Radiological Toolbox 3.0.0 Training

Health Physics Society 50th Midyear Meeting

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Center for Radiation Protection Knowledge

Oak Ridge National Laboratory

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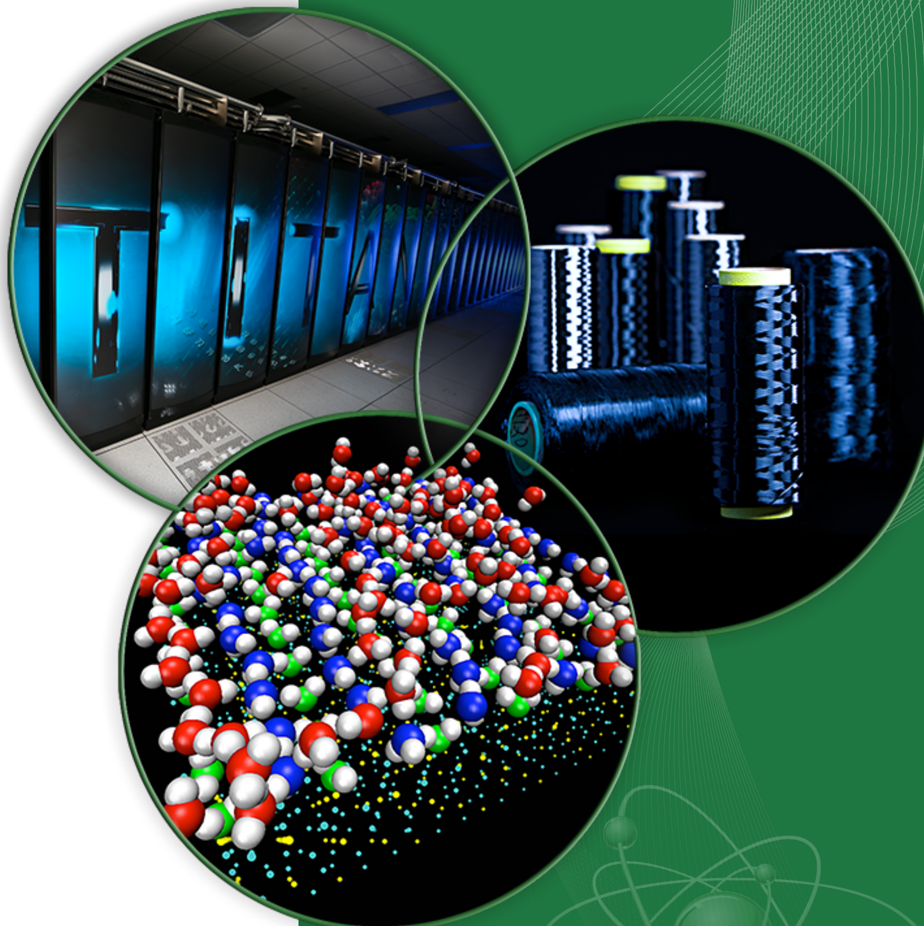
22-25 January, 2017



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Radiological Toolbox 3.0.0 - Outline

1. Meet the Developers
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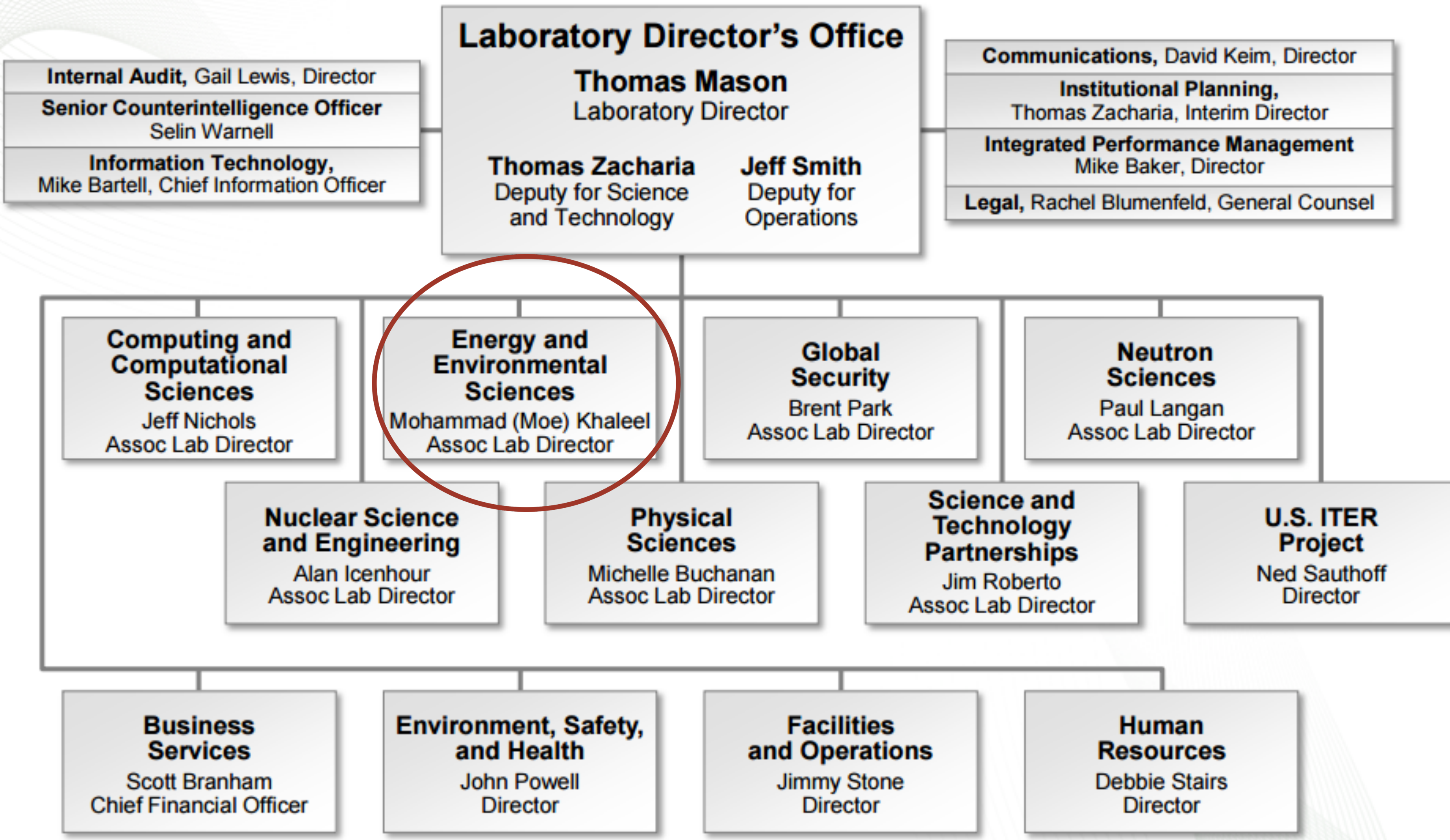
4. Demo (7)

Slide Acknowledgements:
Casper Sun (NRC)
Sami Sherbini (NRC)
Nolan Hertel (Georgia Tech/ORNL-CRPK)

Meet the Developers

Oak Ridge National Laboratory



Environmental Sciences Division
Stan Wullschleger, Acting Director

S&T Program Development Leaders

- **Applied Remediation and Subsurface Science** – Eric Pierce
- **Climate-Ecosystem Dynamics** – Stan Wullschleger
- **Global Energy-Environmental Simulation and Analysis (GEESA)** – Mengdawn Cheng
- **Human Dimensions of Environmental Change** – Ben Preston

Aquatic Ecology – Mark Peterson

Earth Sciences – Eric Pierce

Ecosystem Science* – Paul Hanson

Energy-Water Resource Systems – Brennan Smith

Environmental Data Science and Systems* – Tom Boden

Human Health Risk and Environmental Analysis – Greg Zimmerman

Sustainable Systems and Social Sciences – Amy Wolfe

Terrestrial Systems Modeling* – Peter Thornton

Climate Change Science Institute

- **Data Integration, Dissemination, and Informatics** – Suresh SanthanaVannan, Theme Lead
- **Impact, Adaptation and Vulnerability Science** – Ben Preston, Theme Lead
- **Terrestrial Ecosystem Carbon Cycle Science** – Peter Thornton, Theme Lead

*Co-affiliated with the Climate Change Science Institute

Center for Radiation Protection Knowledge (CRPK)

Center for Radiation Protection Knowledge

http://crpk.ornl.gov/

Top:
Nolan Hertel (JFA, Georgia Institute of Technology)
Keith Eckerman (Emeritus)
Rich Leggett (Senior R&D Scientist)

Middle:
Michael Bellamy (ORNL, R&D Engineer)
Shaheen Dewji (ORNL, R&D Engineer)
Derek Jokisch (JFA, Francis Marion U)

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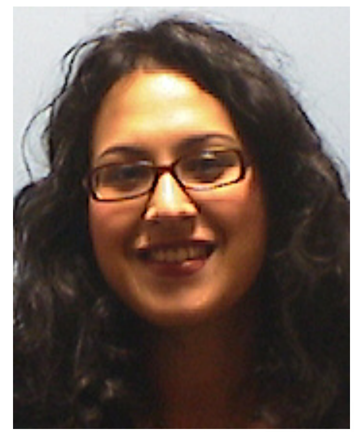
Clay Easterly (Consultant)
Ken Veinot (Consultant)
Pat Scofield (ORNL)
Scott Schwahn (ORNL)

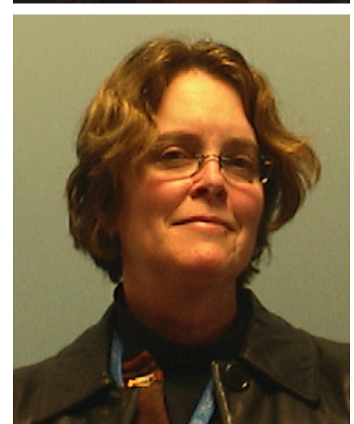
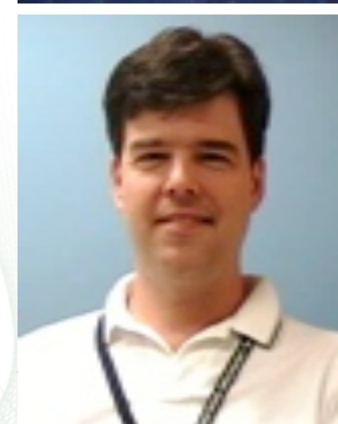
Acknowledgement:
Mauritius Hiller









ORNL Dosimetry Research Program: The Legacy

- Provided the national and international scientific communities with models and data
  - To estimate doses from exposure to radionuclides
  - To establish exposure guidelines for radionuclides.
- These models generally have become international standards.
- A center for archival and computer implementation of biokinetic and dosimetric models.

Center for Radiation Protection Knowledge (http://crpk.ornl.gov/)

- Established at ORNL per MOU 2010
  - DOE, DoD, EPA, NRC, and OSHA
- MOU Renewal in 2015

- Objectives
  - Maintaining/Preserving U.S. expertise and leadership
  - Development/Application of Radiation Dosimetry and Risk Assessment Methodologies/Models
  - Ensure the best scientifically available knowledge in regulatory processes and decision making

Introduction to Radiological Toolbox 3.0.0

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Radiological Toolbox Software

- Developed for the NRC
- K.F. Eckerman, A.L. Sjoreen, “Radiological Toolbox User’s Guide”, ORNL/TM-2013/16, 2013
- Provide electronic access to a vast and varied array of data for radiation protection and shielding
  - Physical, chemical, anatomical, physiological, and mathematical parameters that normally requires access to multiple sources
- Latest release/update is version 3.0.0
  - Available at https://www.usnrc-ramp.com/Radiological-Tools

Radiological Toolbox User's Guide (NUREG/CR-7166, ORNL/TM-2013/16)

- Provides electronic access to the vast and varied data that underlies the field of radiation protection.
  - The initial motivation was to serve the needs of the health physicist away from his office, e.g., NRC inspectors
  - Earlier releases were widely used and accepted around the world by not only practicing health physicists but also those within educational programs
- Version 3.0.0
  - Updated to run on Windows 7 and 8 and on 32- and 64-bit machines
  - Nuclear decay data updated and now includes thermal neutron capture cross sections and cancer risk coefficients

RadToolbox

- **Available** (registration required) on **U.S. Nuclear Regulatory Commission Radiation Protection and Computer Code Maintenance Program (RAMP)**

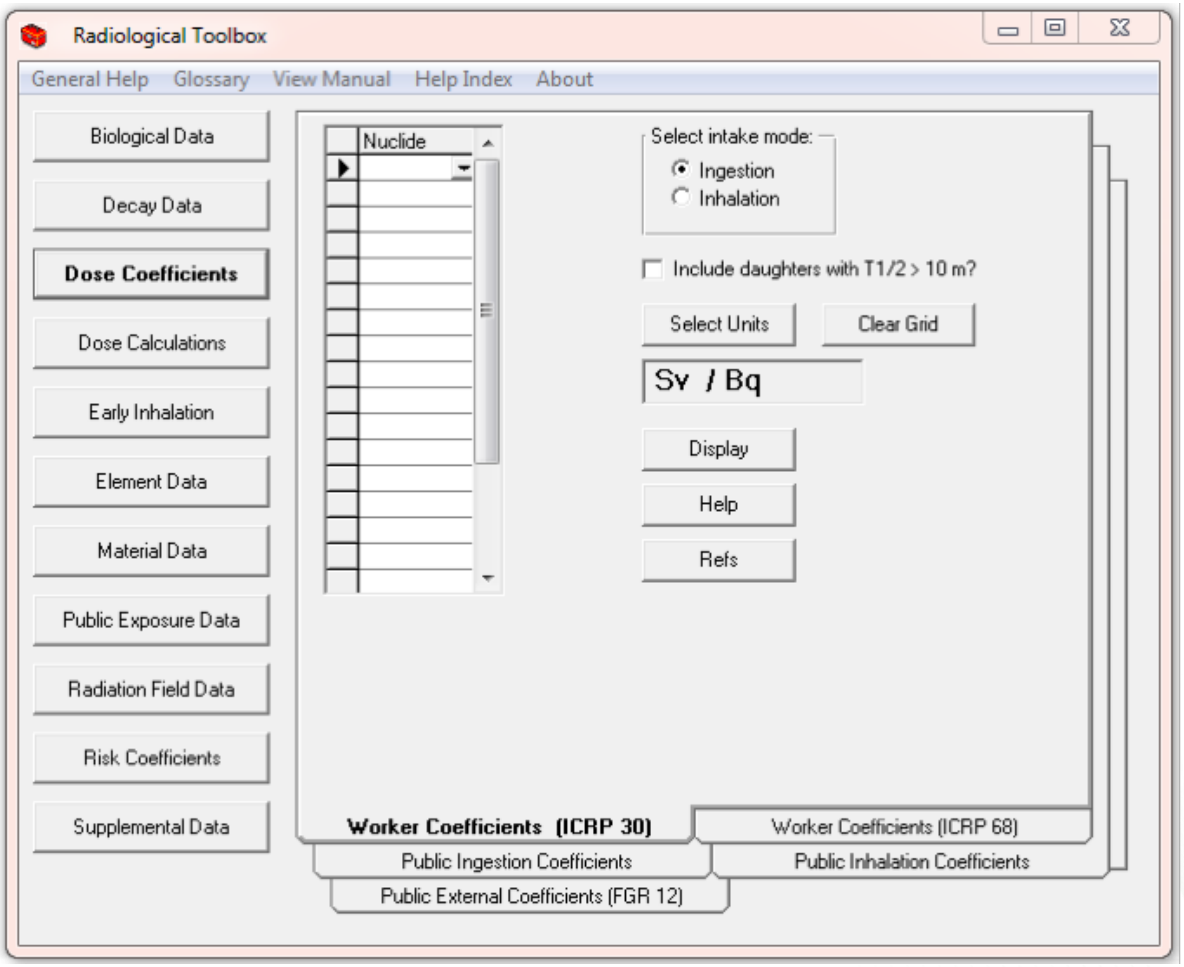
NRC RAMP Website | RAMP Website

- https://www.usnrc-ramp.com

- ORNL inquiry: crpk@ornl.gov

Radiological Toolbox Functionality

RadToolbox Interface



Biological Data

- Biokinetic Models from ICRP 68 and 72
- Bioassay Data - urinary and fecal excretion data and retention data
- Composition of Tissues from Coursey
- Organ Masses from ICRP Publications 23, 72, and 89
- ICRP 89 - extensive set of anatomical and physiological reference values
- Radiation Health Effects
  - deterministic and stochastic
  - summarized from various source

Decay Data

- Detailed radionuclide energy-intensity emission data
- ICRP Publication 107 data
  - NNDC ENSDF - input data into the analysis
  - Updated if necessary to those of NUBAS2003 and AME2003
- Radionuclide activity including the building of radioactive progeny can be calculated
- Option to export Tables of energy-intensity data to EXCEL
- ICRU-defined air kerma-rate constant air-kerma coefficient for the radionuclides
- The decay chain table includes the specific activity, half-life, decay mode, and identification of radioactive progeny with their branching fractions

Dose Coefficients

- External Environmental Dose Coefficients - 826 radionuclides from FGR12
- Committed Dose Coefficients for inhalation and ingestion – 738 radionuclides
  - Workers from ICRP 30 and 68
  - Age-dependent members of the public (six ages at intake) from ICRP 72.
- Display up to 20 nuclides at a time for a chosen route of exposure or intake.
  - Exportable to EXCEL spreadsheet
  - Organ equivalent dose and the effective dose for the selected radionuclide

Dose Calculations

- Simple numerical calculations of dose for a mixture of radionuclides
  - Select appropriate dose coefficients, nuclides and activities
    - ≤ 20 radionuclides
  - External exposure, total dose for the mixture
  - Intake of radionuclides
    - Dose for intake of each chemical form is reported and not the total.
    - User can export the table to EXCEL, delete columns of irrelevant chemical forms, and derive the total dose

Early Inhalation

- Inhalation dose coefficients for deterministic health effects
- Separate low- and high-LET values of absorbed dose are provided and the RBE can then be applied to the absorbed dose components
- These absorbed dose coefficients may be exported to EXCEL

Risk Coefficients

- Federal Guidance Report 13
- Average member of the US public
  - Mortality risk coefficient per unit activity inhaled or ingested for internal exposures or per unit time-integrated activity concentration in air or soil for external exposure
  - Morbidity risk coefficient is a comparable estimate of the average total risk of experiencing a radiogenic cancer, whether or not the cancer is fatal
  - Data presented for 14 cancer sites

Element Data

- Interaction coefficients for alpha, electron, photon, and neutron radiations in elemental absorbers.
  - Not available for every element or for each radiation type
  - Can be plotted
- Geometric progression form of the photon buildup factors from ANSI Standard 6.4
  - 0.015 and 15 MeV at distances ranging from 0.5 to 60 MFP
  - The photon and neutron kerma coefficients were taken from KERMAL, RSICC package DLC-143
- Atomic mass and isotopic abundance data
  - 16th edition of the Chart of the Nuclides
- Can be exported to EXCEL

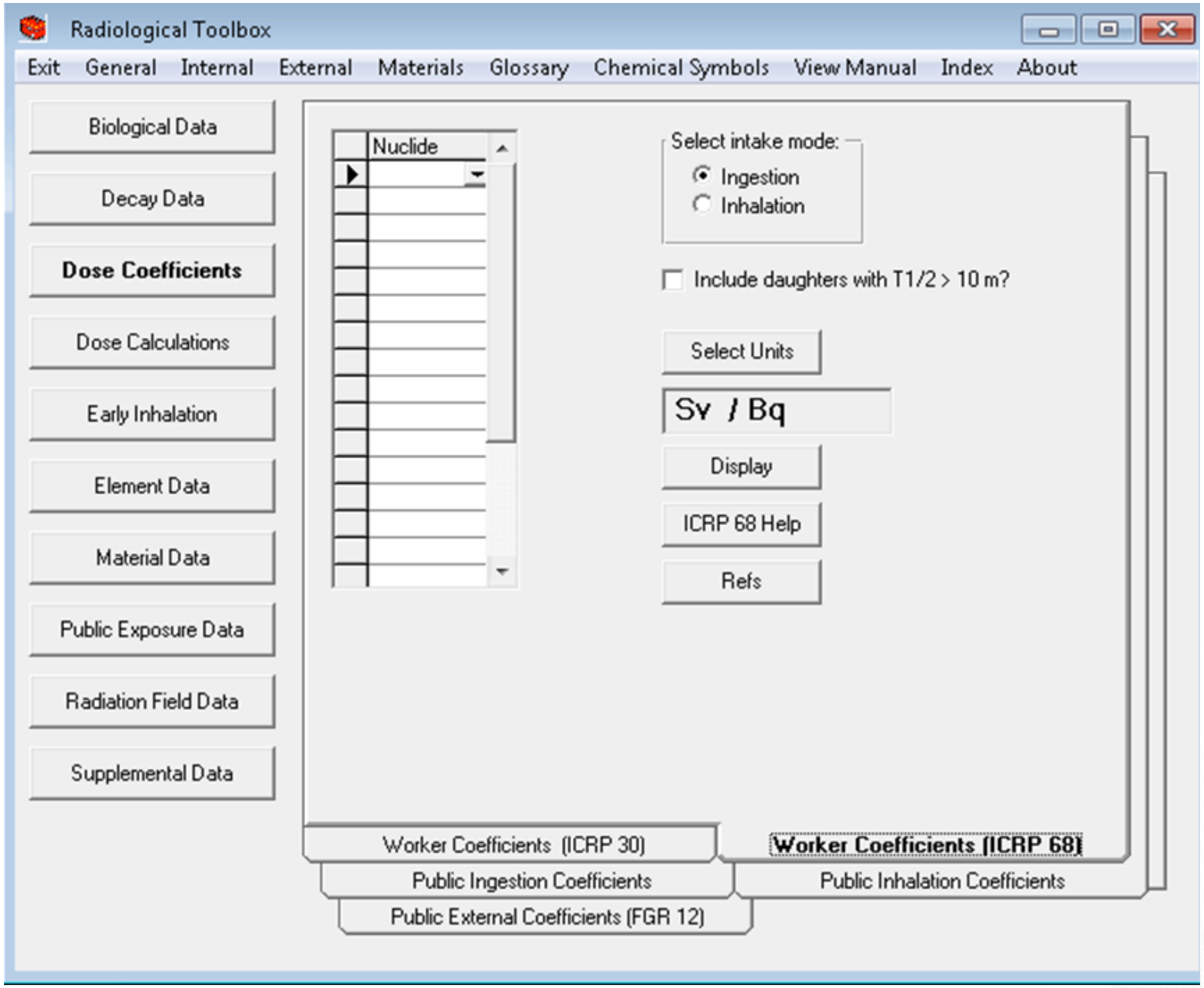
Public Exposure Data

- Natural Background Radiation
- Background Radiation in the Body
- Radionuclides in Materials
- Radionuclides in Devices
- Primordial Radionuclides
- Typical Exposures during Medical Procedures

Other Data

- **Radiation Field Data**
  - ICRP Publication 74/ICRU Report 57 Dose Coefficients
- **Supplemental Data**
  - SI Units
  - Physical Constants
  - Conversion Factors
  - International Nuclear and Radiological Event Scale (INES)
  - Formulas
  - Web Pages
  - DOE Dose Ranges
  - Transport Package Regulations (A1/A2 Table)

RadToolbox – Future Outlook



Time for a smart phone version?

Radiological Toolbox Demo

a.k.a. "Homework"

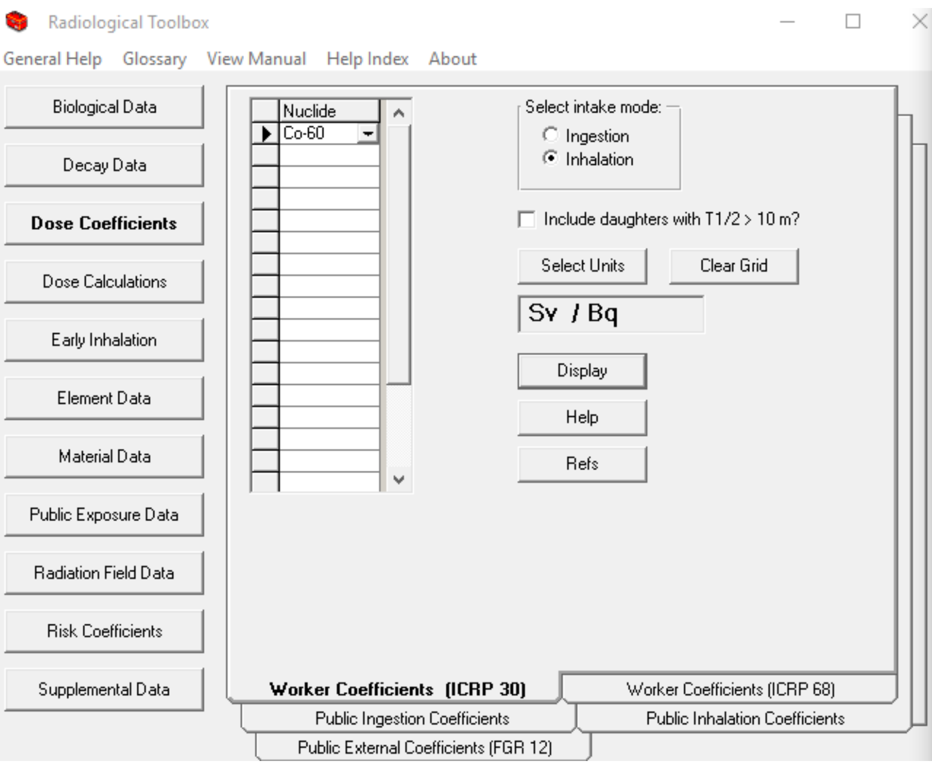
The following questions and solutions were designed by Dr. Sami Sherbini, US-NRC.

Oak Ridge National Laboratory

Question 1

- Calculate committed effective does from repair work in areas where the airborne concentration of ^{60}Co (Type W) is $4x10^3$ Bq m^{-3}. The workers will be remaining in this for 2.5 hours. What are the results from using ICRP-26 and ICRP-60 dose coefficients (Sv/Bq)?

Question 1



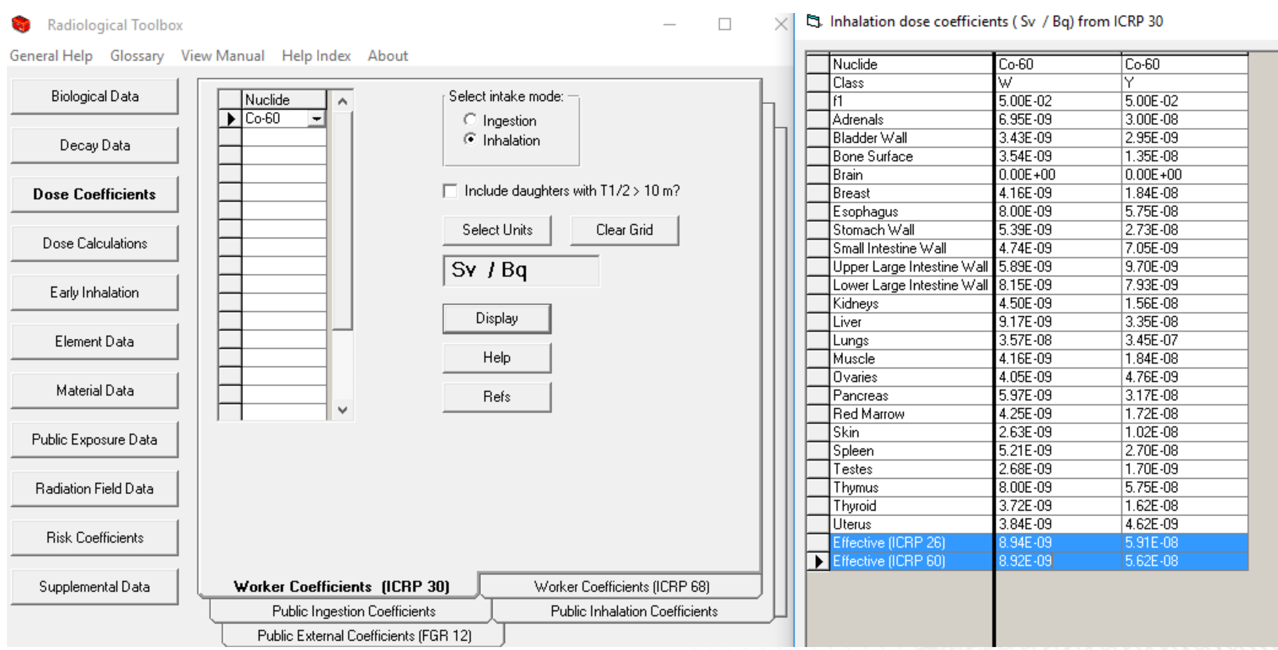
Inhalation dose coefficients (Sv / Bq) from ICRP 30

Nuclide	Co-60	Co-60
Class	W	Y
f1	5.00E-02	5.00E-02
Adrenals	6.95E-09	3.00E-08
Bladder Wall	3.43E-09	2.95E-09
Bone Surface	3.54E-09	1.35E-08
Brain	0.00E+00	0.00E+00
Breast	4.16E-09	1.84E-08
Esophagus	8.00E-09	5.75E-08
Stomach Wall	5.39E-09	2.73E-08
Small Intestine Wall	4.74E-09	7.05E-09
Upper Large Intestine Wall	5.89E-09	9.70E-09
Lower Large Intestine Wall	8.15E-09	7.93E-09
Kidneys	4.50E-09	1.56E-08
Liver	9.17E-09	3.35E-08
Lungs	3.57E-08	3.45E-07
Muscle	4.16E-09	1.84E-08
Ovaries	4.05E-09	4.76E-09
Pancreas	5.97E-09	3.17E-08
Red Marrow	4.25E-09	1.72E-08
Skin	2.63E-09	1.02E-08
Spleen	5.21E-09	2.70E-08
Testes	2.68E-09	1.70E-09
Thymus	8.00E-09	5.75E-08
Thyroid	3.72E-09	1.62E-08
Uterus	3.84E-09	4.62E-09
Effective (ICRP 26)	8.94E-09	5.91E-08
Effective (ICRP 60)	8.92E-09	5.62E-08

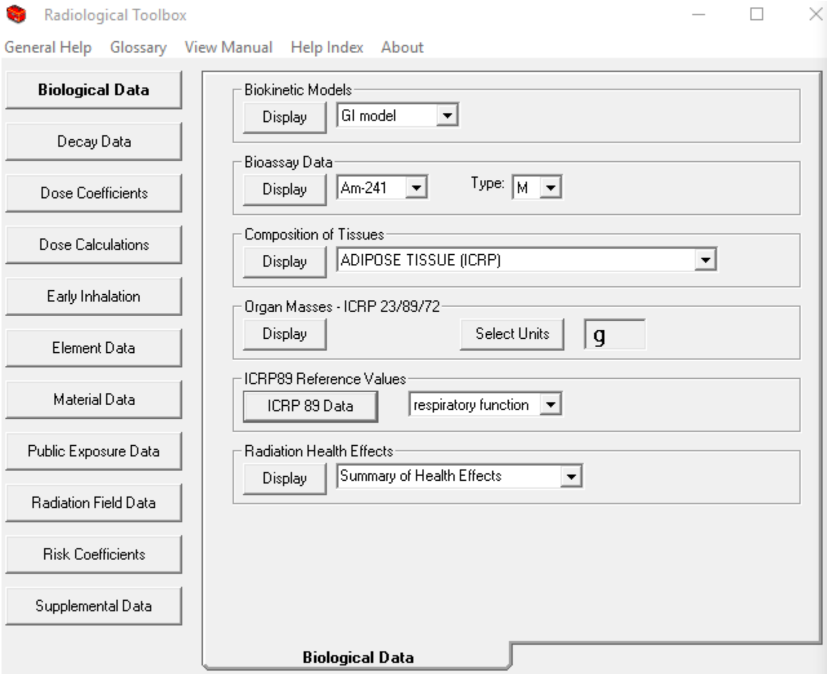
Solving Question 1

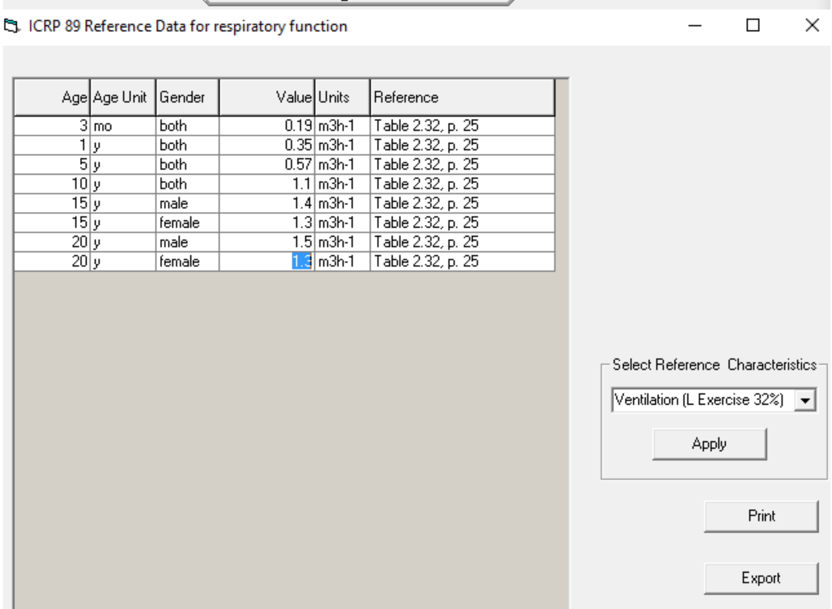
1. Click **Dose Coefficients** tab.
2. Click **Worker Coefficients (ICRP 30)** tab.
3. Click **Units** and choose **Sv/Bq** (this is the default).
4. Enter **Co** and **select Co-60** from the Nuclide drop down menu.
5. Select the **Inhalation** button for intake mode.
6. Click the **Display** tab.
7. Read off the dose coefficients for **Type W**:
   - *8.94E-9 Sv/Bq for ICRP 26*
   - *8.92E-9 Sv/Bq for ICRP 60*

The coefficients show that for ^{60}Co, there is little difference between ICRP26 and ICRP 60.



Solving Question 1





Age	Age Unit	Gender	Value	Units	Reference
3	mo	both	0.19	m3h-1	Table 2.32, p. 25
1	y	both	0.35	m3h-1	Table 2.32, p. 25
5	y	both	0.57	m3h-1	Table 2.32, p. 25
10	y	both	1.1	m3h-1	Table 2.32, p. 25
15	y	male	1.4	m3h-1	Table 2.32, p. 25
15	y	female	1.3	m3h-1	Table 2.32, p. 25
20	y	male	1.5	m3h-1	Table 2.32, p. 25
20	y	female	1.3	m3h-1	Table 2.32, p. 25

8. Click **OK** to close the Dose Coefficient window.
9. Click the **Biological Data** tab.
10. Under the **ICRP-89 Reference Values tab**, select **Respiratory Functions** from the drop-down menu.
11. Click **ICRP89** Data tab.
12. Select **Ventilation (L Exercise)** from the dropdown menu.
13. Read the rate of **1.3 m^3/hr** for a female worker.

Solution 1

Committed effective dose

= 8.92×10^{-9} (Sv/Bq) x 1.3 (m^3/hr) x 2.5 (hr) x 4×10^{5} (Bq/m^3)

= 11.6 mSv (1.16 rem)

Question 2

- The concentration of ^{131}I (Type F) in air in an unrestricted area is 3×10^2 Bq/m^3. Assuming this concentration to remain constant over a period of one year, and using ICRP-60 data
  a) What is the dose coefficient in this case for a 1 year-old child and for an adult?
  b) What is the ratio of these coefficients?
  c) What would be the effective dose to the child and to the adult as a result of the 1 year exposure?
  d) What is the ratio?

Question 2 (a) and (b)

- The concentration of ^{131}I (Type F) in air in an unrestricted area is 3×10^2 Bq/m^3. Assuming this concentration to remain constant over a period of one year, and using ICRP-60 data
  a) What is the dose coefficient in this case for a 1 year-old child and for an adult?
  b) What is the ratio of these coefficients?
  c) What would be the effective dose to the child and to the adult as a result of the 1 year exposure?
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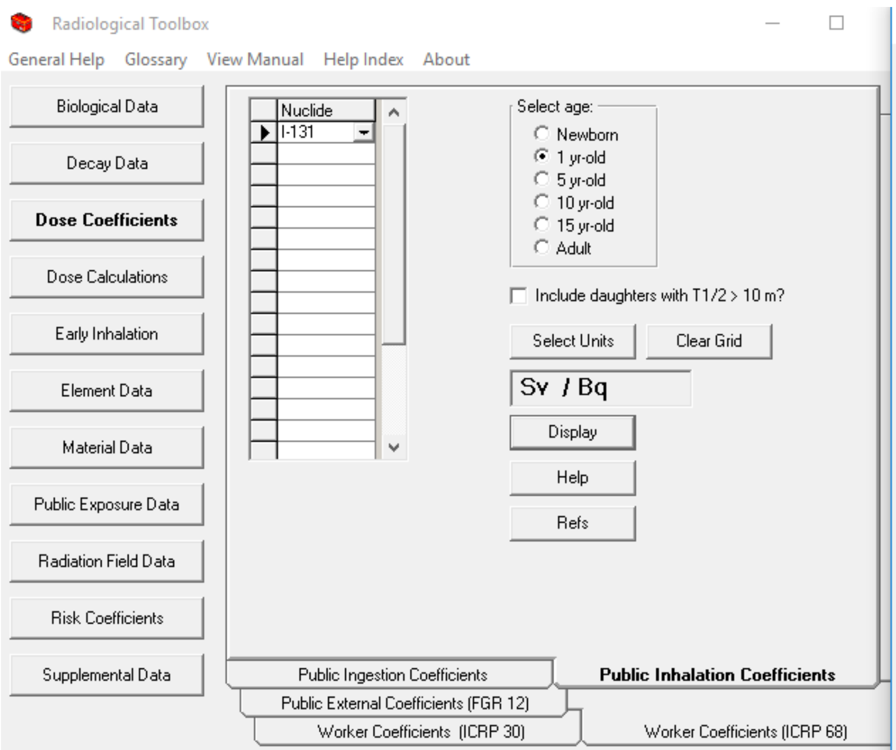
Question 2 (a) and (b)



Inhalation 1 yr-old dose coefficients (Sv / Bq) from ICRP 72

Nuclide	I-131	I-131	I-131	I-131
Half Life	8.04d	8.04d	8.04d	8.04d
Type	V	V	F	M
AMAD	1.00E+00	1.00E+00	1.00E+00	1.00E+00
f1	1 CH3I	1 I2	1.00E+00	1.00E-01
Adrenals	2.30E-10	3.00E-10	1.40E-10	3.60E-10
Urinary Bladder	1.10E-09	1.40E-09	6.00E-10	2.60E-10
Bone Surface	3.10E-10	4.10E-10	1.90E-10	2.20E-10
Brain	2.70E-10	3.50E-10	1.60E-10	5.30E-11
Breast	2.90E-10	3.90E-10	1.80E-10	3.10E-10
Esophagus	1.20E-09	1.60E-09	8.20E-10	4.70E-10
Stomach	2.10E-10	6.30E-10	3.60E-10	7.30E-10
Small Intestine	2.10E-10	2.80E-10	1.30E-10	1.50E-09
Upper Large Intestine	5.30E-10	7.40E-10	3.40E-10	6.70E-09
Lower Large Intestine	1.00E-09	1.50E-09	6.80E-10	1.70E-08
Colon	7.50E-10	1.10E-09	4.90E-10	1.10E-08
Kidneys	2.00E-10	2.60E-10	1.20E-10	1.90E-10
Liver	2.30E-10	3.00E-10	1.40E-10	3.10E-10
Muscle	4.60E-10	6.10E-10	3.00E-10	2.50E-10
Ovaries	2.20E-10	2.80E-10	1.30E-10	5.30E-10
Pancreas	2.30E-10	3.10E-10	1.40E-10	3.20E-10
Red Marrow	2.60E-10	3.40E-10	1.60E-10	1.70E-10
Extratrachial Airways	2.80E-10	8.60E-09	1.50E-08	1.80E-08
Lungs	3.80E-10	2.10E-09	2.90E-10	2.70E-08
Skin	2.40E-10	3.10E-10	1.50E-10	1.10E-10
Spleen	2.20E-10	2.90E-10	1.30E-10	3.00E-10
Testes	1.80E-10	2.30E-10	1.00E-10	9.40E-11
Thymus	1.20E-09	1.60E-09	8.20E-10	4.70E-10
Thyroid	2.50E-06	3.20E-06	1.40E-06	2.10E-07
Uterus	2.20E-10	2.80E-10	1.30E-10	2.90E-10
Remainder	4.20E-10	5.60E-10	2.70E-10	2.40E-10
Effective (ICRP 60)	1.30E-07	1.60E-07	7.20E-08	1.50E-08

Print

Export

OK

Solving Question 2 (a) and (b)

1. Click **Dose Coefficients** tab.
2. Click **Public Inhalation Coefficients**.
3. Select **I-131** from the drop-down nuclide menu,
   - 1 year old button from the age menu.
   - Click **Display**.

Solution 2 (a) and (b)

- a) *Child (1-y) = 7.2E-8 Sv/Bq*

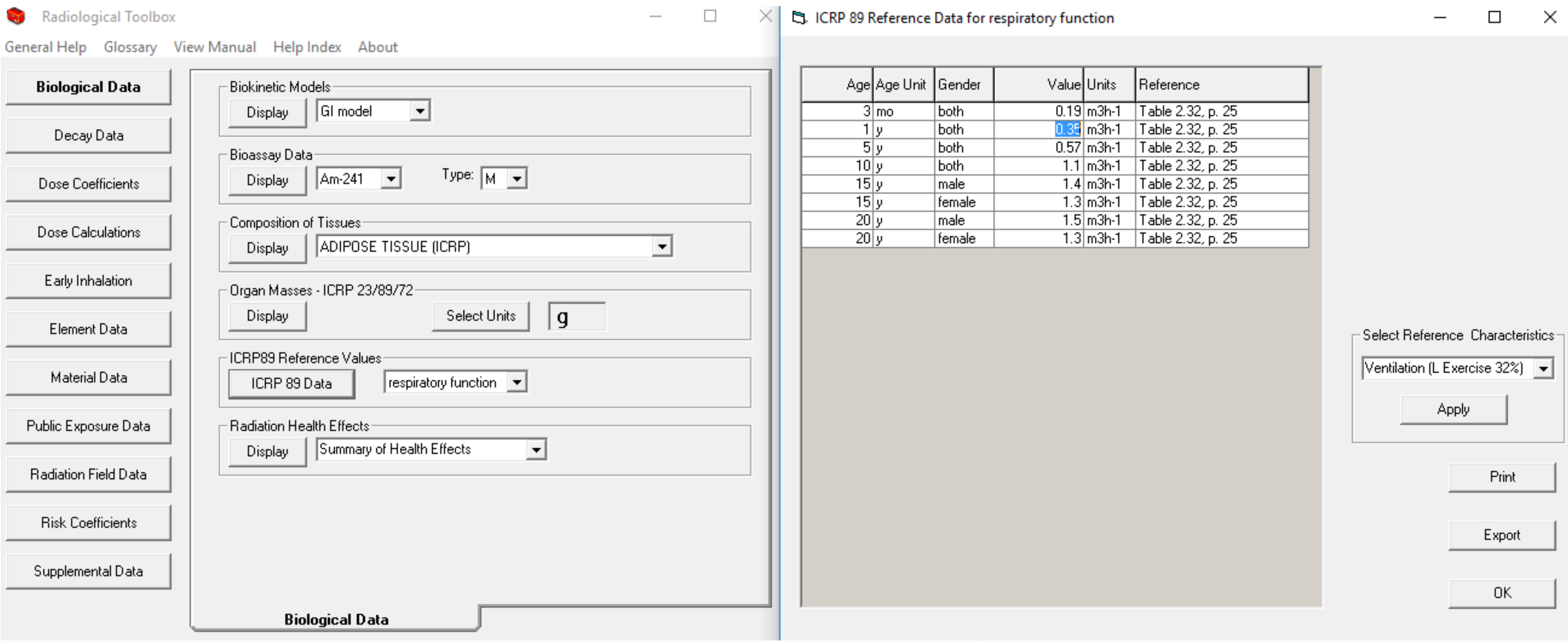
  Adult (>17) = 7.4E-9 Sv/Bq

- b) Ratio of dose coefficients (Child/Adult) = 7.2E-8/7.4E-9 = 9.7

Question 2 (c) and (d)

- The concentration of ^{131}I (Type F) in air in an unrestricted area is 3×10^2 Bq/m^3. Assuming this concentration to remain constant over a period of one year, and using ICRP-60 data
  a) What is the dose coefficient in this case for a 1 year-old child and for an adult?
  b) What is the ratio of these coefficients?
  c) What would be the effective dose to the child and to the adult as a result of the 1 year exposure?
  d) What is the ratio?

Question 2 (c) and (d)



Solving Question 2 (c) and (d)

1. Click Biological Data.
2. ICRP-89 Reference Values.
3. Respiratory Function, Ventilation, Light Exercise:

Child = 0.35 m^3/hr

Adult = 1.5 m^3/hr

Solution 2 (c) and (d)

c) The annual doses are:

- **Child:**

D = 7.2E-8 Sv/Bq x 300 Bq/m^3 x 0.35 m^3/hr x 8760 hr/yr x 1 yr = **0.066 Sv**

- **Adult:**

D = 7.4E-9 Sv/Bq x 300 Bq/m^3 x 1.50 m^3/hr x 8760 hr/yr x 1 yr = **0.029 Sv**

d) Ratio of annual dose (Child/Adult) = 0.066/0.029 = **2.3**

Although the ratio of dose coefficients is 9.7, the ratio of annual doses is 2.3. The reason for this difference in ratios is the difference in breathing rates.

Question 3

- A worker is suspected of having inhaled airborne ^{134}Cs (Type F) and was asked to collect a 24-hour urine sample. The sample was collected 5 days following the suspected intake incident, and showed an activity of 50 Bq/mL of urine. The volume of urine was 950 mL.

a) What is the estimated intake?

b) What is the resulting effective dose?

c) Which organ receive the highest dose from this exposure and does it exceed the 0.5 Sv imposed by US regulations on organ dose?

Question 3 (a)

- A worker is suspected of having inhaled airborne ^{134}Cs (Type F) and was asked to collect a 24-hour urine sample. The sample was collected 5 days following the suspected intake incident, and showed an activity of 50 Bq/mL of urine. The volume of urine was 950 mL.

a) What is the estimated intake?

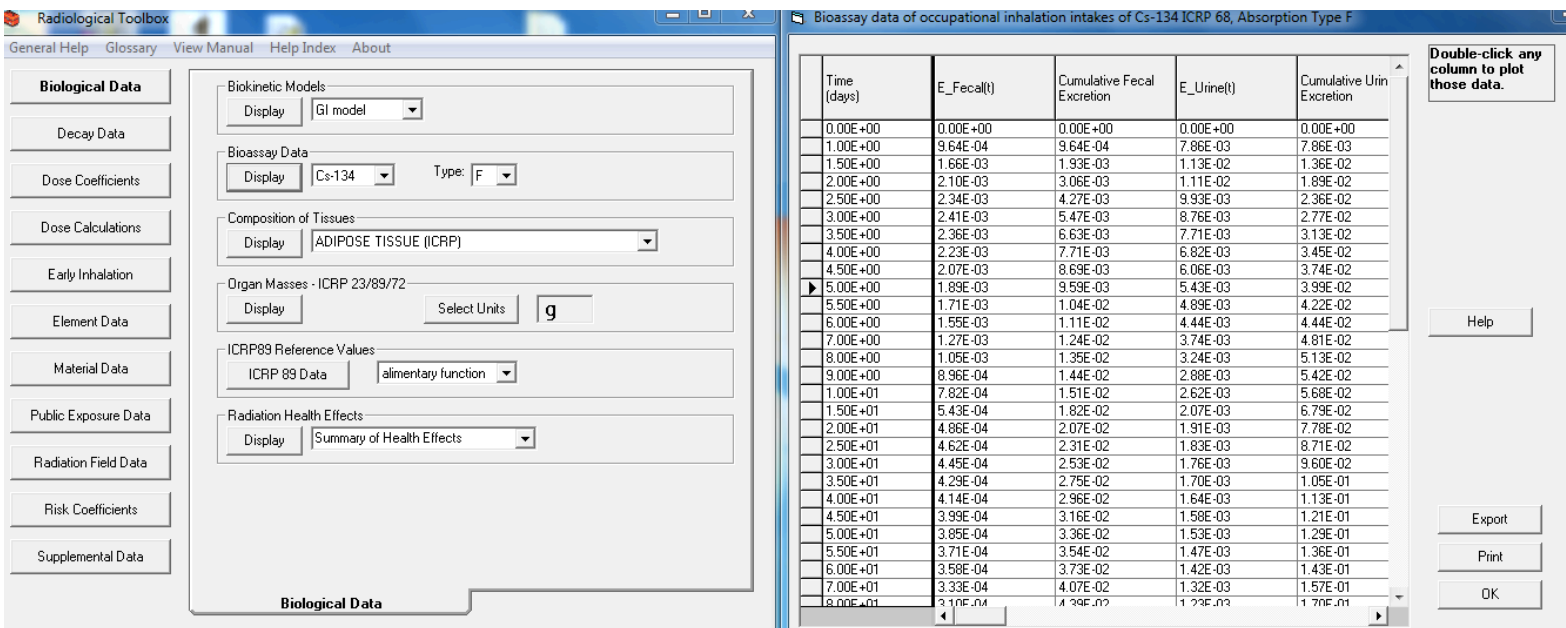
b) What is the resulting effective dose?

c) Which organ receive the highest dose from this exposure and does it exceed the 0.5 Sv imposed by US regulations on organ dose?

Solving 3 (a)

1. Click the **Biological data** tab.
2. In the **Bioassay Data** tab, select **Cs-134** and select **Type F** and click **Display**.
3. In the **E_Urine(t) column** select the row corresponding to **5 days** and read the value 5.43E-3.

This is the urine excretion fraction for that time post-intake.



Time (days)	E_Fecal(t)	Cumulative Fecal Excretion	E_Urine(t)	Cumulative Urin Excretion
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.00E+00	9.64E-04	9.64E-04	7.86E-03	7.86E-03
1.50E+00	1.66E-03	1.93E-03	1.13E-02	1.36E-02
2.00E+00	2.10E-03	3.06E-03	1.11E-02	1.89E-02
2.50E+00	2.34E-03	4.27E-03	9.93E-03	2.36E-02
3.00E+00	2.41E-03	5.47E-03	8.76E-03	2.77E-02
3.50E+00	2.36E-03	6.63E-03	7.71E-03	3.13E-02
4.00E+00	2.23E-03	7.71E-03	6.82E-03	3.45E-02
4.50E+00	2.07E-03	8.69E-03	6.06E-03	3.74E-02
5.00E+00	1.89E-03	9.59E-03	5.43E-03	3.99E-02
5.50E+00	1.71E-03	1.04E-02	4.89E-03	4.22E-02
6.00E+00	1.55E-03	1.11E-02	4.44E-03	4.44E-02
7.00E+00	1.27E-03	1.24E-02	3.74E-03	4.81E-02
8.00E+00	1.05E-03	1.35E-02	3.24E-03	5.13E-02
9.00E+00	8.96E-04	1.44E-02	2.88E-03	5.42E-02
1.00E+01	7.82E-04	1.51E-02	2.62E-03	5.68E-02
1.50E+01	5.43E-04	1.82E-02	2.07E-03	6.79E-02
2.00E+01	4.86E-04	2.07E-02	1.91E-03	7.78E-02
2.50E+01	4.62E-04	2.31E-02	1.83E-03	8.71E-02
3.00E+01	4.45E-04	2.53E-02	1.76E-03	9.60E-02
3.50E+01	4.29E-04	2.75E-02	1.70E-03	1.05E-01
4.00E+01	4.14E-04	2.96E-02	1.64E-03	1.13E-01
4.50E+01	3.99E-04	3.16E-02	1.58E-03	1.21E-01
5.00E+01	3.85E-04	3.36E-02	1.53E-03	1.29E-01
5.50E+01	3.71E-04	3.54E-02	1.47E-03	1.36E-01
6.00E+01	3.58E-04	3.73E-02	1.42E-03	1.43E-01
7.00E+01	3.33E-04	4.07E-02	1.32E-03	1.57E-01
8.00E+01	3.10E-04	4.39E-02	1.23E-03	1.70E-01

Solution 3 (a)

Intake =

(50 (Bq/mL) x 900 (mL))/5.43E-3 = **8.29E6 Bq**

Question 3 (b)

- A worker is suspected of having inhaled airborne ^{134}Cs (Type F) and was asked to collect a 24-hour urine sample. The sample was collected 5 days following the suspected intake incident, and showed an activity of 50 Bq/mL of urine. The volume of urine was 950 mL.

a) What is the estimated intake?

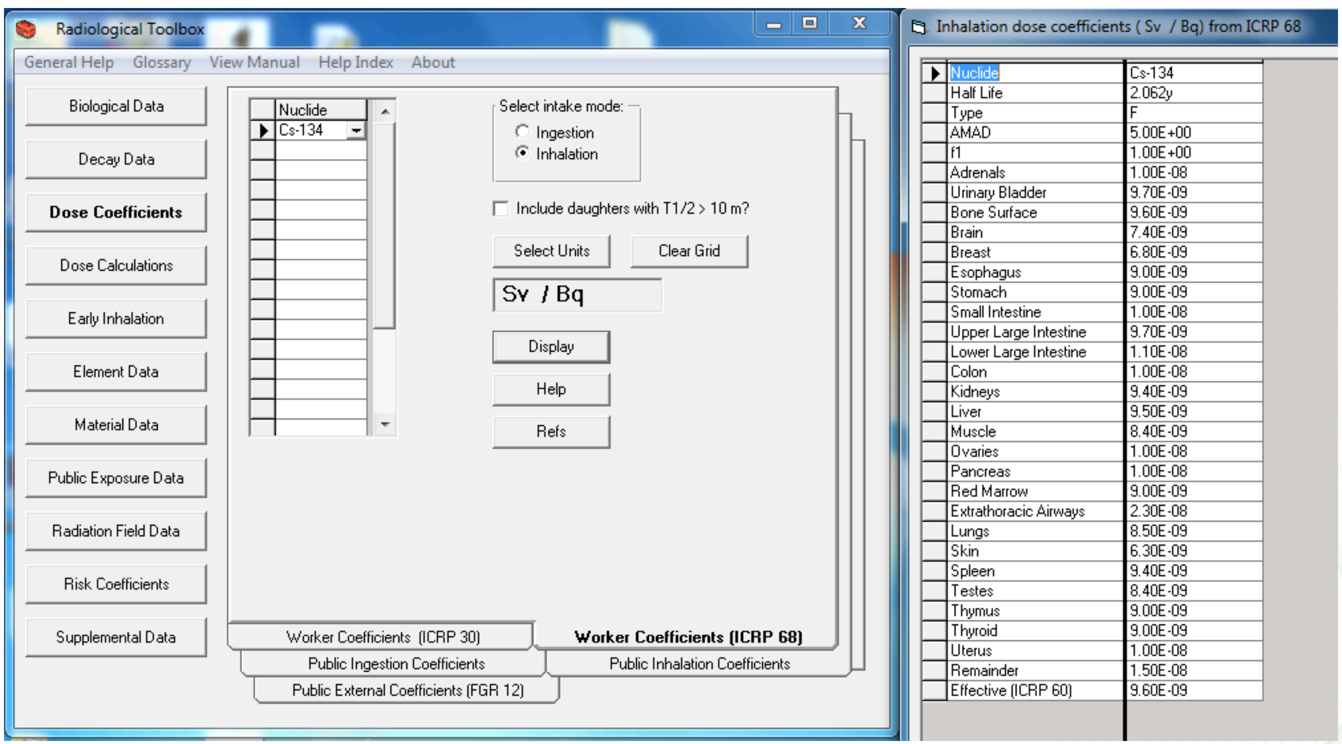
b) What is the resulting effective dose?

c) Which organ receive the highest dose from this exposure and does it exceed the 0.5 Sv imposed by US regulations on organ dose?

Solving 3 (b)

1. Click **Dose Coefficient** tab.
2. ICRP-68 worker data
3. Select Inhalation of Cs-134,

b) Effective dose coefficient is 9.6E-9 Sv/Bq.



Solution 3 (b)

Committed effective dose

= 9.6E-9 (Sv/Bq) x 8.29E6 (Bq)

= 0.08 Sv

Question 3 (c)

- A worker is suspected of having inhaled airborne ^{134}Cs (Type F) and was asked to collect a 24-hour urine sample. The sample was collected 5 days following the suspected intake incident, and showed an activity of 50 Bq/mL of urine. The volume of urine was 950 mL.

a) What is the estimated intake?

b) What is the resulting effective dose?

c) Which organ receive the highest dose from this exposure and does it exceed the 0.5 Sv imposed by US regulations on organ dose?

Solution 3 (c)

- Using the limit of 0.5 Sv for any organ, and an intake of 8.29E6 Bq, any organ with a dose coefficient greater than 0.5/8.29E6 = 6.0E-8 Sv/Bq will exceed the limit.
- A review of the dose coefficient table shows that none of the organs exceeds that dose.

Inhalation dose coefficients (Sv / Bq) from ICRP 68

Nuclide	Cs-134
Half Life	2.062y
Type	F
AMAD	5.00E+00
f1	1.00E+00
Adrenals	1.00E-08
Urinary Bladder	9.70E-09
Bone Surface	9.60E-09
Brain	7.40E-09
Breast	6.80E-09
Esophagus	9.00E-09
Stomach	9.00E-09
Small Intestine	1.00E-08
Upper Large Intestine	9.70E-09
Lower Large Intestine	1.10E-08
Colon	1.00E-08
Kidneys	9.40E-09
Liver	9.50E-09
Muscle	8.40E-09
Ovaries	1.00E-08
Pancreas	1.00E-08
Red Marrow	9.00E-09
Extrathoracic Airways	2.30E-08
Lungs	8.50E-09
Skin	6.30E-09
Spleen	9.40E-09
Testes	8.40E-09
Thymus	9.00E-09
Thyroid	9.00E-09
Uterus	1.00E-08
Remainder	1.50E-08
Effective (ICRP 60)	9.60E-09

Question 4

a) What is the mean energy and the end-point energy of the beta spectrum emitted by ^{32}P?

b) What is the CSDA range, gm/cm^2 of electrons with this end-point energy in leaded glass? What fraction of the beta energy is going to be converted to bremsstrahlung radiation?

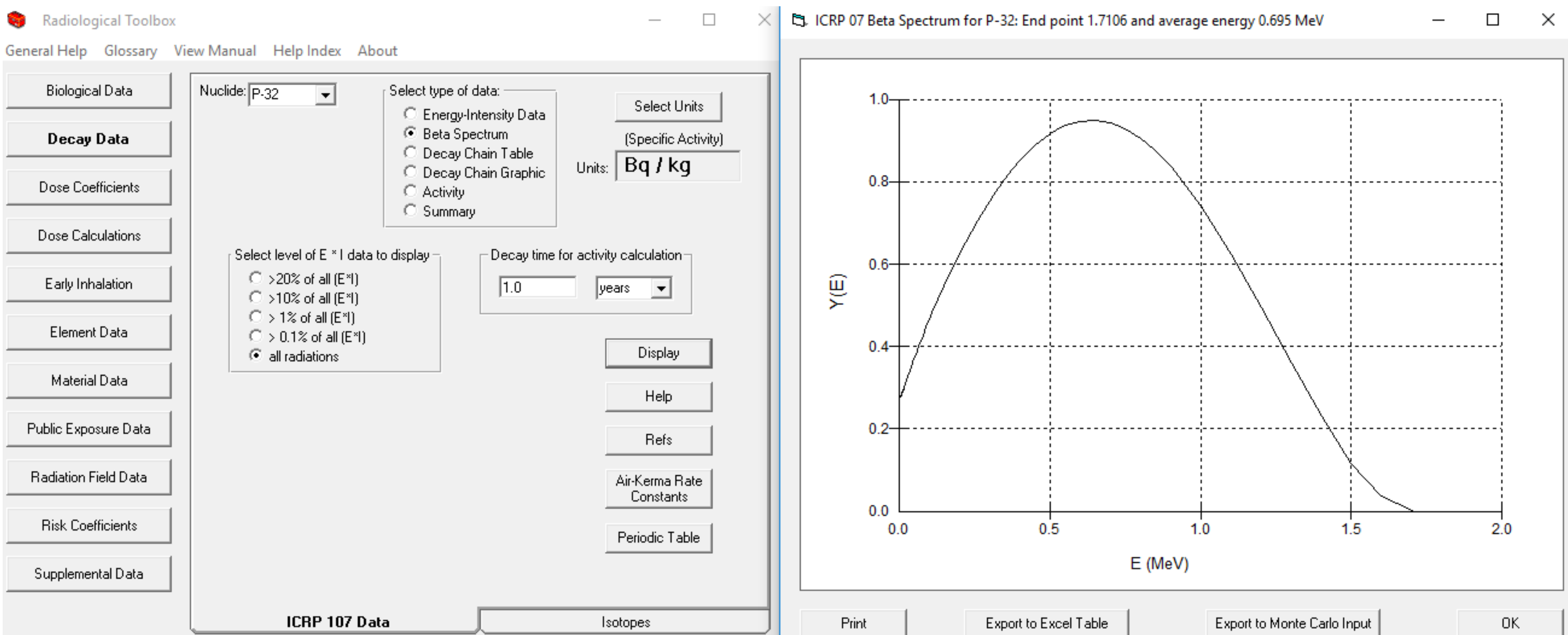
Question 4 (a)

a) What is the mean energy and the end-point energy of the beta spectrum emitted by ^{32}P?

b) What is the CSDA range, gm/cm^2 of electrons with this end-point energy in leaded glass? What fraction of the beta energy is going to be converted to bremsstrahlung radiation?

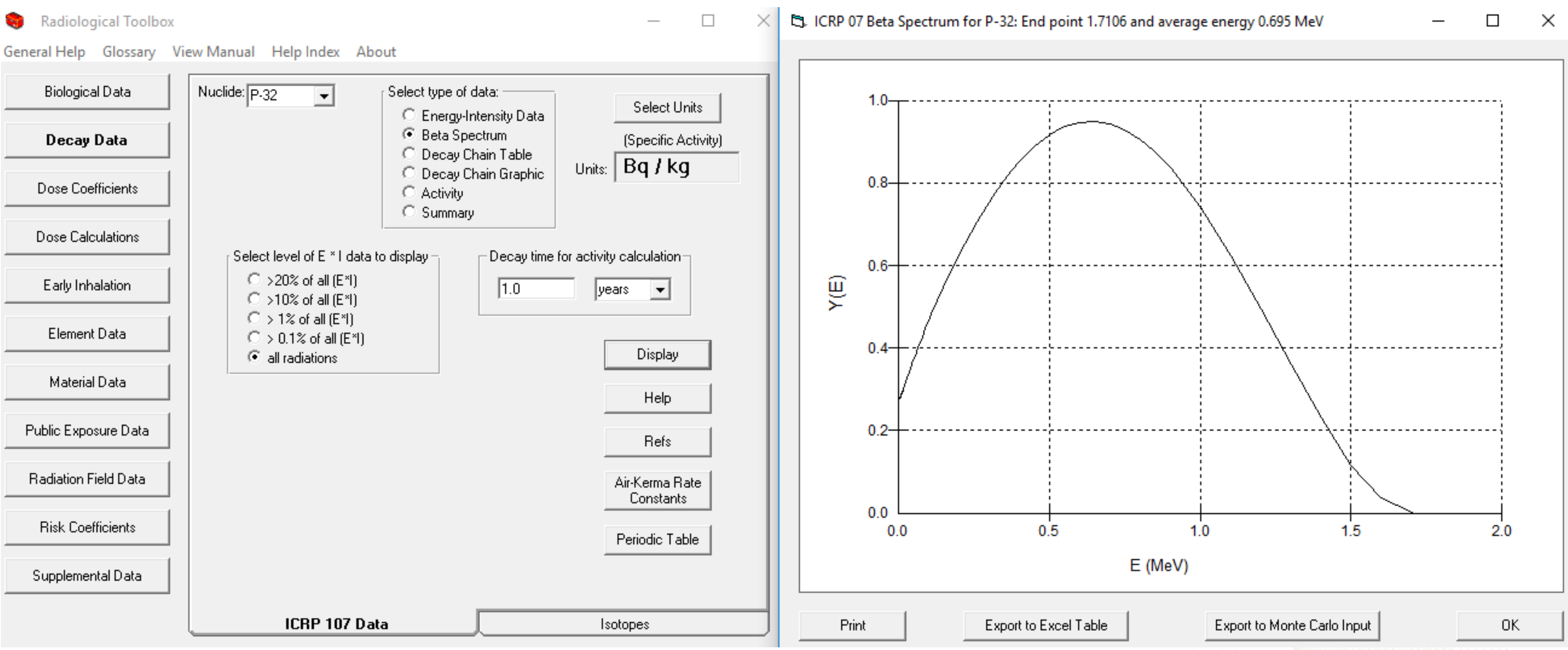
Solving 4 (a)

1. Click the **Decay Data** tab.
2. Select the **ICRP-107 Data** tab.
3. Select **P-32** from the Nuclide drop-down menu.
4. Select the **Beta Spectrum** button.
5. Click **Display**. The average and end-point energies are shown at the top of the beta spectrum.



Solution 4 (a)

- End-point = 1.7106 MeV
- Average = 0.695 MeV



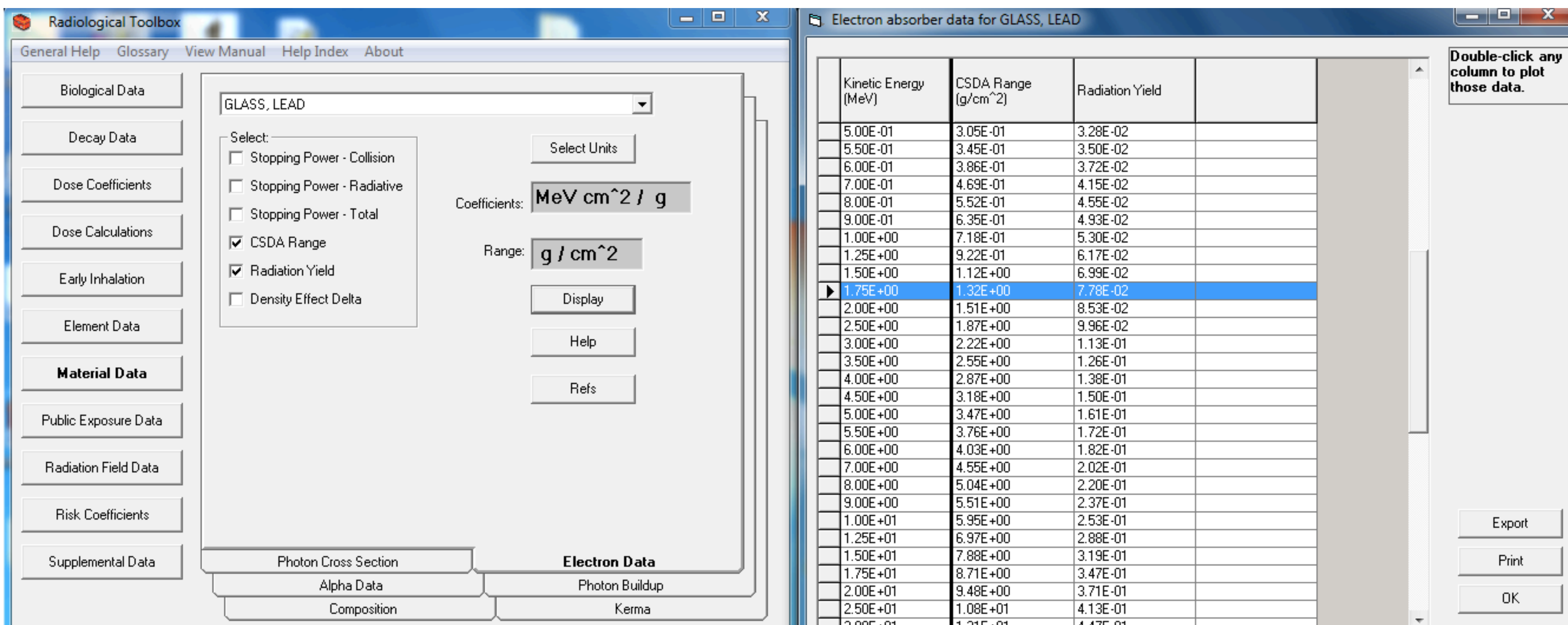
Question 4 (b)

a) What is the mean energy and the end-point energy of the beta spectrum emitted by ^{32}P?

b) What is the CSDA range, gm/cm^2 of electrons with this end-point energy in leaded glass? What fraction of the beta energy is going to be converted to bremsstrahlung radiation?

Solving 4 (b)

1. Click the **Material Data** tab.
2. Select the **Electron Data** tab.
3. Select **Glass**, **Lead** from the material drop-down menu.
4. Check the **CSDA Range** and the **Yield** buttons.
5. Click **Display**.
6. Read the CSDA and Yield



Solution 4 (b)

The values at 1.75 MeV may be considered close enough, or interpolation may be used between values at 1.50 and 1.75 MeV.

- CSDA: 1.32 g/cm^2
- Yield: 7.78E-2 (7.78%)

Question 5

a) For an adult worker, what fraction of a 1000 Bq inhalation of a Type S, 5 μm AMAD ^{58}Co aerosol is exhaled immediately after inhalation of that aerosol?

b) What fraction of the activity is deposited in the thoracic and in the extra-thoracic regions?

c) What activity in a 24-hour urine sample would you expect to find if the sample is taken 10 days after the intake?

Question 5 (a) and (b)

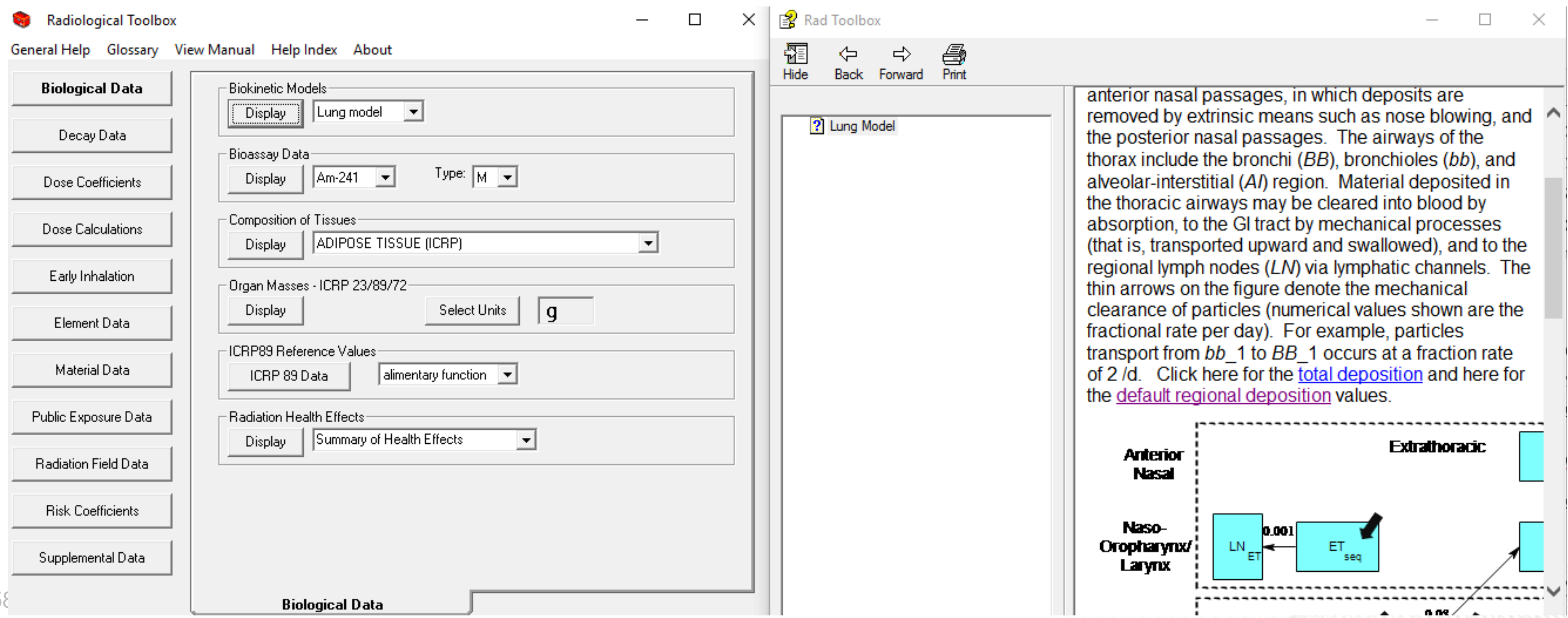
a) For an adult worker, what fraction of a 1000 Bq inhalation of a Type S, 5 μm AMAD ^{58}Co aerosol is exhaled immediately after inhalation of that aerosol?

b) What fraction of the activity is deposited in the thoracic and in the extra-thoracic regions?

c) What activity in a 24-hour urine sample would you expect to find if the sample is taken 10 days after the intake?

Solving 5 (a) and (b)

- Click the **Biological Data tab**.
- In **Biokinetic Models**, select **Lung Model** and click **Display**.
- Click the **Default Regional Deposition** highlighted text.
- In the table under **AMAD = 5 microns**, add the fractions deposited in the **ET, BB, and BB and AI regions**.



Solving 5 (a) and (b)

- Click the **Biological Data tab**.
- In **Biokinetic Models**, select **Lung Model** and click **Display**.
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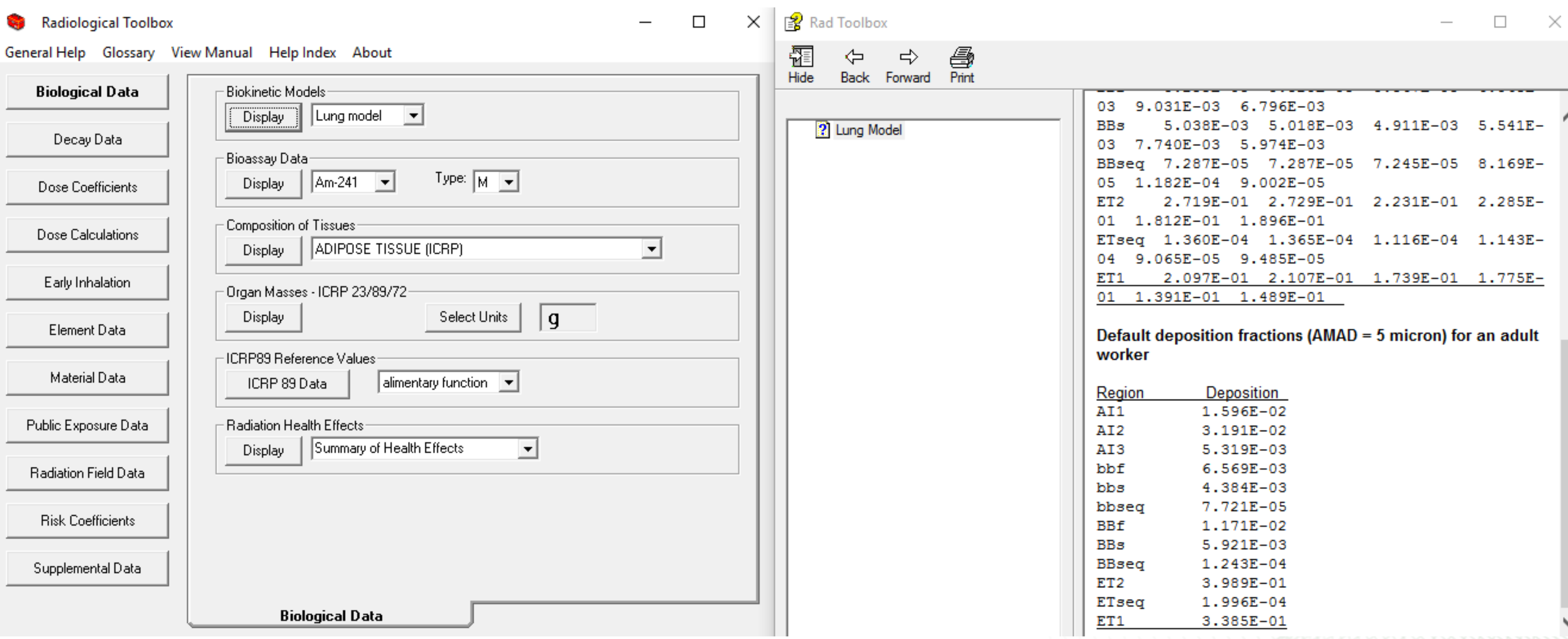


Solution 5 (a) and (b)

Deposition in ET = 73.76%

BB = 1.78%

bb = 1.09%

AI = 5.32%

Total Deposition = 81.93%

Amount exhaled = 18.1%

Note: ET1 corresponds to the nasal lings in a nose breather. According to the table, about 34% of the 5 micron aerosol is deposited there. Therefore, if a nose swab is taken, a qualitative idea of the possible intake is probably more than about three times the activity on the swab, depending on how much of the nasal deposit is collected on the swab.

Question 5 (c)

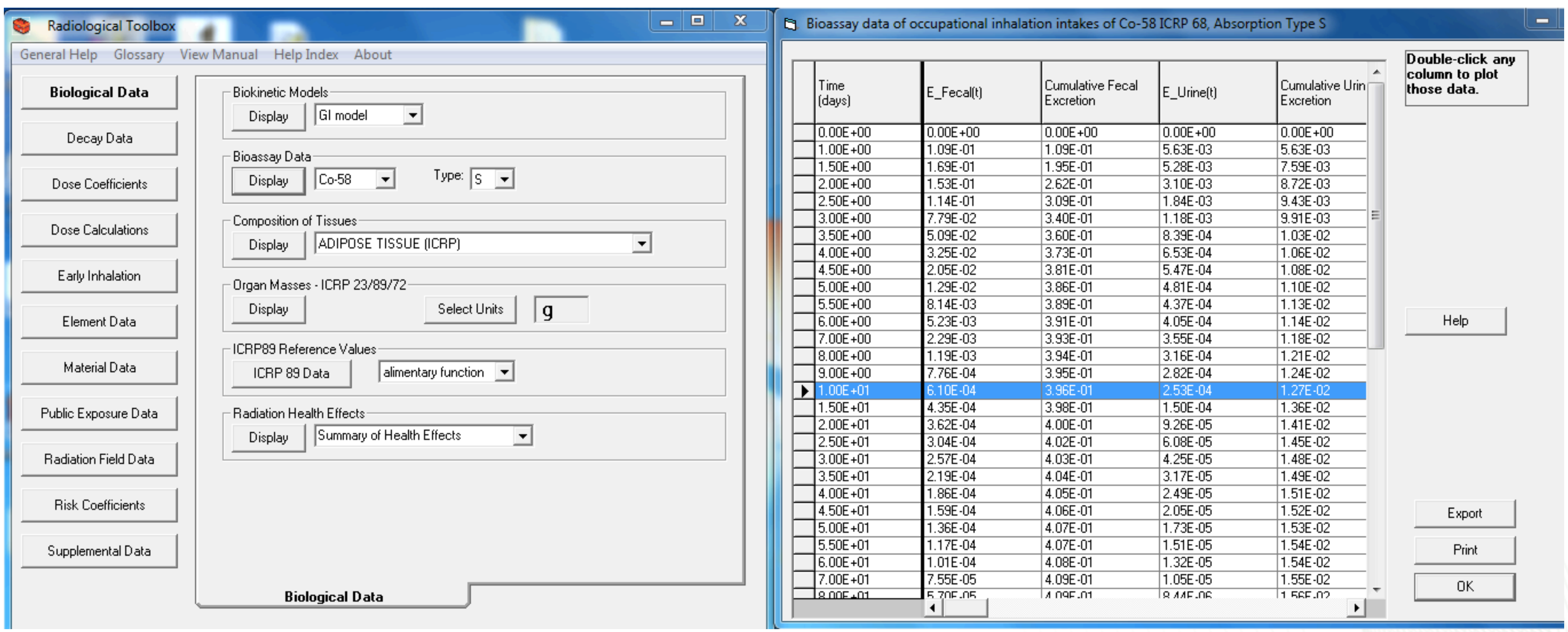
a) For an adult worker, what fraction of a 1000 Bq inhalation of a Type S, 5 μm AMAD ^{58}Co aerosol is exhaled immediately after inhalation of that aerosol?

b) What fraction of the activity is deposited in the thoracic and in the extra-thoracic regions?

c) What activity in a 24-hour urine sample would you expect to find if the sample is taken 10 days after the intake?

Solving 5 (c)

1. Click Biological Data
2. Select 58Co, Type S in Bioassay Data, and click display.
3. Under E_Urine, in the row corresponding to 10 days, read 2.53E-4 (Bq/Bq-Intake).



Solution 5 (c)

Activity expected in the 24-hour urine sample is:

Urine activity = 1,000 x 2.53E-4 = 0.253 Bq.

This type of calculation is helpful to determine whether the available urine counting protocol and equipment are capable of measuring this level of activity in the sample, given the methods used on site for routine bioassay intervals amounts of urine collected per sample, for example, a 24-hour sample or a "grab" sample. The grab sample is taken from one voiding and therefore usually contains much less activity than a 24-hour sample, and so required greater measurement capabilities to detect a given minimum intake level.

Question 6

a) What is the air kerma rate free-in-air at a location where the 0.08 MeV photon fluence is 2.24E8 photons/cm^2?

b) What is the effective dose rate resulting from exposure to this beam when incident on the body in the AP direction at that location? What is the dose rate if the direction was PA with the same fluence rate? What is the rate if the radiation is isotropic?

Question 6 (a)

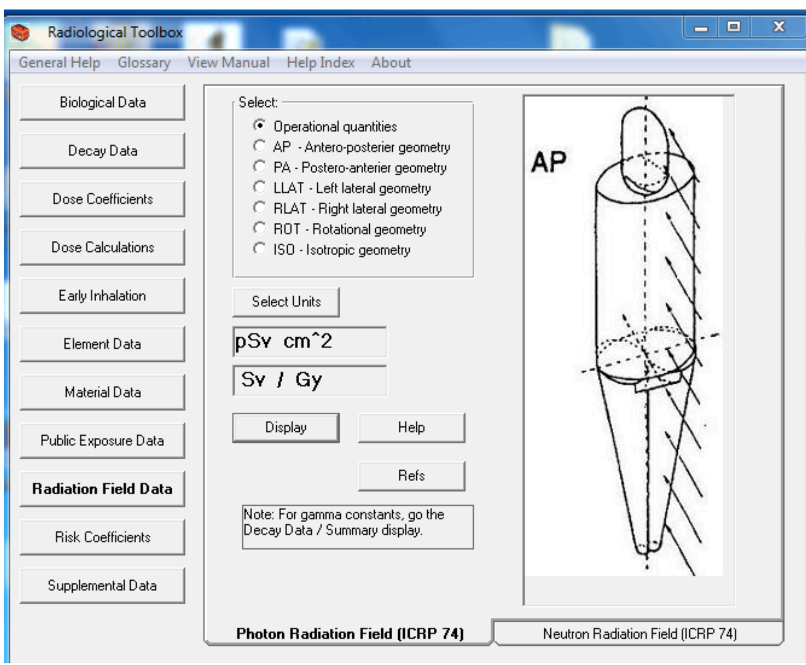
a) What is the air kerma rate free-in-air at a location where the 0.8 MeV photon fluence is 2.24E8 photons/cm^2?

b) What is the effective dose rate resulting from exposure to this beam when incident on the body in the AP direction at that location? What is the dose rate if the direction was PA with the same fluence rate? What is the rate if the radiation is isotropic?

Solving 6 (a)

1. Click the **Radiation Field Data** tab.
2. Select the **Operational quantities** button.
3. Click **Display**.

The air kerma column at 0.8 MeV shows a kerma rate of 3.69 pGy-cm². This unit may be interpreted as ***pGy per photon/cm²*** or the ***kerma per unit fluence***.



PhotonField data for Operational quantities

Photon Energy (MeV)	Direction Dose Equivalent Conv Coeff (Sv / Gy)	AirKerma Free-in-Air per Fluence (pGy cm^2)	Hp(10) per Air Kerma (Sv / Gy)	Hp(0.07) per Ai Kerma (Sv / Gy)
1.00E-02	9.50E-01	7.60E+00	9.00E-03	9.47E-01
1.50E-02	9.90E-01	3.21E+00	2.64E-01	9.81E-01
2.00E-02	1.05E+00	3.21E+00	6.11E-01	1.05E+00
3.00E-02	1.22E+00	7.39E-01	1.11E+00	1.23E+00
4.00E-02	1.41E+00	4.38E-01	1.49E+00	1.44E+00
5.00E-02	1.53E+00	3.28E-01	1.77E+00	1.63E+00
6.00E-02	1.59E+00	2.92E-01	1.89E+00	1.72E+00
8.00E-02	1.61E+00	3.08E-01	1.90E+00	1.73E+00
1.00E-01	1.55E+00	3.72E-01	1.81E+00	1.67E+00
1.50E-01	1.42E+00	6.00E-01	1.61E+00	1.52E+00
2.00E-01	1.34E+00	8.56E-01	1.49E+00	1.43E+00
3.00E-01	1.31E+00	1.38E+00	1.37E+00	1.34E+00
4.00E-01	1.26E+00	1.89E+00	1.30E+00	1.28E+00
5.00E-01	1.23E+00	2.38E+00	1.26E+00	1.24E+00
6.00E-01	1.21E+00	2.84E+00	1.23E+00	1.22E+00
8.00E-01	1.19E+00	3.69E+00	1.19E+00	1.19E+00
1.00E+00	1.17E+00	4.47E+00	1.17E+00	1.17E+00
1.50E+00	1.15E+00	6.12E+00	1.14E+00	
2.00E+00	1.14E+00	7.51E+00	1.13E+00	
3.00E+00	1.13E+00	9.89E+00	1.12E+00	
4.00E+00	1.12E+00	1.20E+01	1.11E+00	
5.00E+00	1.11E+00	1.39E+01	1.11E+00	
6.00E+00	1.11E+00	1.58E+01	1.11E+00	
8.00E+00	1.11E+00	1.95E+01	1.11E+00	
1.00E+01	1.10E+00	2.32E+01	1.11E+00	

Solution 6 (a)

The kerma rate corresponding to the 2.24E8 fluence is:

K = 2.24E8 x 3.69

= 8.27E8 pGy

= **0.827 mGy**

Question 6 (b)

a) What is the air kerma rate free-in-air at a location where the 0.8 MeV photon fluence is 2.24E8 photons/cm^2?

b) What is the effective dose rate resulting from exposure to this beam when incident on the body in the AP direction at that location? What is the dose rate if the direction was PA with the same fluence rate? What is the rate if the radiation is isotropic?

Solving 6 (b)

1. Click on the **AP button** on the same tab and read the effective dose coefficient (Sv/Gy) for AP, PA, and ISO incidence at 0.8 MeV are:

- AP = 1.433
- PA =1.019
- ISO = 0.749

Solution 6 (b)

The dose rates are:

E(AP) = 0.827 (mGy/s) x 1.433 (Sv/Gy) * 0.001 (Gy/mGy)
= 0.0012 mSv/s
= 4.27 Sv/hr

E(PA) = 0.827 (mGy/s) x 1.019 (Sv/Gy) x 0.001 (Gy/mGy)
= 0.00084 mSv/s
= 3.03 Sv/hr

E(ISO) = 0.827(mGy/s) x 0.749 (Sv/Gy) x 0.001 (Gy/mGy)
= 0.00062 mSv/s
= 2.23 Sv/hr

Question 7

- What is the risk resulting from continuous submersion for a year in a cloud of ^{133}Xe with a constant concentration of 1E3 Bq/m^3?

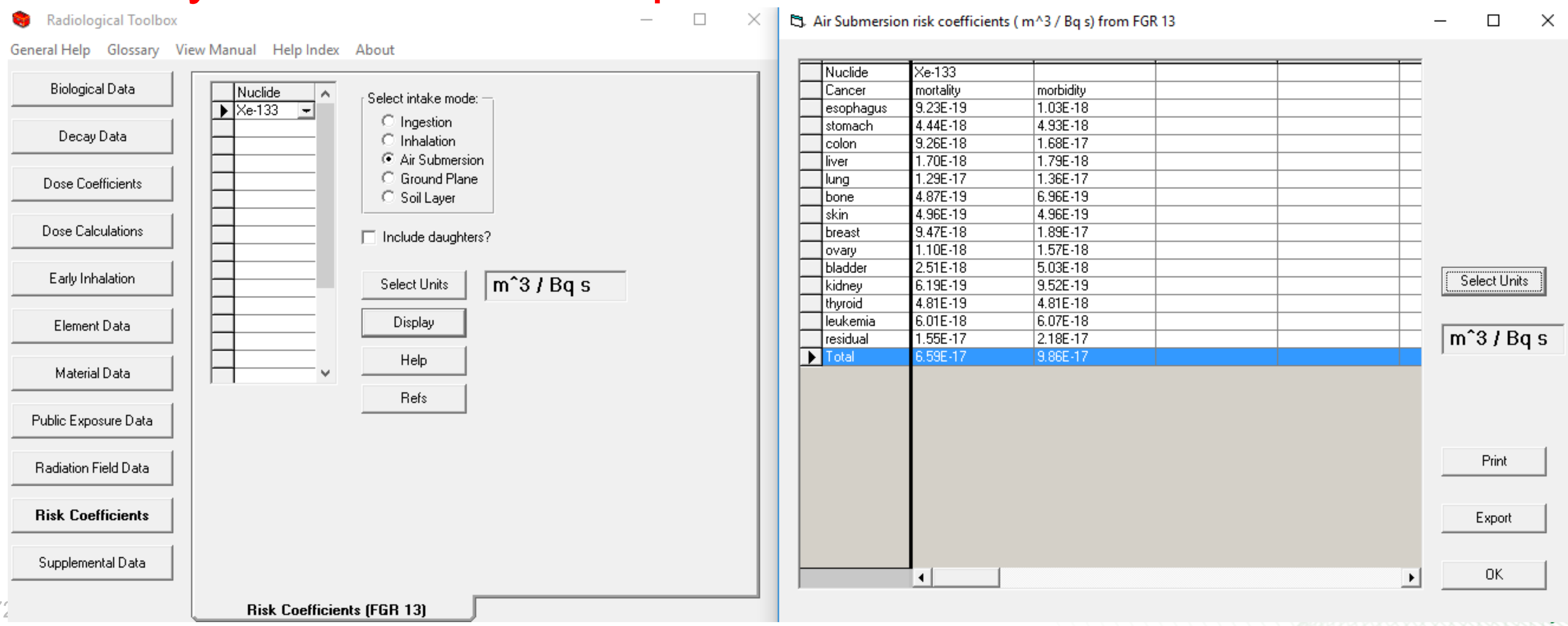
Solving 7

1. Click the **Risk Coefficients** button.
2. Select **Xe-133** from the **Nuclides** list.
3. Click **Display**.

The risk coefficients are:

Mortality = 6.59E-17 m^3/Bq-s

Morbidity = 9.86E-17 m^3/Bq-s



Solution 7

The integrated duration of exposure is:

X = 1E3 (Bq/m^3) x 8760 (h/y) x 3600 (s/h)
= 3.154E10 (Bq-s/m^3)

Mortality risk
= 6.59E-17 (m^3/Bq-s) x 3.154E10 (Bq-s/m^3)
= 2E-6

Morbidity risk
= 9.86E-17 (m^3/Bq-s) x 3.154E10 (Bq-s/m^3)
= 3E-6

Questions?

Lectern – Mr. Scott Moore, Deputy Director NMSS Table (left to right) – Dr. Hertel, Dr. Dewji, Dr. Zanzonico , Peter Crane, JD, and Ms. Stephanie Coffin (moderator, Deputy Director,- Division of Systems Analysis in RES)

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