis

Selected Organisms: Terrestrial Animal, Terrestrial Plant

Organism Name: Terrestrial Animal

DCF / Exposure

Nuclide	External	Internal
Am-241	2.90E-07	5.63E-04
Co-60	1.30E-05	1.31E-05
Cs-137	4.00E-06	4.28E-06
Sr-90	5.71E-06	5.71E-06

DCF_s(Gy/yr)/(Bq/kg)

Internal Size: Default

External Size: Default

Dose Limits: Dose Limit: 0.001 Gy/d, Area Factor: 0.3

External Exposure Geometry Factors

Sediment: 0, Water: 0.5, Soil: 1

Ingestion: ☐ Sediment, ☒ Water, ☒ Soil

BCG

Dose Rate

All dose rate results in Gy/d

Summed Doses

Total: 1.13E-05

Medium: Water: 0.00E+00, Soil: 1.13E-05, Sediment: 0.00E+00

Total (Ext/Int): External: 1.64E-07, Internal: 1.11E-05

Water: 0.00E+00, Soil: 1.64E-07, Sediment: 0.00E+00

Organism: Terrestrial Animal

Dose Report Tissue Report

Nuclide	Ext Water Dose	Ext Soil Dose	Ext Sediment Dose	Internal Dose	Total Dose
Am-241	0.00E+00	9.53E-10	0.00E+00	7.40E-09	8.35E-09
Co-60	0.00E+00	2.14E-08	0.00E+00	1.72E-09	2.31E-08
Cs-137	0.00E+00	9.86E-09	0.00E+00	1.16E-06	1.17E-06
Sr-90	0.00E+00	1.31E-07	0.00E+00	9.96E-06	1.01E-05

Data Input and Dose Results for Grass

RESRAD-BIOTA

File View Sensitivity Analysis Uncertainty Analysis Help

BIOTA Case

Title: Grass and Raven Zone 2 [Run]

Ecosystem: ☒ Terrestrial ☐ Aquatic

Level: ☐ 1 ☐ 2 ☒ 3

Units: ☐ Traditional ☒ SI

Nuclides

Potential Contaminants: Pu-239, Ra-226, Ra-228, Sb-125, Se-75, Tc-99

Contaminants: Am-241, Co-60, Cs-137, Sr-90

Organism Type: ☐ Aquatic Animal, ☐ Riparian Animal, ☒ Terrestrial Animal, ☒ Terrestrial Plant

Concentration: Sediment: ☒ 0 Bq/kg, Water: ☒ 0 Bq/m³, Soil: 28 Bq/kg

Mean: ☐ Mean

RBE's: Alpha: 20, Beta: 1, Gamma: 1

Cut-off Half-life: 100 Years

Results

BCG Dose Rate

All dose rate results in Gy/d

Summed Doses

Total: 2.63E-06

Medium: Water: 0.00E+00, Soil: 2.63E-06, Sediment: 0.00E+00

Total (Ext/Int): External: 5.45E-07, Internal: 2.08E-06

Water: 0.00E+00, Soil: 5.45E-07, Sediment: 0.00E+00

Organism: Terrestrial Plant

Dose Report Tissue Report

Nuclide	Ext Water Dose	Ext Soil Dose	Ext Sediment Dose	Internal Dose	Total Dose
Am-241	0.00E+00	3.18E-09	0.00E+00	4.71E-08	5.03E-08
Co-60	0.00E+00	7.12E-08	0.00E+00	1.58E-08	8.70E-08
Cs-137	0.00E+00	3.29E-08	0.00E+00	3.34E-07	3.67E-07
Sr-90	0.00E+00	4.38E-07	0.00E+00	1.68E-06	2.12E-06

Dose Estimation for Fox in Zone 3

Enter soil concentration in zone 3. Fox spends 30% time in zone 3 and is away from contamination 70% time. Change area factor for terrestrial animal.

Data Input and Dose Results for Fox

The screenshot displays the RESRAD-BIOTA software interface for a Fox in Zone 3. The interface is divided into several panels:

- BIOTA Case:** Title: Fox in Zone 3. Ecosystem: Terrestrial. Level: 1. Units: Traditional. Run button.
- Nuclides:** Potential Contaminants: Pu-239, Ra-226, Ra-228, Sb-125, Se-75, Tc-99. Contaminants: Am-241, Co-60, Cs-137, Sr-90. Concentration: Sediment: 0 Bq/kg, Water: 0 Bq/m³, Soil: 0.01 Bq/kg. RBE's: Alpha: 20, Beta: 1, Cut-off Half-life: 100 Years.
- Organism:** Type: Terrestrial Animal. RBE's: Alpha: 20, Beta: 1, Cut-off Half-life: 100 Years.
- Organism-Specific Parameters:** Selected Organisms: Terrestrial Animal. Organism Name: Terrestrial Animal. DCF / Exposure: Nuclide, External, Internal. Dose Limits: 0.001 Gy/d. Area Factor: 0.3.
- External Exposure Geometry Factors:** Sediment: 0, Water: 0.5, Soil: 1. Ingestion: ☐ ☒ ☒
- Results:** BCG, Dose Rate. Summed Doses: Total: 2.23E-06. Medium: Water: 0.00E+00, Soil: 2.23E-06, Sediment: 0.00E+00. Total (Ext/Int): External: 3.60E-08, Internal: 2.20E-06. Water: 0.00E+00, Soil: 3.60E-08, Sediment: 0.00E+00. Organism: Terrestrial Animal. Dose Report, Tissue Report.
- Dose Rate Results Table:**

Nuclide	Ext Water Dose	Ext Soil Dose	Ext Sediment Dose	Internal Dose	Total Dose
Am-241	0.00E+00	2.38E-12	0.00E+00	1.85E-11	2.09E-11
Co-60	0.00E+00	1.07E-08	0.00E+00	8.62E-10	1.15E-08
Cs-137	0.00E+00	6.58E-09	0.00E+00	7.74E-07	7.80E-07
Sr-90	0.00E+00	1.88E-08	0.00E+00	1.42E-06	1.44E-06

Problem 3 – Question 2

Now change Biv values to match the CR values in Table 3.

Doses are estimated at RESRAD-BIOTA level 3 by entering the soil concentration in different zones. Two types of terrestrial species (terrestrial plant and terrestrial animal) can be evaluated in a single run. Acacia tree is located in zone 1. Grass and Raven occupy zone 2, and fox occupies zone 3. Three separate run will be done. Table 5 summarizes the dose results.

Table 5 Dose Results (Gy/d) with TRS 479 CR Values

Species	External	Internal	Total
Acacia (tree)	9.26E-05	3.86E-05	1.31E-04
Grass	5.45E-07	1.47E-06	2.01E-06
Raven	1.64E-07	1.31E-07	2.95E-07
Fox	3.60E-08	5.97E-08	9.57E-08

Dose Estimation for Acacia

Enter soil concentration in zone 1.

Data input and dose results for Acacia with TRS 479 CR values

RESRAD-BIOTA

File View Sensitivity Analysis Uncertainty Analysis Help

BIOTA Case

Title: Acacia tree

Ecosystem: ☒ Terrestrial ☐ Aquatic

Level: ☐ 1 ☐ 2 ☐ 3

Units: ☒ Traditional ☐ SI

Run

Nuclides

Potential Contaminants: Pu-239, Ra-226, Ra-228, Sb-125, Se-75, Tc-99

Contaminants: Am-241, Co-60, Cs-137, Sr-90

Concentration: Sediment: 0 Bq/kg, Water: 0 Bq/m³, Soil: 1000 Bq/kg

Organism

Type: ☐ Aquatic Animal, ☐ Riparian Animal, ☐ Terrestrial Animal, ☒ Terrestrial Plant

Organism-Specific Parameters

Organism: Terrestrial Plant

DCF / Exposure: Input Source: Input: Reference

BIV: Tissue Concentrations: Allometric

Results

BCG: Dose Rate

All dose rate results in Gy/d

Summed Doses

Total: 1.31E-04

Medium: Water: 0.00E+00, Soil: 1.31E-04, Sediment: 0.00E+00

Total (Ext/Int): External: 9.26E-05, Internal: 3.86E-05

Water: 0.00E+00, Soil: 9.26E-05, Sediment: 0.00E+00

Organism: Terrestrial Plant

Dose Report: Tissue Report

Nuclide	Ext Water Dose	Ext Soil Dose	Ext Sediment Dose	Internal Dose	Total Dose
Am-241	0.00E+00	5.64E-07	0.00E+00	2.95E-05	3.01E-05
Co-60	0.00E+00	7.12E-05	0.00E+00	6.25E-07	7.19E-05
Cs-137	0.00E+00	5.15E-06	0.00E+00	7.72E-07	5.92E-06
Sr-90	0.00E+00	1.56E-05	0.00E+00	7.66E-06	2.33E-05

Dose Estimation for Grass and Raven

Enter soil concentration in zone 2. Raven spends 30% time in zone 2 and is away from contamination 70% time. Change area factor for terrestrial animal.

Dose Results for Raven with TRS 479 CR Values

RESRAD-BIOTA

File View Sensitivity Analysis Uncertainty Analysis Help

BIOTA Case

Title: Grass and Raven Zone 2 Run

Ecosystem: ☒ Terrestrial ☐ Aquatic Level: ☐ 1 ☒ 2 ☐ 3 Units: ☐ Traditional ☒ SI

Nuclides

Potential Contaminants: Pu-239, Ra-226, Ra-228, Sb-125, Se-75, Tc-99

Contaminants: Am-241, Co-60, Cs-137, Sr-90

Concentration: Sediment: ☒ 0 Bq/kg Water: ☒ 0 Bq/m³ Soil: 28 Bq/kg Mean ☐

Organism

Type: ☐ Aquatic Animal ☐ Riparian Animal ☒ Terrestrial Animal ☒ Terrestrial Plant

New Remove Edit

RBE's: Alpha: 20 Beta: 1 Gamma: 1 Cut-off Half-life: 100 Years

Organism-Specific Parameters

Organism: Sensitivity Analysis Uncertainty Analysis

Selected Organisms: Terrestrial Animal Terrestrial Plant

Organism Name: Terrestrial Animal

DCF / Exposure Input Source Input Reference

BIV Tissue Concentrations Allometric

Nuclide	Water	Sediment	Soil
Am-241	8.65E-02	0.00E+00	3.20E-02
Co-60	1.26E-01	0.00E+00	8.00E-02
Cs-137	3.38E+00	0.00E+00	6.70E-01
Sr-90	3.12E+01	0.00E+00	4.80E-01

Results

BCG Dose Rate

All dose rate results in Gy/d

Summed Doses

Total: 2.95E-07

Medium: Water: 0.00E+00 Soil: 2.95E-07 Sediment: 0.00E+00

Total (Ext/Int): External: 1.64E-07 Internal: 1.31E-07

Water: 0.00E+00 Soil: 1.64E-07 Sediment: 0.00E+00

Organism: Terrestrial Animal Dose Report Tissue Report

Nuclide	Ext Water Dose	Ext Soil Dose	Ext Sediment Dose	Internal Dose	Total Dose
Am-241	0.00E+00	9.53E-10	0.00E+00	5.92E-08	6.01E-08
Co-60	0.00E+00	2.14E-08	0.00E+00	1.72E-09	2.31E-08
Cs-137	0.00E+00	9.86E-09	0.00E+00	7.07E-09	1.69E-08
Sr-90	0.00E+00	1.31E-07	0.00E+00	6.30E-08	1.94E-07

Dose Results for Grass with TRS 479 CR Values

RESRAD-BIOTA

File View Sensitivity Analysis Uncertainty Analysis Help

BIOTA Case

Title: Grass and Raven Zone 2 Run

Ecosystem: ☒ Terrestrial ☐ Aquatic Level: 1 2 3 Units: Traditional SI

Nuclides

Potential Contaminants: Pu-239, Ra-226, Ra-228, Sb-125, Se-75, Tc-99

Contaminants: Am-241, Co-60, Cs-137, Sr-90

Concentration: Sediment: 0 Bq/kg Water: 0 Bq/m³ Soil: 28 Bq/kg Mean ☐

Organism Type: ☐ Aquatic Animal ☐ Riparian Animal ☒ Terrestrial Animal ☒ Terrestrial Plant

New Remove Edit

RBE's: Alpha: 20 Beta: 1 Gamma: 1 Cut-off Half-life: 100 Years

Organism-Specific Parameters

Organism: Sensitivity Analysis Uncertainty Analysis

Selected Organisms: Terrestrial Animal, Terrestrial Plant

Organism Name: Terrestrial Plant

DCF / Exposure Input Source Input Reference

BIV Tissue Concentrations Allometric

Nuclide	Water	Sediment	Soil
Am-241	0.00E+00	0.00E+00	1.00E-01
Co-60	0.00E+00	0.00E+00	4.20E-03
Cs-137	0.00E+00	0.00E+00	1.80E+00
Sr-90	0.00E+00	0.00E+00	1.80E+00

New Import Export Close

Results

BCG Dose Rate

All dose rate results in Gy/d

Summed Doses

Total: 2.01E-06

Medium: Water: 0.00E+00 Soil: 2.01E-06 Sediment: 0.00E+00

Total (Ext/Int): External: 5.45E-07 Internal: 1.47E-06

Water: 0.00E+00 Soil: 5.45E-07 Sediment: 0.00E+00

Organism: Terrestrial Plant Dose Report Tissue Report

Nuclide	Ext Water Dose	Ext Soil Dose	Ext Sediment Dose	Internal Dose	Total Dose
Am-241	0.00E+00	3.18E-09	0.00E+00	6.17E-07	6.20E-07
Co-60	0.00E+00	7.12E-08	0.00E+00	3.02E-10	7.15E-08
Cs-137	0.00E+00	3.29E-08	0.00E+00	6.33E-08	9.62E-08
Sr-90	0.00E+00	4.38E-07	0.00E+00	7.88E-07	1.23E-06

Dose Estimation for Fox in Zone 3

Enter soil concentration in zone 3. Fox spends 30% time in zone 3 and is away from contamination 70% time. Change area factor for terrestrial animal.

Data Input and Dose Results for Fox Using TRS 479 CR Values

RESRAD-BIOTA - Fox zone 3.bio

File View Sensitivity Analysis Uncertainty Analysis Help

BIOTA Case

Title: Fox in Zone 3 Run

Ecosystem: ☒ Terrestrial ☐ Aquatic Level: ☐ 1 ☐ 2 ☒ 3 Units: ☒ Traditional ☐ SI

Nuclides

Potential Contaminants: Pu-239, Ra-226, Ra-228, Sb-125, Se-75, Tc-99

Contaminants: Am-241, Co-60, Cs-137, Sr-90

Concentration: Sediment: 0 Bq/kg, Water: 0 Bq/m³, Soil: 0.01 Bq/kg Mean ☐

Organism

Type: ☐ Aquatic Animal, ☐ Riparian Animal, ☒ Terrestrial Animal, ☐ Terrestrial Plant

New Remove Edit

RBE's: Alpha: 20, Beta: 1, Gamma: 1 Cut-off Half-life: 100 Years

Organism-Specific Parameters

Organism: Sensitivity Analysis Uncertainty Analysis

Selected Organisms: Terrestrial Animal

Organism Name: Terrestrial Animal

DCF / Exposure Input Source Input Reference

BIV Tissue Concentrations Allometric

Nuclide	Water	Sediment	Soil
Am-241	8.65E-02	0.00E+00	3.00E-02
Co-60	1.26E-01	0.00E+00	3.00E-01
Cs-137	3.38E+00	0.00E+00	3.20E+00
Sr-90	3.12E+01	0.00E+00	1.80E+00

New Import Export Close

Results

BCG Dose Rate

All dose rate results in Gy/d

Summed Doses

Total: 9.57E-08

Medium: Water: 0.00E+00, Soil: 9.57E-08, Sediment: 0.00E+00

Total [Ext/Int]: External: 3.60E-08, Internal: 5.97E-08

Water: 0.00E+00, Soil: 3.60E-08, Sediment: 0.00E+00

Organism: Terrestrial Animal Dose Report Tissue Report

Nuclide	Ext Water Dose	Ext Soil Dose	Ext Sediment Dose	Internal Dose	Total Dose
Am-241	0.00E+00	2.38E-12	0.00E+00	1.39E-10	1.41E-10
Co-60	0.00E+00	1.07E-08	0.00E+00	3.23E-09	1.39E-08
Cs-137	0.00E+00	6.58E-09	0.00E+00	2.25E-08	2.91E-08
Sr-90	0.00E+00	1.88E-08	0.00E+00	3.38E-08	5.25E-08

By using the species specific CR values from TRS 479 the internal dose is much lower compared to using default Biv values in RESRAD-BIOTA.

Hands-on Problem 4: Sensitivity Analysis

Background

Use sensitivity analysis to find the important parameters at level 3 for terrestrial animal. The terrestrial environment has Co-60 and Am-241 with equal concentrations in water ($3.7\text{E}+04 \text{ Bq/m}^3$ [1000 pCi/L]) and soil (37 Bq/kg [1 pCi/g]).

Problems:

- (a) Add sensitivity analysis for all 4 concentrations in Level 3. Run RESRAD-BIOTA.
- (b) What parameter is the sum dose most sensitive to? Look at the interactive table for different sensitivity parameters in the "Sensitivity" tab for "Dose" Result Type.
- (c) Look at the "Detailed Sensitivity Report" for "Dose" Result Type and "Deterministic Graph" to determine which parameter is more sensitive to soil dose and what parameter is more sensitive to water dose?
- (d) Select "Conc/BCG" Result Type. Why sensitivity is zero?
- (e) Now remove the concentration sensitivities and add the four non-zero Biv parameters for sensitivity analysis for terrestrial animal.
- (f) What parameter is the dose most sensitive to? (Look at the "Detailed Sensitivity Report".)

Question 4a. Input parameters for sensitivity analysis

Sensitivity Parameters

	ID	Parameter	Factor
▶	1	Water concentration of Am-241	2
	2	Soil concentration of Am-241	2
	3	Water concentration of Co-60	2
	4	Soil concentration of Co-60	2

◀ | ▶

ID of Parameter to Remove:

1 ▼

Remove Parameter Remove All

Run Close

Question 4b. The Sum Dose is most sensitive to the water concentration of Am-241.

Results

BCG		Dose Rate		Sensitivity		
Result Type <input checked="" type="radio"/> Dose <input type="radio"/> Conc/BCG <input type="radio"/> Tissue Conc.		All dose results in Gy/d Sensitivity Parameter: Soil concentration of Am-241		Detailed Sensitivity Report Sensitivity Graph		
Dose parameters for Sensitivity Analysis						
Nuclide	Organism	Water	Sediment	Soil	Tissue	Sum
Co-60	Terrestrial Animal	0.00%	0.00%	0.00%	0.00%	0.00%
Am-241	Terrestrial Animal	0.00%	0.00%	100.00%	0.00%	4.95%

Results

BCG		Dose Rate		Sensitivity		
Result Type <input checked="" type="radio"/> Dose <input type="radio"/> Conc/BCG <input type="radio"/> Tissue Conc.		All dose results in Gy/d Sensitivity Parameter: Soil concentration of Co-60		Detailed Sensitivity Report Sensitivity Graph		
Dose parameters for Sensitivity Analysis						
Nuclide	Organism	Water	Sediment	Soil	Tissue	Sum
Co-60	Terrestrial Animal	0.00%	0.00%	0.00%	0.00%	63.29%
Am-241	Terrestrial Animal	0.00%	0.00%	0.00%	0.00%	0.00%

Results

BCG		Dose Rate		Sensitivity		
Result Type <input checked="" type="radio"/> Dose <input type="radio"/> Conc/BCG <input type="radio"/> Tissue Conc.		All dose results in Gy/d Sensitivity Parameter: Water concentration of Am-241		Detailed Sensitivity Report Sensitivity Graph		
Dose parameters for Sensitivity Analysis						
Nuclide	Organism	Water	Sediment	Soil	Tissue	Sum
Co-60	Terrestrial Animal	0.00%	0.00%	0.00%	0.00%	0.00%
Am-241	Terrestrial Animal	100.00%	0.00%	0.00%	0.00%	95.05%

Results

BCG		Dose Rate		Sensitivity		
Result Type <input checked="" type="radio"/> Dose <input type="radio"/> Conc/BCG <input type="radio"/> Tissue Conc.		All dose results in Gy/d Sensitivity Parameter: Water concentration of Co-60		Detailed Sensitivity Report Sensitivity Graph		
Dose parameters for Sensitivity Analysis						
Nuclide	Organism	Water	Sediment	Soil	Tissue	Sum
Co-60	Terrestrial Animal	100.00%	0.00%	0.00%	0.00%	36.71%
Am-241	Terrestrial Animal	0.00%	0.00%	0.00%	0.00%	0.00%

Question 4c. The soil dose is more sensitive to Co-60 soil concentration and the water dose is more sensitive to Am-241 water concentration.

RESRAD-BIOTA Dose Sensitivity Analysis Report

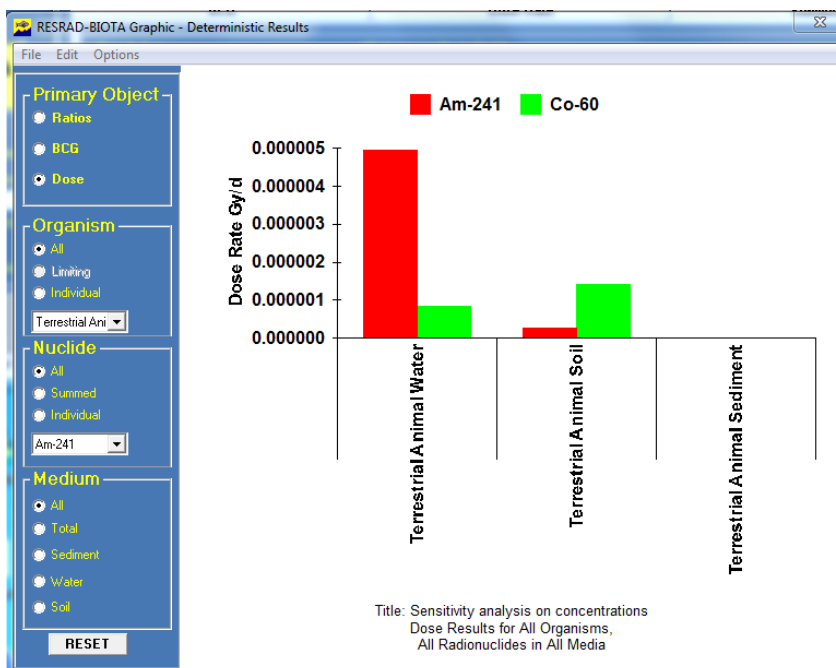
Title: Sensitivity analysis on concentrations

Soil concentration of Am-241						
Nuclide	Organism	Water Sensitivity	Sediment Sensitivity	Soil Sensitivity	Tissue Sensitivity	Summed Sensitivity
Co-60	Terrestrial Animal	0.00%	0.00%	0.00%	0.00%	0.00%
Am-241	Terrestrial Animal	0.00%	0.00%	100.00%	0.00%	4.95%

Soil concentration of Co-60						
Nuclide	Organism	Water Sensitivity	Sediment Sensitivity	Soil Sensitivity	Tissue Sensitivity	Summed Sensitivity
Co-60	Terrestrial Animal	0.00%	0.00%	100.00%	0.00%	63.29%
Am-241	Terrestrial Animal	0.00%	0.00%	0.00%	0.00%	0.00%

Water concentration of Am-241						
Nuclide	Organism	Water Sensitivity	Sediment Sensitivity	Soil Sensitivity	Tissue Sensitivity	Summed Sensitivity
Co-60	Terrestrial Animal	0.00%	0.00%	0.00%	0.00%	0.00%
Am-241	Terrestrial Animal	100.00%	0.00%	0.00%	0.00%	95.05%

Water concentration of Co-60						
Nuclide	Organism	Water Sensitivity	Sediment Sensitivity	Soil Sensitivity	Tissue Sensitivity	Summed Sensitivity
Co-60	Terrestrial Animal	100.00%	0.00%	0.00%	0.00%	36.71%
Am-241	Terrestrial Animal	0.00%	0.00%	0.00%	0.00%	0.00%



Question 4d. The BCG's are independent of medium concentrations.

RESRAD-BIOTA Conc/BCG ... x

File Edit View Favorites Tools Help

Convert Select

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RESRAD-BIOTA BCG Sensivity Analysis Report

Title: Sensivity analysis on concentrations

Soil concentration of Am-241				
Nuclide	Organism	Water Sensitivity	Sediment Sensitivity	Soil Sensitivity
Co-60	Terrestrial Animal	0.00%	0.00%	0.00%
Am-241	Terrestrial Animal	0.00%	0.00%	0.00%

Soil concentration of Co-60				
Nuclide	Organism	Water Sensitivity	Sediment Sensitivity	Soil Sensitivity
Co-60	Terrestrial Animal	0.00%	0.00%	0.00%
Am-241	Terrestrial Animal	0.00%	0.00%	0.00%

Water concentration of Am-241				
Nuclide	Organism	Water Sensitivity	Sediment Sensitivity	Soil Sensitivity
Co-60	Terrestrial Animal	0.00%	0.00%	0.00%
Am-241	Terrestrial Animal	0.00%	0.00%	0.00%

Water concentration of Co-60				
Nuclide	Organism	Water Sensitivity	Sediment Sensitivity	Soil Sensitivity
Co-60	Terrestrial Animal	0.00%	0.00%	0.00%
Am-241	Terrestrial Animal	0.00%	0.00%	0.00%

Question 4e: Input parameters for sensitivity analysis

Sensitivity Parameters

ID	Parameter	Factor
1	Water b-value of Am-241 in Terrestrial Animal	2
2	Water b-value of Co-60 in Terrestrial Animal	2
3	Soil b-value of Am-241 in Terrestrial Animal	2
4	Soil b-value of Co-60 in Terrestrial Animal	2

ID of Parameter to Remove:

1

Remove Parameter Remove All

Run Close

Question 4f: The sum dose for Terrestrial Animal is most sensitive to the Am-241 water Biv.

RESRAD-BIOTA Dose Sensitivity Analysis Report

Title: Question 4 - Sensitivity Analysis

Soil b-value of Am-241 in Terrestrial Animal						
Nuclide	Organism	Water Sensitivity	Sediment Sensitivity	Soil Sensitivity	Tissue Sensitivity	Summed Sensitivity
Co-60	Terrestrial Animal	0.00%	0.00%	0.00%	0.00%	0.00%
Am-241	Terrestrial Animal	0.00%	0.00%	88.58%	0.00%	4.38%

Soil b-value of Co-60 in Terrestrial Animal						
Nuclide	Organism	Water Sensitivity	Sediment Sensitivity	Soil Sensitivity	Tissue Sensitivity	Summed Sensitivity
Co-60	Terrestrial Animal	0.00%	0.00%	7.48%	0.00%	4.72%
Am-241	Terrestrial Animal	0.00%	0.00%	0.00%	0.00%	0.00%

Water b-value of Am-241 in Terrestrial Animal						
Nuclide	Organism	Water Sensitivity	Sediment Sensitivity	Soil Sensitivity	Tissue Sensitivity	Summed Sensitivity
Co-60	Terrestrial Animal	0.00%	0.00%	0.00%	0.00%	0.00%
Am-241	Terrestrial Animal	99.70%	0.00%	0.00%	0.00%	94.77%

Water b-value of Co-60 in Terrestrial Animal						
Nuclide	Organism	Water Sensitivity	Sediment Sensitivity	Soil Sensitivity	Tissue Sensitivity	Summed Sensitivity
Co-60	Terrestrial Animal	20.22%	0.00%	0.00%	0.00%	7.42%
Am-241	Terrestrial Animal	0.00%	0.00%	0.00%	0.00%	0.00%

Hands-on Problem 5: Hanford Case Study – Aquatic Environment

Background

The 300 Area of the Hanford Site was used to produce nuclear fuel elements for the Hanford reactors. Metallic uranium was extruded into pipe-like cylinders and encapsulated with aluminum or zirconium cladding to produce nuclear fuel rods. Process wastes contained uranium and other heavy metals. These wastes were discharged as liquids into subsurface areas adjacent to the Columbia River shoreline. Subsequent surveys revealed that contamination from the waste sites entered the aquatic environment via ground water migration and emergence as seeps along the riverbank. Environmental samples were taken during low river stage to facilitate locating and collecting riverbank spring water samples. The following table lists the sampling results –

Radio-nuclide	Water Minimum Detection Limit (Bq/m ³)	Water (Bq/m ³)	Sediment Minimum Detection Limit (Bq/kg)	Sediment (Bq/kg)
Sr-90	2.22	7.5E+00	1.9	9.6E-01
Cs-137	370		1.1	8.5E+00
U-234	2.22	2.0E+03	0.75	1.0E+02
U-235	2.22	8.3E+01	0.75	3.8E+00
U-238	2.22	1.8E+03	0.75	9.1E+01

Problems:

- (a) Based on the sampling results, run RESRAD-BIOTA for Level 1 analysis (see Fig. 1). Water concentration for Cs-137 is not available, what value should be used for the analysis? Also the measured sediment concentration for Sr-90 is lower than the detection limit, should the measured concentration be used for the analysis? Determine the Cs-137 and Sr-90 concentrations and enter them to RESRAD-BIOTA. Can you duplicate the Level 1 General Screening results as shown in Fig. 2? What is the water concentration for Cs-137 according to Fig.2 and how is it determined? Display the graphical output (See Fig. 3). Note the sum of fractions and the limiting organisms.

- (b) Select Level 2 in RESRAD-BIOTA (Site-specific screening phase). Select and input site-specific bioaccumulation coefficients (Biv parameters) for uranium in water for aquatic animal, using a value of 11. Rerun the program. See Fig. 4 for results. How does the limiting organism change?
- (c) Select Level 3 Analysis in RESRAD-BIOTA (Site-specific analysis phase). In the box labeled "Organism Type" select the "new" button. This will launch the Organism Wizard. Walk through the Wizard, entering the following information when prompted:
 - a. Name for organism: clam
 - b. Select geometry for organism: use the slider bar to move through the 8 organism sizes. Review the example receptors provided for each of the geometries. Select geometry 2.
 - c. Enter a weight for the organism. Select the default mass of 0.001 kg
 - d. Select a model for the internal ingestion parameters. Select the generic aquatic animal
 - e. Enter comments about the organism.
 - f. Run the Level 3 analysis. Examine dose and BCG output. See Fig. 5, 6, 7,8 for results

Figure 1. This is what the image should look like for Level 1 analysis:

RESRAD-BIOTA - \question5a.bio

File View Sensitivity Analysis Uncertainty Analysis Help

BIOTA Case

Title: Hanford-Question-5a [Run]

Ecosystem: ☐ Terrestrial ☒ Aquatic

Level: ☒ 1 ☐ 2 ☐ 3

Units: ☐ Traditional ☒ SI

Nuclides

Potential Contaminants: Th-229, Th-230, Th-232, Th-234, U-233, Zn-65

Contaminants: Cs-137, Sr-90, U-234, U-235, U-238

Concentration:

Sediment: ☒ 100 Bq/kg

Water: ☒ 2000 Bq/m³

Soil: 0 Bq/kg

Organism

Type: ☒ Aquatic Animal, ☒ Riparian Animal, ☐ Terrestrial Animal, ☐ Terrestrial Plant [View]

RBE's: Alpha: 20, Beta: 1, Gamma: 1

Cut-off Half-life: 100 Years

Figure 2. This is what the output should look like for Level 1 analysis:

Results

BCG

All concentrations and BCG results in Bq/kg or Bq/m³

Summed Ratios for Limiting Organism: Total: 5.09E-01, Water: 5.08E-01, Soil: 0.00E+00, Sediment: 1.61E-03

Organism: Limiting Media: Water BCG Report

Nuclide	Concentration	BCG	Ratio	Limiting Organism
Cs-137	1.70E+01	1.58E+03	1.08E-02	Riparian Animal
Sr-90	7.50E+00	1.03E+04	7.28E-04	Riparian Animal
U-234	2.00E+03	7.46E+03	2.68E-01	Aquatic Animal
U-235	8.30E+01	8.05E+03	1.03E-02	Aquatic Animal
U-238	1.80E+03	8.26E+03	2.18E-01	Aquatic Animal

* The Summed Ratios for Limiting Organism are the Limiting Ratios for all media and nuclides

Deterministic Graph Close

Figure 3. This is the graphical output from Level 1 analysis

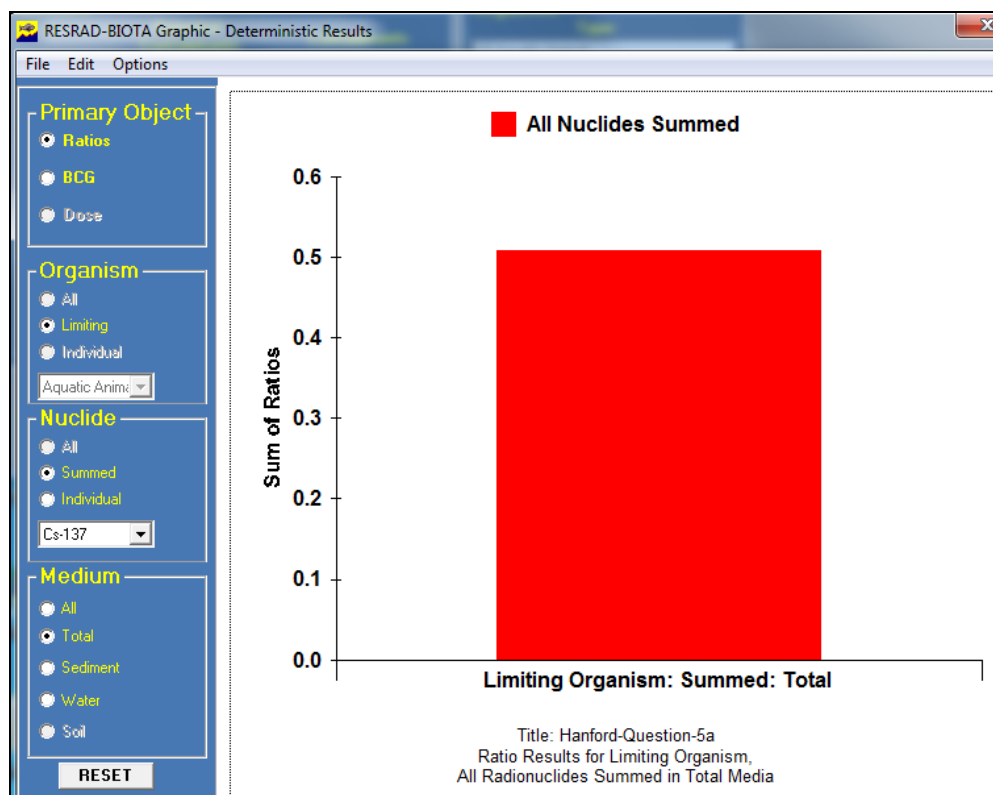


Figure 4. Level 2 results after changing U Biv values

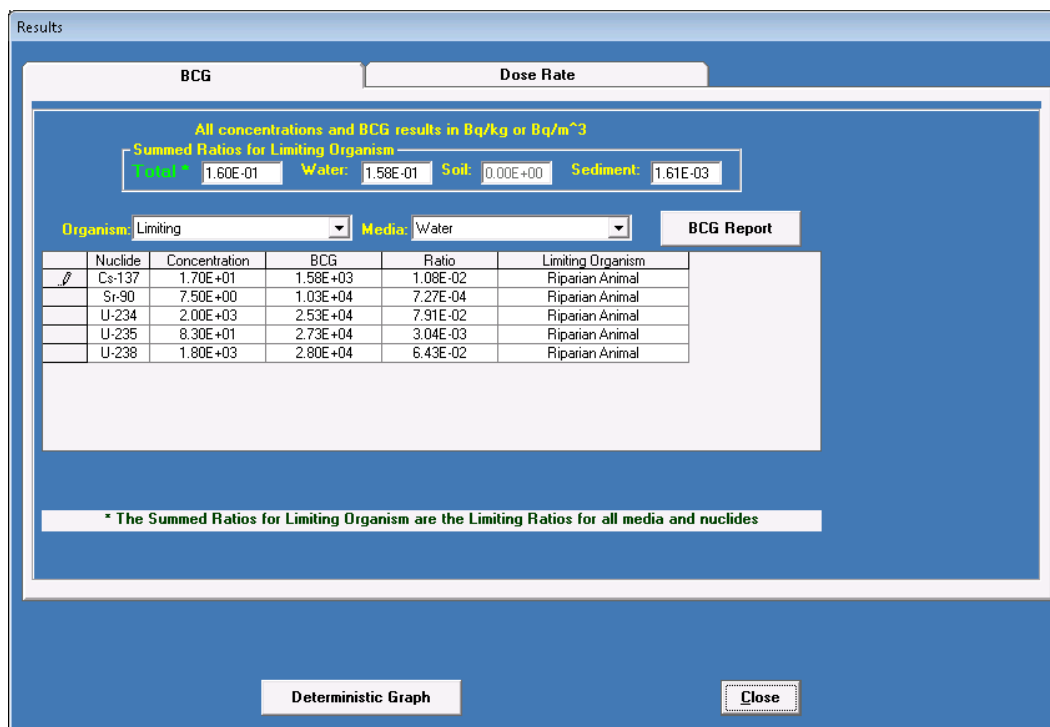


Figure 5. Level 3 results after running Organism Wizard

RESRAD-BIOTA - \question5a.bio

File View Sensitivity Analysis Uncertainty Analysis Help

BIOTA Case

Title: Hanford-Question-5a [Run]

Ecosystem: ☐ Terrestrial ☒ Aquatic

Level: ☐ 1 ☐ 2 ☒ 3

Units: ☐ Traditional ☒ SI

Nuclides

Potential Contaminants: Th-229, Th-230, Th-232, Th-234, U-233, Zn-65

Contaminants: Cs-137, Sr-90, U-234, U-235, U-238

Concentration: []

Organism Type: ☒ Aquatic Animal, ☒ Riparian Animal, ☐ Terrestrial Animal, ☐ Terrestrial Plant, ☒ clam

[New] [Remove] [Edit]

Results

BCG Dose Rate

All concentrations and BCG results in Bq/kg or Bq/m³

Summed Ratios for Limiting Organism

Total: 1.60E-01 Water: 1.58E-01 Soil: 0.00E+00 Sediment: 1.61E-03

Organism: Limiting Media: Water BCG Report

	Nuclide	Concentration	BCG	Ratio	Limiting Organism
	Cs-137	1.70E+01	1.58E+03	1.08E-02	Riparian Animal
	Sr-90	7.50E+00	1.03E+04	7.27E-04	Riparian Animal
	U-234	2.00E+03	2.53E+04	7.91E-02	Riparian Animal
	U-235	8.30E+01	2.73E+04	3.04E-03	Riparian Animal
	U-238	1.80E+03	2.80E+04	6.43E-02	Riparian Animal

* The Summed Ratios for Limiting Organism are the Limiting Ratios for all media and nuclides

Deterministic Graph [Close]

Figure 6. Graphical output from Level 3 screening.

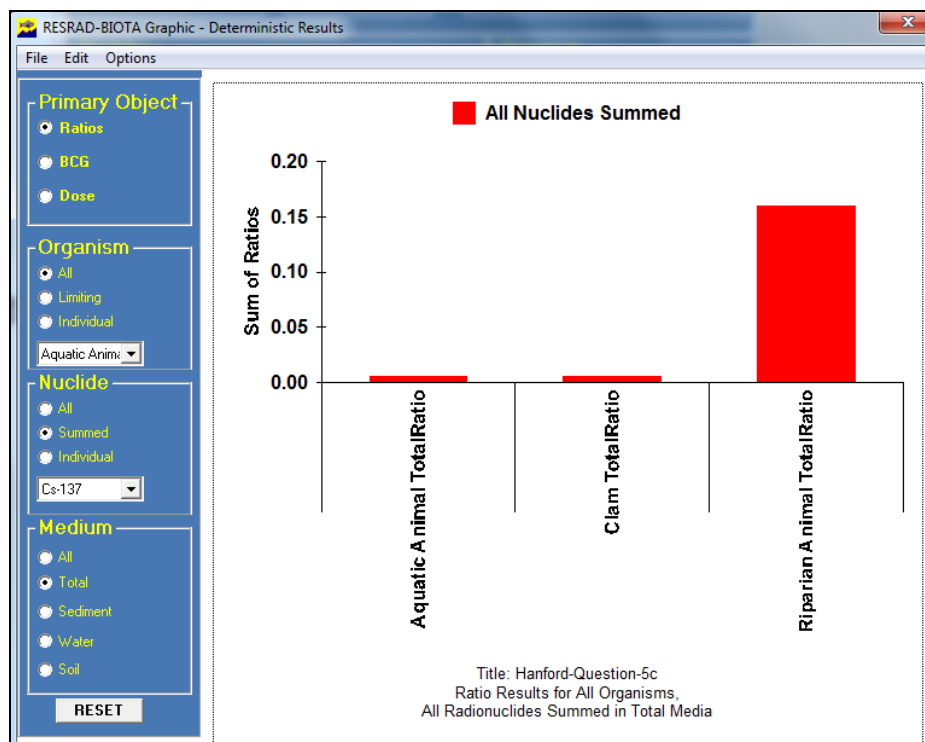


Figure 7. Nuclide contribution to limit

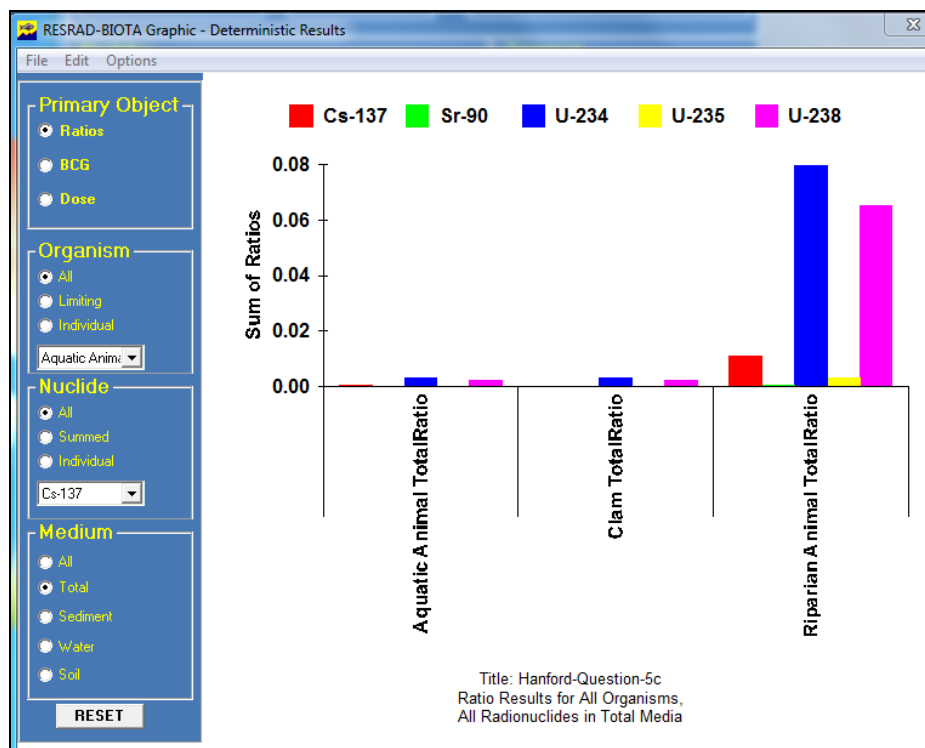


Figure 8 – Dose Output

Dose Report for Level 3 in Gy/d

Title: Hanford-Question-5c

Aquatic Animal												
Nuclide	External				Internal				Total			
	ext_Wtr	ext_Soil	ext_Sed	ext_Sum	int_Wtr	int_Soil	int_Sed	int_Sum	tot_Wtr	tot_Soil	tot_Sed	tot_Sum
Cs-137	9.32E-11	0.00E+00	4.66E-08	4.67E-08	4.39E-06	0.00E+00	0.00E+00	4.39E-06	4.39E-06	0.00E+00	4.66E-08	4.43E-06
Sr-90	5.87E-11	0.00E+00	1.76E-09	1.82E-09	3.75E-08	0.00E+00	0.00E+00	3.75E-08	3.76E-08	0.00E+00	1.76E-09	3.93E-08
U-234	1.78E-10	0.00E+00	8.92E-09	9.10E-09	2.94E-05	0.00E+00	0.00E+00	2.94E-05	2.94E-05	0.00E+00	8.92E-09	2.96E-05
U-235	2.05E-10	0.00E+00	9.37E-09	9.57E-09	1.13E-06	0.00E+00	0.00E+00	1.13E-06	1.13E-06	0.00E+00	9.37E-09	1.14E-06
U-238	1.13E-08	0.00E+00	5.73E-07	5.85E-07	2.39E-05	0.00E+00	0.00E+00	2.39E-05	2.40E-05	0.00E+00	5.73E-07	2.45E-05
Summed	1.19E-08	0.00E+00	6.40E-07	6.52E-07	5.89E-05	0.00E+00	0.00E+00	5.89E-05	5.90E-05	0.00E+00	6.40E-07	5.96E-05

Riparian Animal												
Nuclide	External				Internal				Total			
	ext_Wtr	ext_Soil	ext_Sed	ext_Sum	int_Wtr	int_Soil	int_Sed	int_Sum	tot_Wtr	tot_Soil	tot_Sed	tot_Sum
Cs-137	9.32E-11	0.00E+00	4.66E-08	4.67E-08	1.08E-05	0.00E+00	2.69E-08	1.08E-05	1.08E-05	0.00E+00	7.34E-08	1.08E-05
Sr-90	5.87E-11	0.00E+00	1.76E-09	1.82E-09	7.27E-07	0.00E+00	8.71E-09	7.36E-07	7.27E-07	0.00E+00	1.05E-08	7.38E-07
U-234	1.78E-10	0.00E+00	8.92E-09	9.10E-09	7.91E-05	0.00E+00	5.04E-07	7.96E-05	7.91E-05	0.00E+00	5.13E-07	7.96E-05
U-235	2.05E-10	0.00E+00	9.37E-09	9.57E-09	3.04E-06	0.00E+00	1.78E-08	3.06E-06	3.04E-06	0.00E+00	2.71E-08	3.07E-06
U-238	1.13E-08	0.00E+00	5.73E-07	5.85E-07	6.43E-05	0.00E+00	4.14E-07	6.47E-05	6.43E-05	0.00E+00	9.88E-07	6.53E-05
Summed	1.19E-08	0.00E+00	6.40E-07	6.52E-07	1.58E-04	0.00E+00	9.71E-07	1.59E-04	1.58E-04	0.00E+00	1.61E-06	1.60E-04

Clam												
Nuclide	External				Internal				Total			
	ext_Wtr	ext_Soil	ext_Sed	ext_Sum	int_Wtr	int_Soil	int_Sed	int_Sum	tot_Wtr	tot_Soil	tot_Sed	tot_Sum
Cs-137	6.78E-11	0.00E+00	3.39E-08	3.39E-08	1.21E-06	0.00E+00	0.00E+00	1.21E-06	1.21E-06	0.00E+00	3.39E-08	1.24E-06
Sr-90	1.52E-11	0.00E+00	4.57E-10	4.72E-10	2.77E-08	0.00E+00	0.00E+00	2.77E-08	2.77E-08	0.00E+00	4.57E-10	2.82E-08
U-234	1.22E-11	0.00E+00	6.10E-10	6.22E-10	2.94E-05	0.00E+00	0.00E+00	2.94E-05	2.94E-05	0.00E+00	6.10E-10	2.94E-05
U-235	1.05E-10	0.00E+00	4.83E-09	4.93E-09	1.12E-06	0.00E+00	0.00E+00	1.12E-06	1.12E-06	0.00E+00	4.83E-09	1.12E-06
U-238	3.01E-09	0.00E+00	1.52E-07	1.55E-07	2.35E-05	0.00E+00	0.00E+00	2.35E-05	2.35E-05	0.00E+00	1.52E-07	2.36E-05
Summed	3.21E-09	0.00E+00	1.92E-07	1.95E-07	5.53E-05	0.00E+00	0.00E+00	5.53E-05	5.53E-05	0.00E+00	1.92E-07	5.54E-05

> If the Tissue-Concentration option is selected (i.e., a tissue concentration was entered rather than a BIV value or allometric parameters in the organism 'input source' and 'input' tabs), then the internal dose to the organism from the radionuclide is calculated based on this concentration.

- This dose is not attributed to any media, i.e. it is listed in the dose table under the heading 'int_Sum'.

- The external dose from each medium, calculated based on the user input media concentrations, are listed in the dose table under the headings for each medium (Water, Soil, or Sediment).

- The total external dose, ext_sum, is added into the total internal dose, int_sum (Tissue Concentration) to get the total dose which is reported under the heading 'tot_Sum'.

> If the tissue concentration input option is not used, then the calculated internal and external doses based on media concentrations are reported.

Hands-on Problem 6: Import/Export Features

Background

You want to share the setup for the clam organism made in problem 5. Then a new case can be constructed with the new organism. Perform some analysis and save the file

Problems:

- (a) Open case for problem 5.
- (b) Go to level 3. Select clam. Select "Export". Save as "clam.org"
- (c) Close Biota. Launch the code again. Go to level 3. Select "Import" and browse to where clam.org is saved. Open the file.
- (d) Make some changes in the case and clam.org. Save the file as mod_clam.bio.
- (e) What files should be sent if you want a colleague to reproduce your results? Is there enough documentation to know what was done?

Hands-on Problem 7: Allometric Approach and Food Chain Features

Background

In this problem, you are tasked to perform an ecological risk assessment for a hypothetical site where Am-241, Cs-137, and Sr-90 contamination is detected in soil and surface water.

A variety of animal species feed or inhabit within this site, including mammals and birds. After a thorough study, representative species for different trophic levels were identified and the food chain relationships between the species and the environment were established, as illustrated by Figure 1. According to the food chain relationships, vegetation and insects are the foundation food sources and they were sampled routinely as the contaminated environmental media. Table 1 lists the maximum concentrations measured through the samplings. Table 2 provides specific dietary compositions for the representative species.

Perform a Level 3 site-specific assessment for a terrestrial ecosystem. Utilize the organism wizard to create new species in the order of low to high trophic level. Select the allometric input option to obtain tissue concentrations in lower level organisms, and then derive the corresponding Biv's (which are the ratios between the calculated tissue concentrations to the respective environmental medium concentrations) for use in the subsequent evaluation of higher-level organisms.

Table 1. Maximum Radionuclide Concentration Measured

Nuclide	Water (Bq/m ³ [pCi/L])	Soil (Bq/kg [pCi/g])	Plant (Bq/kg [pCi/g])	Insects (Bq/kg [pCi/g])
Am-241	370 (10)	37 (1)	0.296 (0.008)	12.95 (0.35)
Cs-137	740 (20)	185 (5)	7.4 (0.2)	64.75 (1.75)
Sr-90	555 (15)	129.5 (3.5)	38.85 (1.05)	45.325 (1.225)

Table2: Terrestrial Organisms Data from EPA's Wildlife Exposure Factor Handbook

Species	Body Weight	Dietary Composition	Soil Ingestion Rate	Water Ingestion Rate
Kangaroo rat	0.0411 kg	insect: 4%, vegetation: 96%	2% of food ingestion rate	5.3 mL/d
Kit fox	2 kg	mammals (kangaroo rat): 66%, birds (mourning dove): 10%, insects: 24%	2.8% of food ingestion rate	0.1839 L/d
Mourning dove	0.125 kg	vegetation: 97%, insect: 3%	10.4% of food ingestion rate	13.6 mL/d

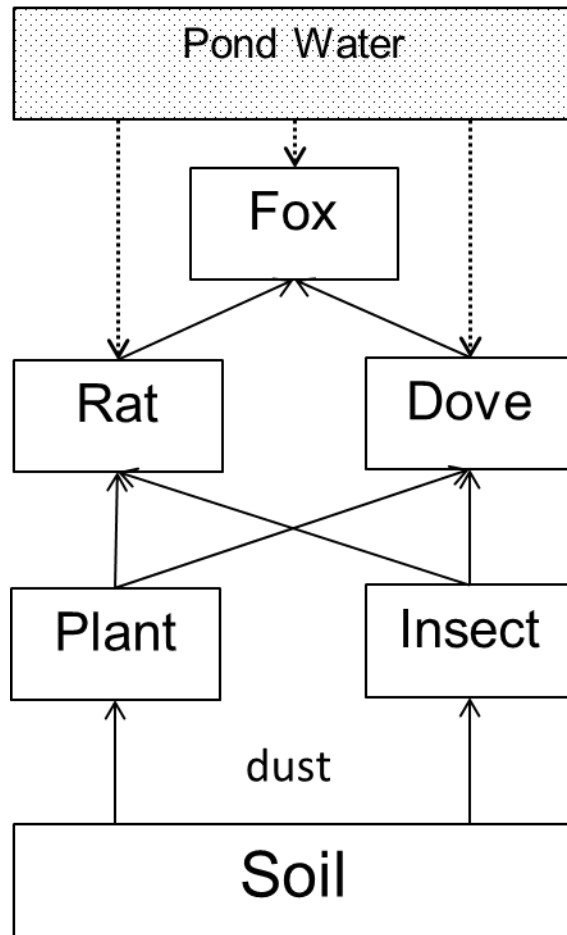


Figure 1: Conceptual Model (Food Chain) for the Representative Species

Questions:

- (1) What are the maximum tissue concentrations in Kangaroo rats, Mourning doves, and Kit Foxes? Assume 100% of the air inhaled and food ingested are contaminated.
- (2) Calculate the internal doses for these three organisms using the tissue concentrations obtained in part 1.
- (3) Calculate the total annual doses received by these three organisms.

Answers:

- (1) Approach: The contamination in soil could be dispersed into the air through the resuspension of soil particles. Use the default values to consider the exposures through the inhalation pathway.

Calculate the soil Biv's for plants and insects using the given concentrations. Then evaluate the exposures of Kangaroo rats and Mourning doves with the plant and insect Biv's by using the allometric input option.

The calculated tissue concentrations of Kangaroo rats and Mourning doves can be used to derive the corresponding soil and water Biv's, which then can be used in the next round of calculation to evaluate the exposures of Kit foxes.

Table 3 Plant and Insect Biv Calculations Using the Given Measured Concentrations

Nuclide	Water (Bq/m ³ [pCi/L])	Soil (Bq/kg [pCi/g])	Plant (Bq/kg [pCi/g])	Insects (Bq/kg [pCi/g])	Plant Biv for soil	Insect Biv for soil
Am-241	370 (10)	37 (1)	0.296 (0.008)	12.95 (0.35)	8.00E-03	3.50E-01
Cs-137	740 (20)	185 (5)	7.4 (0.2)	64.75 (1.75)	4.00E-02	3.50E-01
Sr-90	555 (15)	129.5 (3.5)	38.85 (1.05)	45.33 (1.23)	3.00E-01	3.50E-01

Choose Terrestrial ecosystem and Level 3 for the analysis. In the first analysis, create two new organisms - Kangaroo rat and Mourning dove, using the "Organism" wizard and the body weights and dietary compositions given in Table 2. In the second analysis, add another organism – Kit fox, and enter the Biv's for Kangaroo rat and Mourning dove obtained from the first analysis.

All of the three organisms are terrestrial animals. Choose conservative internal and external DCFs based on the sizes, i.e. body weights, provided in Table 2.

Tissue Concentration Calculations for Kangaroo rat

Change input parameters as shown in the following four screens -

Fraction of soil in diet from Table 2 –

Organism-Specific Parameters

Organism Sensitivity Analysis Uncertainty Analysis

Selected Organisms:

- Kangaroo rat
- Mourning dove
- Kit fox

New
Import
Export
Close

Organism Name: Kangaroo rat

DCF / Exposure Input Source **Input** Reference

BIV Tissue Concentrations **Allometric**

Metabolism **Equations/Parameter** Intake Rates Food Chain

Food Intake Rate (g/d)

$r = \frac{a}{dc} 70 M^b$

m: Body mass, kg 4.11E-02

a: Ratio of active to basal metabolic rate 2.00E+00

c: Caloric value of food, kcal/g 5.00E+00

d: Fraction of energy ingested that is assimilated and oxidized 4.40E-01

x: Mass loading factor, g/m³ 1.00E-04

Soil Intake Rate

$r_{soil} = f * r$

f: Fraction of soil in diet 2.00E-02

Water ingestion rate from Table 2 –

Organism-Specific Parameters

Organism Sensitivity Analysis Uncertainty Analysis

Selected Organisms:

- Kangaroo rat
- Mourning dove
- Kit fox

New
Import
Export
Close

Organism Name: Kangaroo rat

DCF / Exposure Input Source **Input** Reference

BIV Tissue Concentrations **Allometric**

Metabolism Equations/Parameters **Intake Rates** Food Chain

Override allometric calculations?

r: Food intake rate, g/d 5.81E+00 ☐

r_sed/soil: Sediment/Soil ingestion rate, g/d 1.16E-01 ☐

i_w: Water ingestion rate, L/d 5.30E-03 ☒

r_inh: Breathing intake rate, g/d 4.25E-06 ☐

T: Maximum lifespan, yr 3.92E-01 ☐

Diet fractions from Table 2 –

Organism-Specific Parameters

Organism Sensitivity Analysis Uncertainty Analysis

Selected Organisms:

- Kangaroo rat
- Mourning Dove
- Kit Fox

Organism Name: Kangaroo rat

DCF / Exposure Input Source **Input** Reference

BIV Tissue Concentrations **Allometric**

Metabolism Equations/Parameters Intake Rates **Food Chain**

Food Chain Characteristics: Food Source Characteristics

Add Food Source Delete Food Source

	'Food Source'	'Diet Fraction'
▶	insects	0.04
	vegetation	0.96

New Import Export Close

Food source Biv's from Table 3 –

Organism-Specific Parameters

Organism Sensitivity Analysis Uncertainty Analysis

Selected Organisms:

- Kangaroo rat
- Mourning dove
- Kit fox

Organism Name: Kangaroo rat

DCF / Exposure Input Source **Input** Reference

BIV Tissue Concentrations **Allometric**

Metabolism Equations/Parameters Intake Rates **Food Chain**

Food Chain Characteristics **Food Source Characteristics**

Sort by: ☒ Food Source ☐ Nuclide

Food Source BIVs

	'Food Source'	Nuclide	Soil	Water	Sediment
▶	insects	Am-241	3.50E-01	0.00E+00	0.00E+00
	insects	Cs-137	3.50E-01	0.00E+00	0.00E+00
	insects	Sr-90	3.50E-01	0.00E+00	0.00E+00
	seeds	Am-241	8.00E-03	0.00E+00	0.00E+00
	seeds	Cs-137	4.00E-02	0.00E+00	0.00E+00
	seeds	Sr-90	3.00E-01	0.00E+00	0.00E+00

New Import Export Close

Tissue Concentration Calculations for Mourning Dove

Change parameter values as shown in the following four screens -

Fraction of soil in diet from Table 2 –

Organism-Specific Parameters

Organism Sensitivity Analysis Uncertainty Analysis

Selected Organisms:

- Kangaroo rat
- Kit fox
- Mourning dove**

Organism Name: Mourning dove

DCF / Exposure	Input Source	Input	Reference
BIV	Tissue Concentrations	Allometric	
Metabolism	Equations/Parameter	Intake Rates	Food Chain

Food Intake Rate (g/d)

$$r = \frac{a}{dc} 70 M^b$$

m: Body mass, kg

a: Ratio of active to basal metabolic rate

c: Caloric value of food, kcal/g

d: Fraction of energy ingested that is assimilated and oxidized

x: Mass loading factor, g/m³

Soil Intake Rate

$$r_{soil} = f * r$$

f: Fraction of soil in diet

New Import Export Close

Water ingestion rate from Table 2 –

Organism-Specific Parameters

Organism Sensitivity Analysis Uncertainty Analysis

Selected Organisms:

- kangaroo rats
- mourning doves**
- Kit fox

Organism Name: mourning doves

DCF / Exposure	Input Source	Input	Reference
BIV	Tissue Concentrations	Allometric	
Metabolism	Equations/Parameters	Intake Rates	Food Chain

Override allometric calculations?

r: Food intake rate, g/d ☐

r_{sed/soil}: Sediment/Soil ingestion rate, g/d ☐

i_w: Water ingestion rate, L/d ☒

r_{inh}: Breathing intake rate, g/d ☐

T: Maximum lifespan, yr ☐

New Import Export Close

Diet fractions from Table 2 –

Organism-Specific Parameters

Organism Sensitivity Analysis Uncertainty Analysis

Selected Organisms:

- Kangaroo rat
- Mourning dove**
- Kit fox

Organism Name: Mourning dove

DCF / Exposure Input Source **Input** Reference

BIV Tissue Concentrations **Allometric**

Metabolism Equations/Parameters Intake Rates **Food Chain**

Food Chain Characteristics Food Source Characteristics

Add Food Source Delete Food Source

	'Food Source'	'Diet Fraction'
▶	vegetation	0.97
	insect	0.03

Note that the sum of the diet fractions is greater than 1. The calculations will still be performed with this conservative assumption.

New Import Export Close

Food source Bivs from Table 3 –

Organism-Specific Parameters

Organism Sensitivity Analysis Uncertainty Analysis

Selected Organisms:

- Kangaroo rat
- Mourning dove**
- Kit fox

Organism Name: Mourning dove

DCF / Exposure Input Source **Input** Reference

BIV Tissue Concentrations **Allometric**

Metabolism Equations/Parameters Intake Rates **Food Chain**

Food Chain Characteristics **Food Source Characteristics**

Sort by: ☒ Food Source ☐ Nuclide

Food Source BIVs

	'Food Source'	Nuclide	Soil	Water	Sediment
▶	vegetation	Am-241	8.00E-03	0.00E+00	0.00E+00
	vegetation	Cs-137	4.00E-02	0.00E+00	0.00E+00
	vegetation	Sr-90	3.00E-01	0.00E+00	0.00E+00
	insect	Am-241	3.50E-01	0.00E+00	0.00E+00
	insect	Cs-137	3.50E-01	0.00E+00	0.00E+00
	insect	Sr-90	3.50E-01	0.00E+00	0.00E+00

New Import Export Close

Run the RESRAD-BIOTA and find tissue concentrations for Kangaroo rat and Mourning dove.

Tissue concentrations from the Tissue Report –

Tissue Concentration Report for Level 3 in Bq/kg

Title: Problem 7

Kangaroo rat				
Nuclide	water	Soil	sediment	Total(Tissue Conc)
Am-241	1.11E-03	5.11E-03	0.00E+00	6.23E-03
Cs-137	1.17E+00	2.33E+01	0.00E+00	2.45E+01
Sr-90	2.58E+00	2.12E+02	0.00E+00	2.15E+02

Mourning dove				
Nuclide	water	Soil	sediment	Total(Tissue Conc)
Am-241	2.52E-03	2.71E-02	0.00E+00	2.96E-02
Cs-137	1.45E+00	4.88E+01	0.00E+00	5.02E+01
Sr-90	3.37E+00	2.80E+02	0.00E+00	2.83E+02

Now calculate Biv values for Kangaroo rat and Mourning dove. The calculated Biv's can be used in the next RESRAD-BIOTA run to obtain tissue concentrations of Kit fox.

Table 4. Water and Soil Biv Calculations for Kangaroo Rat and Mourning Dove Using the Given Soil and Water Concentrations

Kangaroo rat tissue conc. (Bq/kg) from different media (see tissue concentration report)					Media Conc.		Kangaroo rat Biv for Different Media	
Nuclide	water	Soil	sediment	Total	Water (Bq/m ³)	Soil (Bq/kg)	Water [(Bq/kg) per (Bq/L)]	Soil [(Bq/kg) per Bq/kg]
Am-241	1.11E-03	5.11E-03	0.00E+00	6.23E-03	370	37	3.01E-03	1.38E-04
Cs-137	1.17E+00	2.33E+01	0.00E+00	2.45E+01	740	185	1.59E+00	1.26E-01
Sr-90	2.58E+00	2.12E+02	0.00E+00	2.15E+02	555	129.5	4.65E+00	1.64E+00

Mourning dove tissue conc. (Bq/kg) from different media (see tissue concentration report)					Media Conc.		Mourning dove Biv for Different Media	
Nuclide	water	Soil	sediment	Total	Water (Bq/m ³)	Soil (Bq/kg)	Water [(Bq/kg) per (Bq/L)]	Soil [(Bq/kg) per Bq/kg]
Am-241	2.52E-03	2.71E-02	0.00E+00	2.96E-02	370 (10)	37 (1)	6.80E-03	7.32E-04
Cs-137	1.45E+00	4.88E+01	0.00E+00	5.02E+01	740 (20)	185 (5)	1.96E+00	2.64E-01
Sr-90	3.37E+00	2.80E+02	0.00E+00	2.83E+02	555 (15)	129.5 (3.5)	6.07E+00	2.16E+00

(Note: Convert water conc. from Bq/m³ to Bq/L to obtain Biv's with the correct unit)

Tissue Concentration Calculations for Kit Fox

Change parameter values as shown in the following four screens –

Fraction of soil in diet from Table 2

Organism-Specific Parameters

Organism Sensitivity Analysis Uncertainty Analysis

Selected Organisms:

- Kangaroo rat
- Mourning dove
- Kit fox**

Organism Name: Kit fox

DCF / Exposure	Input Source	Input	Reference
BIV	Tissue Concentrations	Allometric	
Metabolism	Equations/Parameter	Intake Rates	Food Chain

Food Intake Rate (g/d)

$r = \frac{a}{dc} 70 M^b$

m: Body mass, kg

a: Ratio of active to basal metabolic rate

c: Caloric value of food, kcal/g

d: Fraction of energy ingested that is assimilated and oxidized

x: Mass loading factor, g/m³

Soil Intake Rate

$r_{soil} = f * r$

f: Fraction of soil in diet

New
Import
Export
Close

Water ingestion rate from Table 2

Organism-Specific Parameters

Organism Sensitivity Analysis Uncertainty Analysis

Selected Organisms:

- Kangaroo rat
- Mourning dove
- Kit fox**

Organism Name: Kit fox

DCF / Exposure	Input Source	Input	Reference
BIV	Tissue Concentrations	Allometric	
Metabolism	Equations/Parameters	Intake Rates	Food Chain

Override allometric calculations?

r: Food intake rate, g/d ☐

r_sed/soil: Sediment/Soil ingestion rate, g/d ☐

i_w: Water ingestion rate, L/d ☒

r_inh: Breathing intake rate, g/d ☐

T: Maximum lifespan, yr ☐

New
Import
Export
Close

Diet fractions from Table 2

Organism-Specific Parameters

Organism Sensitivity Analysis Uncertainty Analysis

Selected Organisms:

Kangaroo rat
Mourning Dove
Kit Fox

New
Import
Export
Close

Organism Name: Kit Fox

DCF / Exposure Input Source **Input** Reference

BIV Tissue Concentrations **Allometric**

Metabolism Equations/Parameters Intake Rates **Food Chain**

Food Chain Characteristics Food Source Characteristics

Add Food Source Delete Food Source

	'Food Source'	'Diet Fraction'
▶	Kangaroo rat	0.66
	Mourning dove	0.1
	insects	0.24

Food source Bivs from Table 3 and Table 4

Organism-Specific Parameters

Organism Sensitivity Analysis Uncertainty Analysis

Selected Organisms:

Kangaroo rat
Mourning dove
Kit fox

New
Import
Export
Close

Organism Name: Kit fox

DCF / Exposure Input Source **Input** Reference

BIV Tissue Concentrations **Allometric**

Metabolism Equations/Parameters Intake Rates **Food Chain**

Food Chain Characteristics **Food Source Characteristics**

Sort by:
☒ **Food Source** ☐ **Nuclide**

Food Source BIVs

	'Food Source'	Nuclide	Soil	Water	Sediment
▶	Kangaroo rat	Am-241	1.38E-04	3.01E-03	0.00E+00
	Kangaroo rat	Cs-137	1.26E-01	1.59E+00	0.00E+00
	Kangaroo rat	Sr-90	1.64E+00	4.65E+00	0.00E+00
	mourning dove	Am-241	7.32E-04	6.80E-03	0.00E+00
	mourning dove	Cs-137	2.64E-01	1.96E+00	0.00E+00
	mourning dove	Sr-90	2.16E+00	6.07E+00	0.00E+00
	insects	Am-241	3.50E-01	0.00E+00	0.00E+00
	insects	Cs-137	3.50E-01	0.00E+00	0.00E+00
	insects	Sr-90	3.50E-01	0.00E+00	0.00E+00

Run RESRAD-BIOTA and get the tissue concentrations for Kit fox from the Tissue Report (results are shown below) –

Tissue Concentration Report for Level 3 in Bq/kg

Title: Problem 7

Kit fox				
Nuclide	water	Soil	sediment	Total(Tissue Conc)
Am-241	1.08E-02	6.89E-02	0.00E+00	7.95E-02
Cs-137	3.68E+00	6.85E+01	0.00E+00	7.22E+01
Sr-90	1.78E+01	1.09E+03	0.00E+00	1.11E+03

(2) Use conservative internal DCFs for internal dose calculations
(see the following three screens for conservative internal DCFs size selection) –

Organism-Specific Parameters

Organism Sensitivity Analysis Uncertainty Analysis

Selected Organisms:

- Kangaroo rat
- Mourning dove
- Kit fox

Organism Name: Kangaroo rat

DCF / Exposure Input Source Input Reference

DCF_s(Gy/y)/(Bq/kg)

Nuclide	External	Internal
Am-241	1.17E-07	5.60E-04
Cs-137	2.79E-06	1.53E-06
Sr-90	5.93E-07	5.50E-06

Internal Size: 4

External Size: 3

Dose Limits

Dose Limit: 0.001 Gy/d

Area Factor: 1

External Exposure Geometry Factors

Sediment Water Soil

0 0.5 1

Ingestion: ☐ ☒ ☒

Organism-Specific Parameters

Organism Sensitivity Analysis Uncertainty Analysis

Selected Organisms:

- Kangaroo rat
- Mourning dove
- Kit fox

Organism Name: Mourning dove

DCF / Exposure Input Source Input Reference

DCF_s(Gy/y)/(Bq/kg)

Nuclide	External	Internal
Am-241	1.17E-07	5.60E-04
Cs-137	2.79E-06	1.53E-06
Sr-90	5.93E-07	5.50E-06

Internal Size: 4

External Size: 3

Dose Limits

Dose Limit: 0.001 Gy/d

Area Factor: 1

External Exposure Geometry Factors

Sediment Water Soil

0 0.5 1

Ingestion: ☐ ☒ ☒

Organism-Specific Parameters

Organism: Sensitivity Analysis: Uncertainty Analysis

Selected Organisms:

Kangaroo rat
Mourning dove
Kit fox

Organism Name: Kit fox

DCF / Exposure	Input Source	Input	Reference
-DCF/(Gy/y)/(Bq/kg)			
Nuclide	External	Internal	
Am-241	9.74E-08	5.60E-04	
Cs-137	2.56E-06	1.95E-06	
Sr-90	1.94E-07	5.62E-06	

Internal Size: 5

External Size: 4

Dose Limits

Dose Limit: 0.001 Gy/d

Area Factor: 1

External Exposure Geometry Factors

	Sediment	Water	Soil
0	0.5	1	

Ingestion: ☐ ☒ ☒

The following three screens show the calculated dose results –

Results

BCG Dose Rate

All dose rate results in Gy/d

Summed Doses

Total: 4.99E-06

Medium

Water: 4.88E-08 Soil: 4.94E-06 Sediment: 0.00E+00

Total (Ext/ Int)

External: 1.64E-06 Internal: 3.35E-06

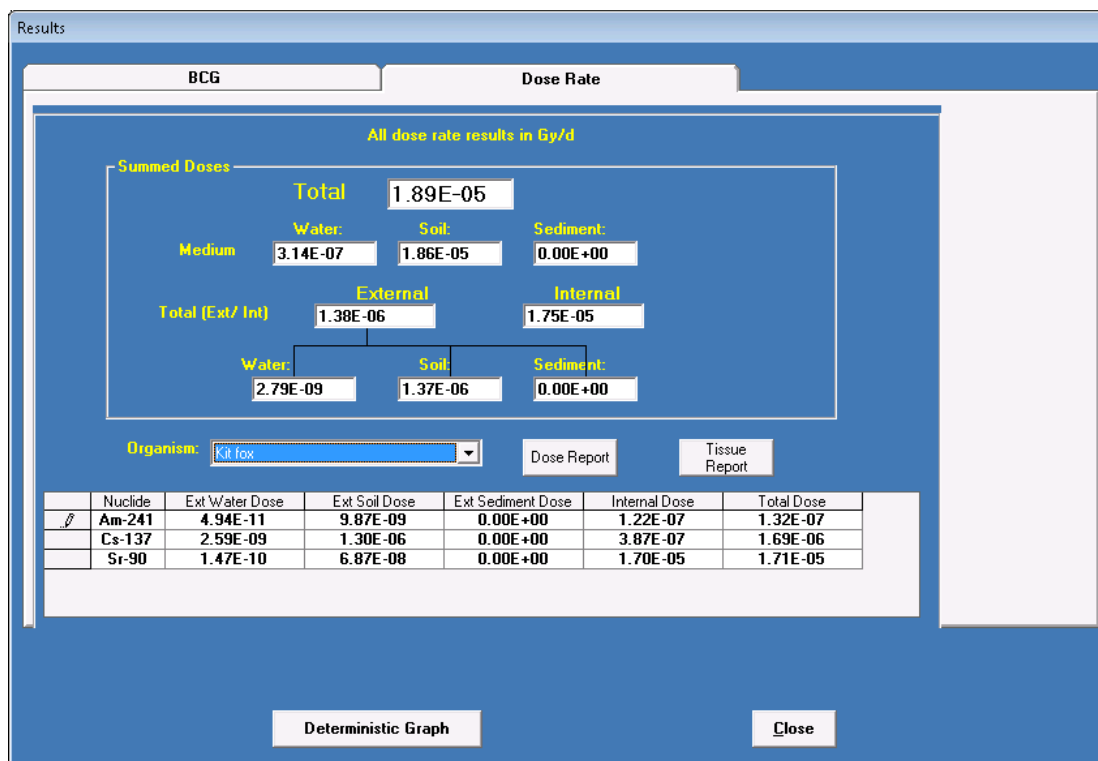
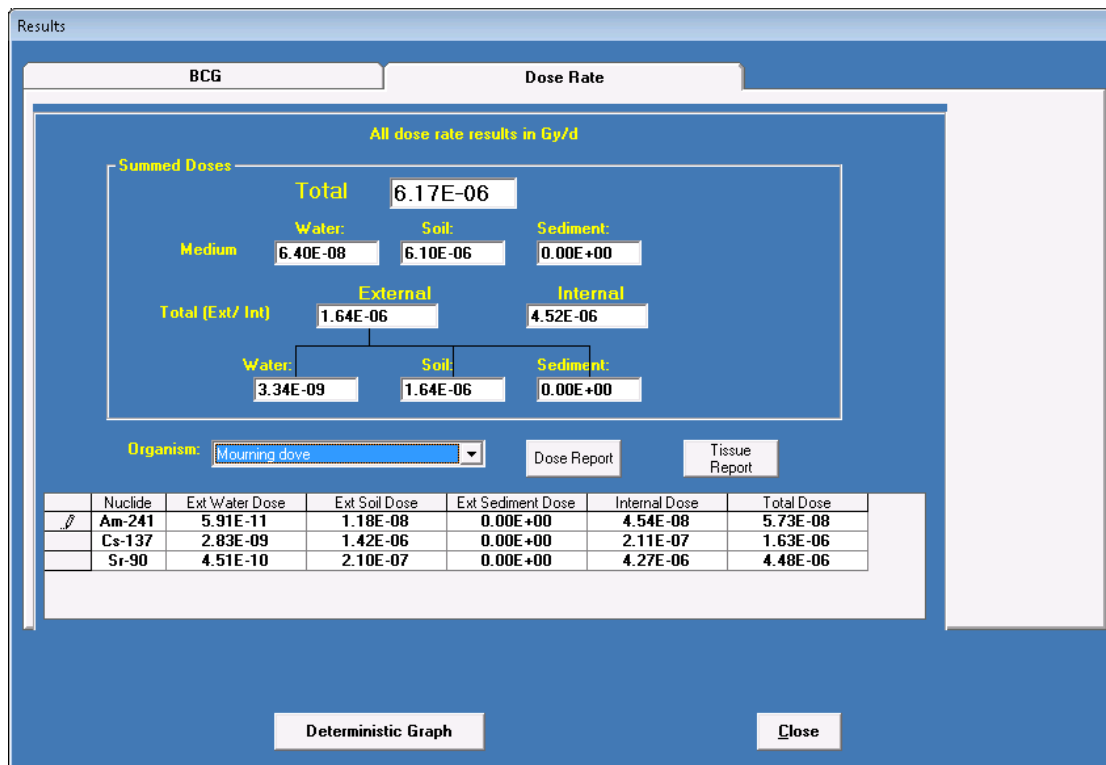
Water: 3.34E-09 Soil: 1.64E-06 Sediment: 0.00E+00

Organism: Kangaroo rat

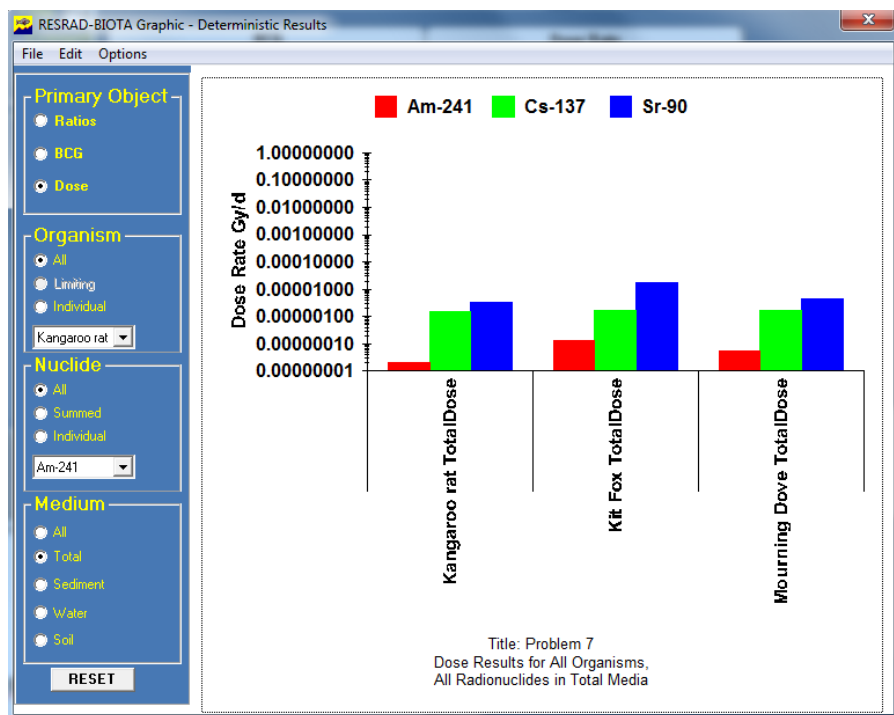
Dose Report Tissue Report

Nuclide	Ext Water Dose	Ext Soil Dose	Ext Sediment Dose	Internal Dose	Total Dose
Am-241	5.91E-11	1.18E-08	0.00E+00	9.55E-09	2.14E-08
Cs-137	2.83E-09	1.42E-06	0.00E+00	1.03E-07	1.52E-06
Sr-90	4.51E-10	2.10E-07	0.00E+00	3.24E-06	3.45E-06

Deterministic Graph Close



(3) Use conservative external DCFs for external dose calculations and check the total dose rates in the deterministic graphics as well as in the dose report.



Dose Report for Level 3 in Gy/d

Title: Problem 7

Kangaroo rat												
Nuclide	External				Internal				Total			
	ext_Wtr	ext_Soil	ext_Sed	ext_Sum	int_Wtr	int_Soil	int_Sed	int_Sum	tot_Wtr	tot_Soil	tot_Sed	tot_Sum
Am-241	5.91E-11	1.18E-08	0.00E+00	1.19E-08	1.71E-09	7.84E-09	0.00E+00	9.55E-09	1.77E-09	1.97E-08	0.00E+00	2.14E-08
Cs-137	2.83E-09	1.42E-06	0.00E+00	1.42E-06	4.94E-09	9.79E-08	0.00E+00	1.03E-07	7.77E-09	1.51E-06	0.00E+00	1.52E-06
Sr-90	4.51E-10	2.10E-07	0.00E+00	2.11E-07	3.88E-08	3.20E-06	0.00E+00	3.24E-06	3.93E-08	3.41E-06	0.00E+00	3.45E-06
Summed	3.34E-09	1.64E-06	0.00E+00	1.64E-06	4.55E-08	3.30E-06	0.00E+00	3.35E-06	4.88E-08	4.94E-06	0.00E+00	4.99E-06

Mourning dove												
Nuclide	External				Internal				Total			
	ext_Wtr	ext_Soil	ext_Sed	ext_Sum	int_Wtr	int_Soil	int_Sed	int_Sum	tot_Wtr	tot_Soil	tot_Sed	tot_Sum
Am-241	5.91E-11	1.18E-08	0.00E+00	1.19E-08	3.86E-09	4.15E-08	0.00E+00	4.54E-08	3.92E-09	5.33E-08	0.00E+00	5.73E-08
Cs-137	2.83E-09	1.42E-06	0.00E+00	1.42E-06	6.09E-09	2.05E-07	0.00E+00	2.11E-07	8.92E-09	1.62E-06	0.00E+00	1.63E-06
Sr-90	4.51E-10	2.10E-07	0.00E+00	2.11E-07	5.07E-08	4.22E-06	0.00E+00	4.27E-06	5.12E-08	4.43E-06	0.00E+00	4.48E-06
Summed	3.34E-09	1.64E-06	0.00E+00	1.64E-06	6.07E-08	4.48E-06	0.00E+00	4.52E-06	6.40E-08	6.10E-06	0.00E+00	6.17E-06

Kit fox												
Nuclide	External				Internal				Total			
	ext_Wtr	ext_Soil	ext_Sed	ext_Sum	int_Wtr	int_Soil	int_Sed	int_Sum	tot_Wtr	tot_Soil	tot_Sed	tot_Sum
Am-241	4.94E-11	9.87E-09	0.00E+00	9.92E-09	1.63E-08	1.08E-07	0.00E+00	1.22E-07	1.63E-08	1.18E-07	0.00E+00	1.32E-07
Cs-137	2.59E-09	1.30E-06	0.00E+00	1.30E-06	1.97E-08	3.67E-07	0.00E+00	3.87E-07	2.23E-08	1.66E-06	0.00E+00	1.69E-06
Sr-90	1.47E-10	6.87E-08	0.00E+00	6.89E-08	2.75E-07	1.67E-05	0.00E+00	1.70E-05	2.75E-07	1.68E-05	0.00E+00	1.71E-05
Summed	2.79E-09	1.37E-06	0.00E+00	1.38E-06	3.11E-07	1.72E-05	0.00E+00	1.75E-05	3.14E-07	1.88E-05	0.00E+00	1.89E-05

> If the Tissue-Concentration option is selected (i.e., a tissue concentration was entered rather than a BIV value or allometric parameters in the organism 'input source' and 'input' tabs), then the internal dose to the organism from the radionuclide is calculated based on this concentration.

- This dose is not attributed to any media, i.e. it is listed in the dose table under the heading 'Int_Sum'.

- The external dose from each medium, calculated based on the user input media concentrations, are listed in the dose table under the headings for each medium (Water, Soil, or Sediment).

- The total external dose, ext_sum, is added into the total internal dose, int_sum (Tissue Concentration) to get the total dose which is reported under the heading 'tot_Sum'.

> If the tissue concentration input option is not used, then the calculated internal and external doses based on media concentrations are reported.

Hands-on Problem 8: Uncertainty Analysis (Including Modifications of Exposure Geometry, Area Factor, and RBE)

Background –

A large lake is located near a uranium mining facility. Over the years, surface runoff from the facility has flowed to the lake and contaminated the water. Perform a probabilistic analysis using the RESRAD-BIOTA code to evaluate the potential impacts to the aquatic organisms living in the lake, including benthic fish, pelagic fish, and frogs.

As part of the environmental monitoring program, water and sediment samples from the lake are routinely collected for contamination analysis. Table 1 lists the radionuclide concentrations measured with the collected samples.

Use the following information for your analysis; if information on a parameter is not provided, use the default value – alpha RBE = 10, cutoff half-life = 180 days, number of observations = 100, and sampling repetition = 3.

Table 1 Radionuclide Concentration in Water and Sediment Samples		
Radionuclide	Mean water concentration (Bq/m ³)	Mean sediment concentrations (Bq/kg)
Pb-210	55	1.45E4
Po-210	35	1.38E4
Ra-226	95	2.85E3
Th-230		1.08E3
U-238	6450	1.75E5

Table 2 Distributions of Water Biv's for Fish						
Element	Distribution	Lambda	Mean	Error Factor	Min	Max
Pb-210	Exponential	3.33E-03	300			
Po-210	Exponential	4.17E-03	240			
Ra-226	Bounded Lognormal		80	6.5	0.3	810
Th-230	Bounded Lognormal		110	4	15	560
Uranium	Bounded Lognormal		30	8.95	0.3	200

Table 3 Mass and Occupancy Factors				
Species	Mass (g)	Occupancy		
		Away	Inside water	Sediment-water interface
Pelagic Fish	1200	0%	75%	25%
Benthic Fish	1191	0%	30%	70%
Frog	12	25%	25%	50%

Questions –

- (1) Calculate the radiation doses for pelagic fish, benthic fish, and frog with a deterministic analysis.
- (2) Calculate the mean, 75%, and 90% tissue concentrations for pelagic fish.
- (3) Calculate 90% total water and sediment dose rates, respectively, for benthic fish.
- (4) Calculate mean and 95% total dose for fish species. Explain the difference in dose rates.

Answers –

First set up the analysis with the following selections –

Title – Problem 8,
Ecosystem – Aquatic,
Level – 3,
Units – SI,
Cut-off Half-Life = 180 days, and
Alpha RBE = 10.

Select the 5 radionuclides of concern - Po-210, Pb-210, Ra-226, Th-230, and U-238, and input the measured sediment and water concentrations from Table 1. For Th-230, measured water concentration is not provided; use the default K_d to estimate an equilibrium water concentration based on the measured sediment concentration. (Pay attention to the units!)

Create a new species "pelagic fish," using the organism wizard

RESRAD-BIOTA

File View Sensitivity Analysis Uncertainty Analysis Help

BIOTA Case

Title: Problem 8 [Run]

Ecosystem: ☐ Terrestrial ☒ Aquatic

Level: ☐ 1 ☐ 2 ☒ 3

Units: ☐ Traditional ☒ SI

Nuclides

Potential Contaminants: Th-232, Th-234, U-233, U-234, U-235, Zn-65

Contaminants: Pb-210, Po-210, Ra-226, Th-230, U-238

Concentration:

Sediment: ☒ 175000 Bq/kg

Water: ☒ 6450 Bq/m³

Soil: 0 Bq/kg

☐ Mean

Organism

Type:

☐ Aquatic Animal

☒ Riparian Animal

☐ Terrestrial Animal

☐ Terrestrial Plant

[New] [Remove] [Edit]

RBE's

Alpha: 10

Beta: 1

Gamma: 1

Cut-off Half-life: 100 Years

New Organism Wizard

This wizard will walk you through the steps necessary to create a new organism for use in RESRAD-BIOTA.

Enter a name for the new organism:

pelagic fish

[Help] [Cancel] [Back] [Next]

Select the appropriate geometry based on the mass of the organism as provided in Table 3. Select "Generic Aquatic Animal" to generate a template for input parameters. Change "External Exposure Geometry Factors" based on the occupancy factors provided in Table 3. The following screen shows the input values –

Input screen for external exposure geometry factors for pelagic fish -

Organism-Specific Parameters

Organism Sensitivity Analysis Uncertainty Analysis

Selected Organisms:

- benthic fish
- frog
- pelagic fish

Organism Name: pelagic fish

DCF / Exposure Input Source Input Reference

DCF_s(Gy/y)/(Bq/kg)

Nuclide	External	Internal
Pb-210	3.42E-08	2.75E-04
Po-210	3.84E-11	2.72E-04
Ra-226	7.99E-06	1.23E-03
Th-230	2.05E-09	2.39E-04
U-238	2.58E-07	2.19E-04

Internal
Size: 4

External
Size: 4

Dose Limits

Dose Limit: 0.01 Gy/d

Area Factor: 1

External Exposure Geometry Factors

	Sediment	Water	Soil
Ingestion:	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

New
Import
Export
Close

Enter the mean Biv values from Table 2.

Organism-Specific Parameters

Organism Sensitivity Analysis Uncertainty Analysis

Selected Organisms:

- benthic fish
- frog
- pelagic fish

Organism Name: pelagic fish

DCF / Exposure Input Source Input Reference

BIV Tissue Concentrations Allometric

Nuclide	Water	Sediment	Soil
Pb-210	3.00E+02	0.00E+00	0.00E+00
Po-210	2.40E+02	0.00E+00	0.00E+00
Ra-226	8.00E+01	0.00E+00	0.00E+00
Th-230	1.10E+02	0.00E+00	0.00E+00
U-238	30	0.00E+00	0.00E+00

New
Import
Export
Close

Create new species "frog" using the organism wizard

Select an appropriate geometry based on the mass of the organism as provided in Table 3. Choose "Generic riparian animal" to generate a template for input parameters.

Change “External Exposure Geometry Factors” and “Area Factor” based on the occupancy factors provided in Table 3. Use the RESRAD-BIOTA default Biv values for water and sediment. The following screen shows the input values –

Input screen for changing external exposure geometry factors for frog -

Organism-Specific Parameters

Organism Sensitivity Analysis Uncertainty Analysis

Selected Organisms:

- pelagic fish
- frog**

Organism Name: frog

DCF / Exposure: Input Source Input Reference

DCFs (Gy/y)/(Bq/kg)

Nuclide	External	Internal
Pb-210	8.80E-08	2.74E-04
Po-210	4.14E-11	2.72E-04
Ra-226	8.82E-06	1.23E-03
Th-230	3.14E-09	2.39E-04
U-238	5.66E-07	2.19E-04

Internal Size: 3

External Size: 3

Dose Limits

Dose Limit: 0.001 Gy/d

Area Factor: 0.75

External Exposure Geometry Factors

	Sediment	Water	Soil
Ingestion:	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

Buttons: New, Import, Export, Close

(What is the difference if “Generic aquatic animal” was selected to generate an input template?)

Create new species "benthic fish" using the organism wizard

Select an appropriate geometry based on the mass of the organism as provided in Table 3. Select “Generic Aquatic Animal” to generate a template for input parameters. Change “External Exposure Geometry Factors” based on the occupancy factors provided in Table 3.

Input screen for external exposure geometry factors for benthic fish -

Organism-Specific Parameters
 Organism Sensitivity Analysis Uncertainty Analysis

Selected Organisms:
 benthic fish
 frog
 pelagic fish

Organism Name: benthic fish

DCF / Exposure	Input Source	Input	Reference
DCF_s(Gy/y)/(Bq/kg)			
Nuclide	External	Internal	
Pb-210	3.42E-08	2.75E-04	
Po-210	3.84E-11	2.72E-04	
Ra-226	7.99E-06	1.23E-03	
Th-230	2.05E-09	2.39E-04	
U-238	2.58E-07	2.19E-04	

Internal Size: 4

External Size: 4

Dose Limits
 Dose Limit: 0.01 Gy/d
 Area Factor: 1

External Exposure Geometry Factors

	Sediment	Water	Soil
Ingestion:	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

New
 Import
 Export
 Close

Use the mean Biv values from Table 2.

Organism-Specific Parameters
 Organism Sensitivity Analysis Uncertainty Analysis

Selected Organisms:
 benthic fish
 frog
 pelagic fish

Organism Name: benthic fish

DCF / Exposure	Input Source	Input	Reference
BIV			
	Tissue Concentrations		Allometric
Nuclide	Water	Sediment	Soil
Pb-210	3.00E+02	0.00E+00	0.00E+00
Po-210	2.40E+02	0.00E+00	0.00E+00
Ra-226	8.00E+01	0.00E+00	0.00E+00
Th-230	1.10E+02	0.00E+00	0.00E+00
U-238	3.00E+01	0.00E+00	0.00E+00

New
 Import
 Export
 Close

Run the RESRAD-BIOTA code. Obtain the dose rates for pelagic fish, frog, and benthic fish, respectively.

Total dose rate for benthic fish = 2.27E-4 Gy/d

Total dose rate for frog = 9.59E-4 Gy/d

Total dose rate for pelagic fish = 1.85E-4 Gy/d

(2) Select water Biv for each radionuclide for pelagic fish and press F8 or click “uncertainty analysis.” Change the number of observations to 100. Select the distribution function and enter the distribution parameters as provided in Table 2. The following two screens show the input parameter values –

Uncertainty analysis input summary screen - change number of observations –

The screenshot shows the 'Uncertainty Analysis Input Summary' dialog box with the 'Sample specifications' tab selected. The 'Sampling parameters' section contains three input fields: 'Random Seed' (1000), 'Number of Observations' (100), and 'Number of Repetitions' (3). The 'Sampling Technique' section has two radio buttons: 'Latin Hypercube' (selected) and 'Monte Carlo'. The 'Grouping of observations' section has two radio buttons: 'Correlated or Uncorrelated' (selected) and 'Random'. The 'Information about current selection' text box explains that the number of sample values generated will be used to generate a set of outputs, from which the uncertainty / probability statistics will be generated. It notes that for 500 observations and 10 repetitions, 10 sets of 500 sample values will be generated for each input variable. The bottom of the dialog has two radio buttons: 'Perform uncertainty analysis' (selected) and 'Suppress uncertainty analysis this session', along with 'Help' and 'OK' buttons.

Parameter distributions for water Biv values for pelagic fish –

The screenshot shows the 'Uncertainty Analysis Input Summary' dialog box with the 'Parameter distributions' tab selected. The 'Variable Description' list on the left includes five entries: 'Water BIV of Pb-210 in pelagic fish', 'Water BIV of Po-210 in pelagic fish', 'Water BIV of Ra-226 in pelagic fish', 'Water BIV of Th-230 in pelagic fish', and 'Water BIV of U-238 in pelagic fish'. The 'Statistics of Uncertain variable' section for 'Water BIV of U-238 in pelagic fish' shows a 'Distribution' of 'BOUNDED LOGNORMAL'. The 'Mean' is 30, 'Error Factor (Erf)' is 8.95, 'Minimum' is 0.3, and 'Maximum' is 200. The bottom of the dialog has two radio buttons: 'Perform uncertainty analysis' (selected) and 'Suppress uncertainty analysis this session', along with 'Help' and 'OK' buttons.

Uncertainty Analysis Results - Pelagic fish tissue concentrations

File

Graphics

Input Specifications

Parameter Statistics

Results

Text

Graphics

Statistical Object

Primary Object

Tissue concentration

Organism

pelagic fish

Medium

Tissue

Radionuclide

Pb-210

Statistical Property

Percentile

Results

Percentile	Tissue concentration	+ / -
5-th Percentile	7.85E-01	5.48E-02
10-th Percentile	1.62E+00	5.22E-02
15-th Percentile	2.62E+00	9.22E-03
20-th Percentile	3.57E+00	7.30E-02
25-th Percentile	4.62E+00	2.02E-02
30-th Percentile	5.78E+00	5.50E-02
35-th Percentile	7.01E+00	5.72E-02
40-th Percentile	8.26E+00	6.10E-02
45-th Percentile	9.70E+00	1.14E-01
50-th Percentile	1.13E+01	1.18E-01
55-th Percentile	1.31E+01	3.54E-02
60-th Percentile	1.49E+01	8.44E-02
65-th Percentile	1.70E+01	7.18E-02
70-th Percentile	1.96E+01	1.75E-01
75-th Percentile	2.26E+01	2.45E-01
80-th Percentile	2.61E+01	3.43E-01
85-th Percentile	3.05E+01	1.89E-01
90-th Percentile	3.66E+01	1.02E-01
95-th Percentile	4.78E+01	9.55E-01

Table 4 provides the calculated mean, 75%, 90% tissue concentrations for pelagic fish.

Table 4 Predicted Tissue Concentrations (Bq/kg) at Different Percentiles in Pelagic Fish Species			
Contaminant	Concentration (Bg/kg) at mean	Concentration (Bg/kg) at 75%	Concentration (Bg/kg) at 90%
Pb-210	16.4 ± 0.13	22.6 ± 0.25	36.6 ± 0.10
Po-210	8.37 ± 0.15	11.6 ± 0.11	18.9 ± 0.088
Ra-226	7.13 ± 0.15	8.33 ± 0.11	16.3 ± 0.43
Th-230	1.91 ± 0.015	2.41 ± 0.016	3.88 ± 0.020
U-238	153 ± 1.3	182 ± 1.6	378 ± 4.25

(3) Select water Biv for each contaminant for Benthic fish and press F8 or click "Uncertainty analysis." Select the distribution function and enter the distribution parameters as provided in Table 2. Run the RESRAD-BIOTA code. In the uncertainty analysis result screen, select "Dose" for the primary object, "water" for medium, and note the dose at 90th-percentile for each radionuclide.

The screenshot shows the RESRAD-BIOTA software interface. The 'Results' tab is active, displaying a table of statistical measures for the dose. The 'Statistical Object' section on the left is configured with 'Dose' as the Primary Object, 'benthic fish' as the Organism, 'Water' as the Medium, and 'Pb-210' as the Radionuclide. The 'Statistical Property' is set to 'General Statistics'.

Measure	Dose	+ / -
Min	1.91E-08	
Max	7.37E-05	
Mean	1.24E-05	1.44E-07
Standard Deviation	1.22E-05	6.69E-07
50-th Percentile	8.47E-06	5.36E-08
90-th Percentile	2.85E-05	8.12E-08
95-th Percentile	3.62E-05	6.52E-07

Table 5 list 90% water and sediment dose rates from the probabilistic analysis.

Table 5 Water and Sediment dose rates (Gy/d) at 90% for Benthic Fish						
Results	Pb-210	Po-210	Ra-226	Th-230	U-238	Total
90% water dose rate	2.85E-5	1.42E-5	5.46E-5	2.55E-6	2.31E-4	2.73E-4
90% sediment dose rate	4.76E-7	5.08E-10	2.18E-5	2.12E-9	4.32E-5	6.56E-5

The calculated dose for the water medium shows some distribution; while the calculated dose for the sediment medium does not, i.e. the mean, 50%, 90%, and 95% values are the same. Why?

Tables 6 and 7 provide mean and 95% total dose rates for Benthic and Pelagic fish, respectively.

Table 6 Total Dose Rates (Gy/d) for Benthic Fish						
Results	Pb-210	Po-210	Ra-226	Th-230	U-238	Total
Mean	1.295E-5	6.27E-6	4.56E-5	1.26E-6	1.35E-4	2.02E-4
95%	3.67E-5	1.85E-5	1.03E-4	3.33E-6	3.71E-4	4.77E-4

Table 7 Total Dose Rates (Gy/d) for Pelagic Fish						
Percentile	Pb-210	Po-210	Ra-226	Th-230	U-238	Total
Mean	1.25E-5	6.25E-6	3.19E-5	1.25E-6	1.07E-4	1.59E-4
95%	3.61E-5	1.81E-5	8.67E-5	3.24E-6	3.57E-4	4.12E-4

The difference in the dose rates between benthic fish and pelagic fish is due to the difference in the external exposure geometry factors.