



Radiological Toolbox

Casper Sun, PhD, CHP, MCP

Radiation Protection Branch

Office of Nuclear Regulatory Research

The United States Nuclear Regulatory Commission

Timelines

- This “Toolbox” existed for years....
- 2003 – NRC contracted ORNL to shape it.
- 2007 – Radiological Toolbox V2 issued.
- 2013 – Radiological Toolbox V3 issued with NUREG/CR-7166, the user’s manual.

What's in The Latest



Radiological Toolbox User's Guide

Manuscript Completed: April 2013
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Prepared by:
K. F. Eckerman and A. L. Sjoeren

Oak Ridge National Laboratory
Managed by UT-Battelle, LLC
Oak Ridge, TN 37831-6170

C. Sun, NRC Project Manager

NRC Job V6088

Office of Nuclear Regulatory Research

NUREG/CR-7166
ORNL/TM-2013/16

- **Rad-Toolbox V3.0 (April 2013)**

- Windows 7 and OS 64-bit compatible
- Code is 27 MB in size and one click to install.
- TRM certified for NRC workstations
- *Forum: Look for your feedback*

- **User's Manual (May 2013)**

- In color and PDF searchable
- References are up to date
- Built-in under "View-Manual" tab

ABSTRACT: NUREG/CR-7166

“Toolbox” software developed by ORNL for USNRC is designed to provide electronic access to the vast and varied data...These data represent physical, chemical, anatomical, physiological, and mathematical parameters detailed in various handbooks... This release has been tested on Windows 7...The nuclear decay data has been updated, thermal neutron capture cross sections, and cancer risk coefficients.

Something You Should Know

- The software can be removed by clicking on the unins000.exe that resides in the Toolbox folder
- **User's Guide, PDF: Can be highlighted or add note...**
- Knowing bugs: The decay chain graphics have not been tested for all potential parent nuclides.
- **The default units for dose coefficient is SI units , i.e., the units of the original data.**
- A note of caution in Page 9.
- **Runtime Error '3051' has been received. Your input and feedback are welcome.**

Must Know the Basic!

- <http://www.hps1.org/aahp/abhp/exams/formulas.pdf>

$$A = \lambda N$$

$$T_{1/2}^p = \frac{0.693}{\lambda_p}$$

$$A(t) = A_0 e^{-\lambda t}$$

$$\frac{1}{T_{1/2}^e} = \frac{1}{T_{1/2}^p} + \frac{1}{T_{1/2}^b}$$

$$X_2 = X_1 \frac{d_1^2}{d_2^2}$$

$$SA(\text{Ci} / \text{g}) = \frac{1.129 \times 10^{13}}{T_{1/2}^p(\text{s}) \text{ AtomicMass}}$$

$$\dot{X}(d) = A \frac{\Gamma}{d^2}$$

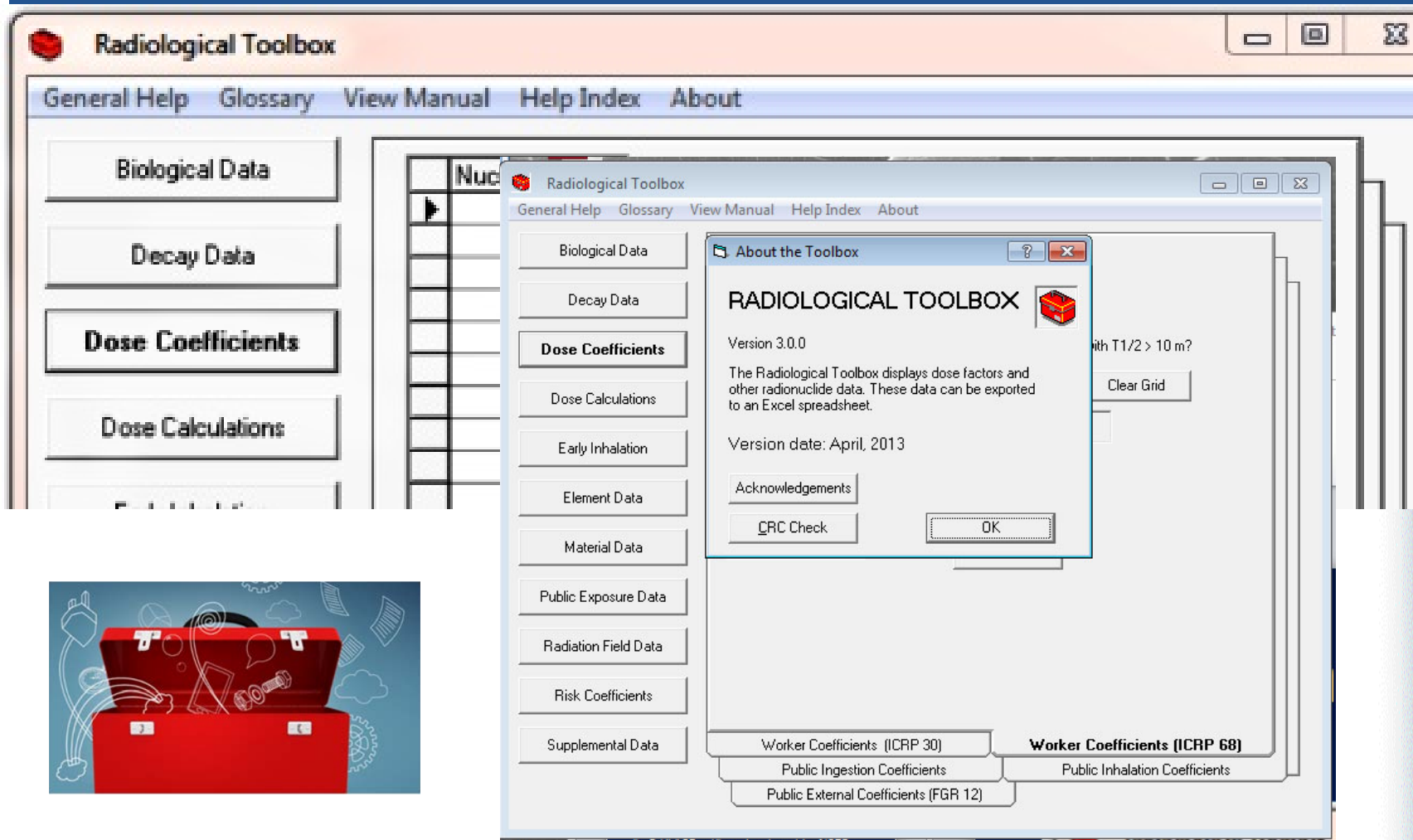
HP Constants

Useful Constants and Conversions

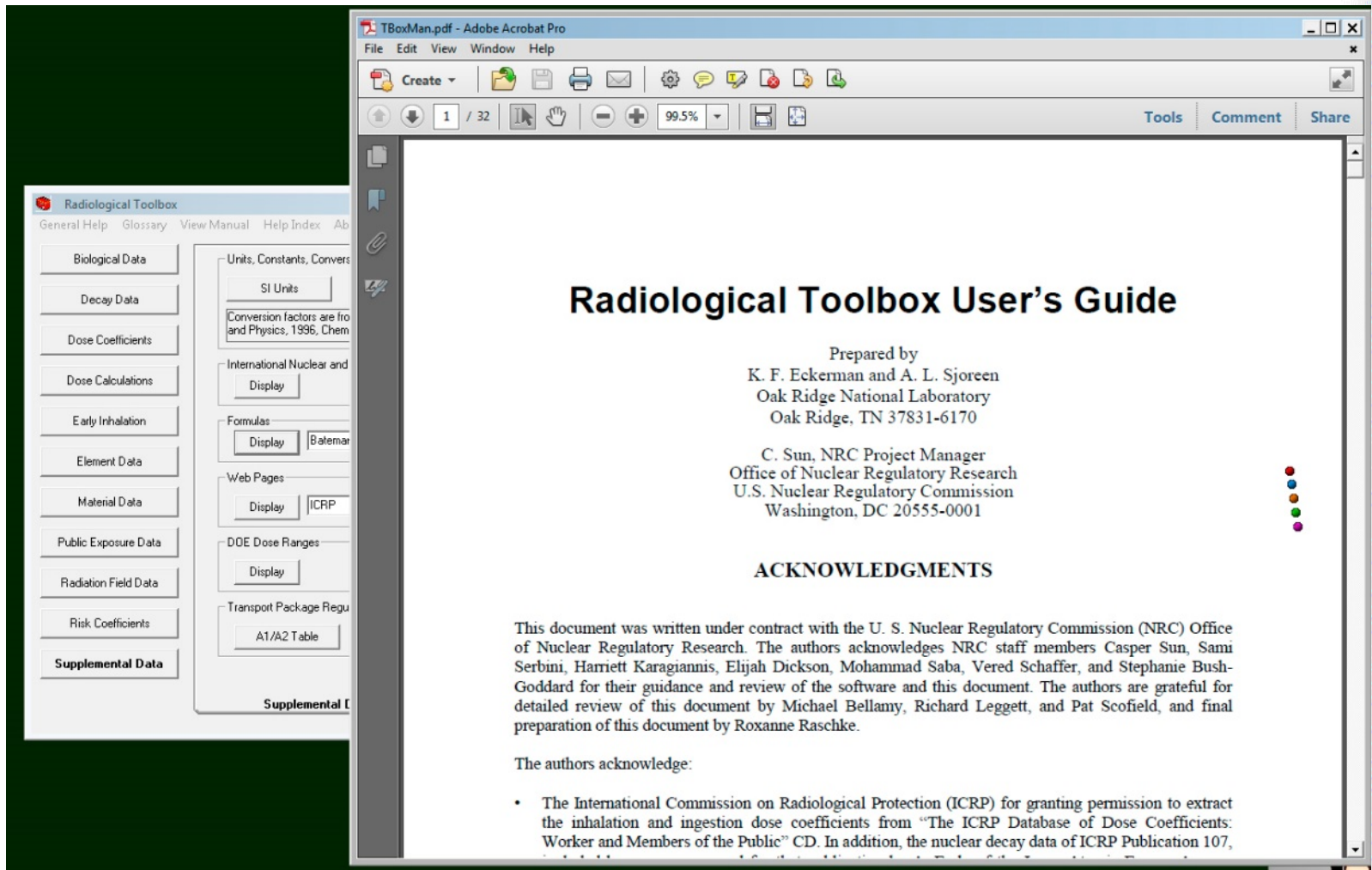
Avogadro's number	$6.023 \times 10^{23} \text{ mol}^{-1}$
Planck's constant	$6.625 \times 10^{-34} \text{ J s}$
volume of ideal gas (STP)	22.4 L mol^{-1}
charge (e^{-1})	$1.602 \times 10^{-19} \text{ C}$
roentgen (STP)	$2.58 \times 10^{-4} \text{ C kg}^{-1}$
1 MeV	$1.602 \times 10^{-13} \text{ J}$
1 atm	760 mm Hg
w	$33.7 \text{ eV ion pair}^{-1}$
rad	$6.242 \times 10^7 \text{ MeV g}^{-1}$
1 m ³	1000 L
1 ft ³	28.32 L
universal gas constant (R)	$8.32 \times 10^7 \text{ erg } ^\circ\text{C}^{-1} \text{ g}^{-1} \text{ mol}^{-1}$
standard temperature	0°C
standard pressure	1 atm
1 barn (b)	10^{-24} cm^2



Menu Bar (About)



Menu Bar (View Manual)



Radiological Toolbox User's Guide

Prepared by
K. F. Eckerman and A. L. Sjoreen
Oak Ridge National Laboratory
Oak Ridge, TN 37831-6170

C. Sun, NRC Project Manager
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

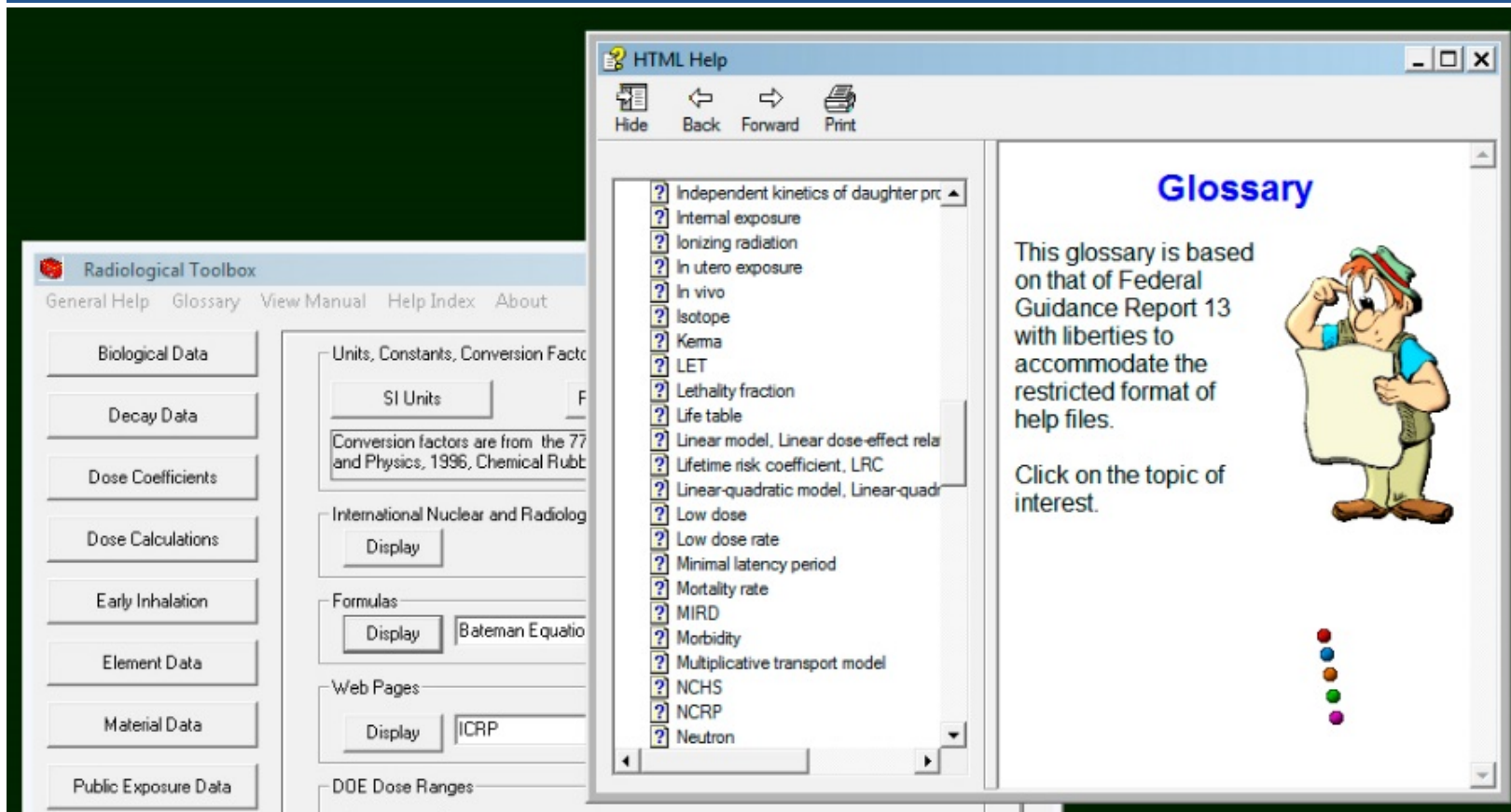
ACKNOWLEDGMENTS

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The authors acknowledge:

- The International Commission on Radiological Protection (ICRP) for granting permission to extract the inhalation and ingestion dose coefficients from "The ICRP Database of Dose Coefficients: Worker and Members of the Public" CD. In addition, the nuclear decay data of ICRP Publication 107,

Menu Bar (Glossary)



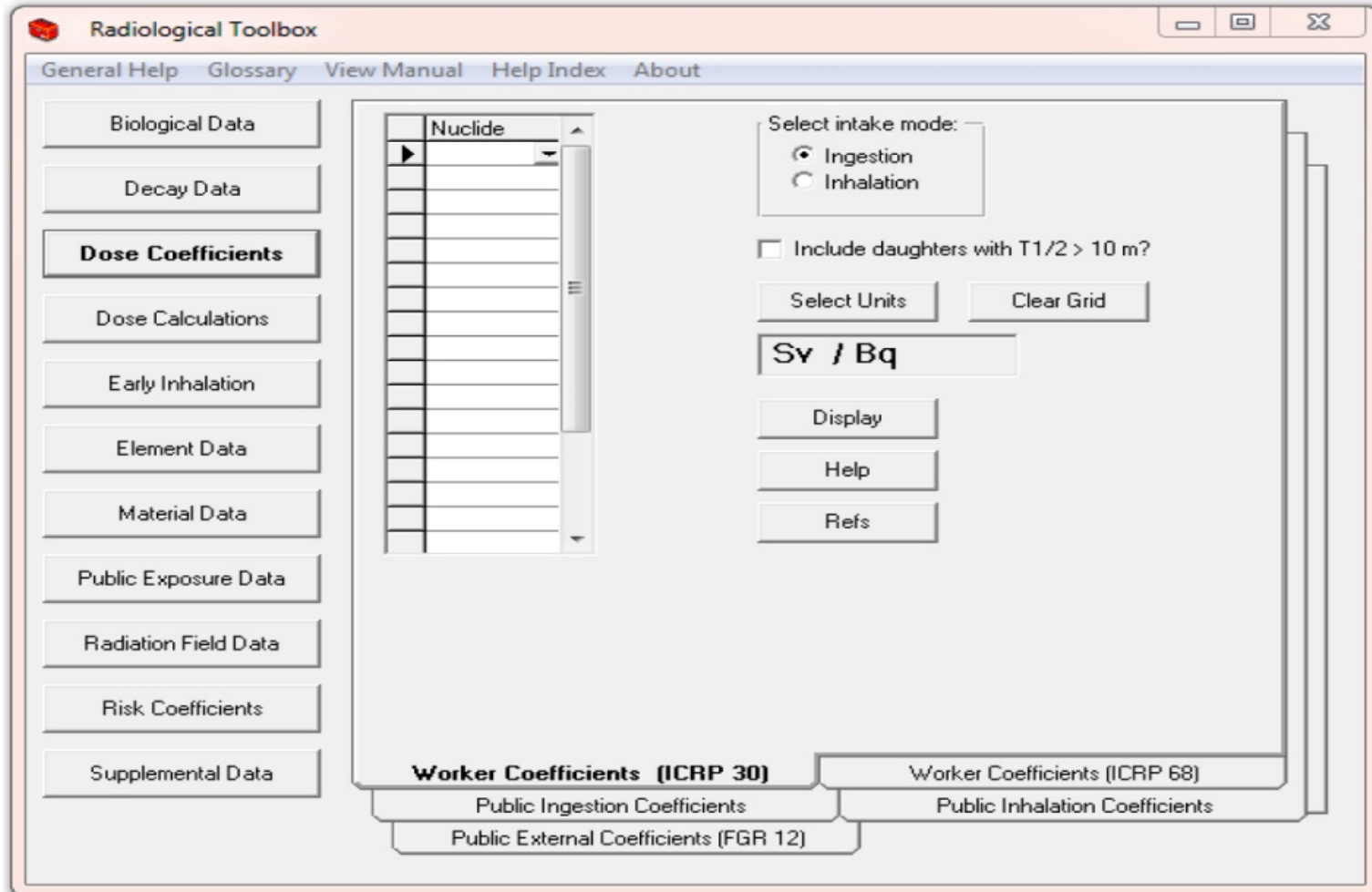
The screenshot displays the Radiological Toolbox software interface. On the left, a vertical menu bar lists various data categories: Biological Data, Decay Data, Dose Coefficients, Dose Calculations, Early Inhalation, Element Data, Material Data, and Public Exposure Data. The main window is titled "Radiological Toolbox" and contains several sections: "Units, Constants, Conversion Factors" with a "SI Units" button, "International Nuclear and Radiological" with a "Display" button, "Formulas" with a "Display" button and "Bateman Equations", "Web Pages" with a "Display" button and "ICRP", and "DOE Dose Ranges". Overlaid on the right is an "HTML Help" window titled "Glossary". The window has a menu bar with "Hide", "Back", "Forward", and "Print" options. The main content area of the HTML Help window shows a list of topics with question mark icons, including: Independent kinetics of daughter products, Internal exposure, Ionizing radiation, In utero exposure, In vivo, Isotope, Kerma, LET, Lethality fraction, Life table, Linear model, Linear dose-effect relationship, Lifetime risk coefficient, LRC, Linear-quadratic model, Linear-quadratic, Low dose, Low dose rate, Minimal latency period, Mortality rate, MIRD, Morbidity, Multiplicative transport model, NCHS, NCRP, and Neutron. To the right of the list, a cartoon character is holding a large sheet of paper, and the text reads: "This glossary is based on that of Federal Guidance Report 13 with liberties to accommodate the restricted format of help files. Click on the topic of interest."

Toolbox's Data Collections

Table 1.1. General Description of the Radiological Toolbox Data Elements

Data Collections	Description of Data Collection
Biological Data	Biokinetic models, reference anatomical data, bioassay data, and summary information on radiation health effects
Decay Data	Detailed information on the radiations emitted by radionuclides and members of serial decay chains
Dose Coefficients	Internal dose coefficients for intakes of radionuclides by workers and members of the public and external dose coefficients for members of the public exposed to radionuclides external to the body
Dose Calculation	Calculation of dose for worker or member of the public exposed to a radionuclide mixture
Early Inhalation	Absorbed dose coefficient integrated over a user-specific time period following an inhalation intake
Element Data	Radiation interaction coefficients with elements for alpha, electron, photon, and neutron radiations
Material Data	Radiation interaction coefficients with materials for alpha, electron, photon, and neutron radiations
Public Exposure Data	Summary information on radiation exposures to natural background radiation and from medical exposure
Radiation Field Data	Organ doses for workers resulting from idealized photon and neutron radiation fields
Risk Coefficients	Nuclide-specific risk coefficients for public exposure
Supplemental Data	Collection of reference information ranging from SI units to numerical limits on the activity content of radionuclides in transport

Rad-Toolbox 11 Database



The screenshot displays the "Radiological Toolbox" application window. The title bar includes standard window controls. The menu bar contains "General Help", "Glossary", "View Manual", "Help Index", and "About".

On the left is a vertical sidebar with buttons for various data categories: "Biological Data", "Decay Data", "Dose Coefficients" (which is highlighted), "Dose Calculations", "Early Inhalation", "Element Data", "Material Data", "Public Exposure Data", "Radiation Field Data", "Risk Coefficients", and "Supplemental Data".

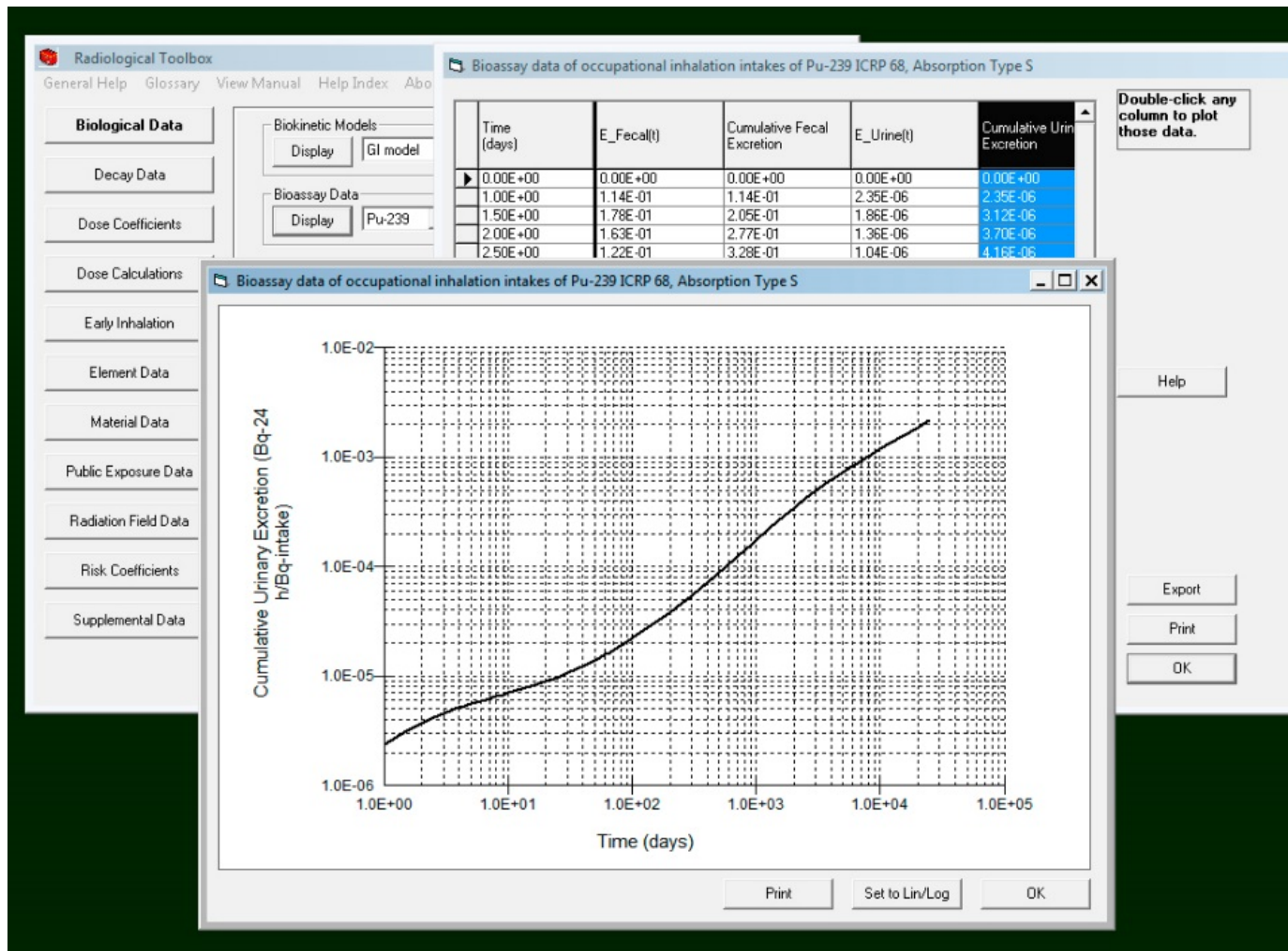
The main content area is divided into several sections:

- Nuclide:** A list box with a dropdown arrow at the top and a scroll bar on the right. It contains several empty rows.
- Select intake mode:** A group box containing two radio buttons: "Ingestion" (selected) and "Inhalation".
- Include daughters with T1/2 > 10 m?** A checkbox that is currently unchecked.
- Select Units:** A button.
- Clear Grid:** A button.
- Sv / Bq:** A text box displaying the unit conversion.
- Display:** A button.
- Help:** A button.
- Refs:** A button.

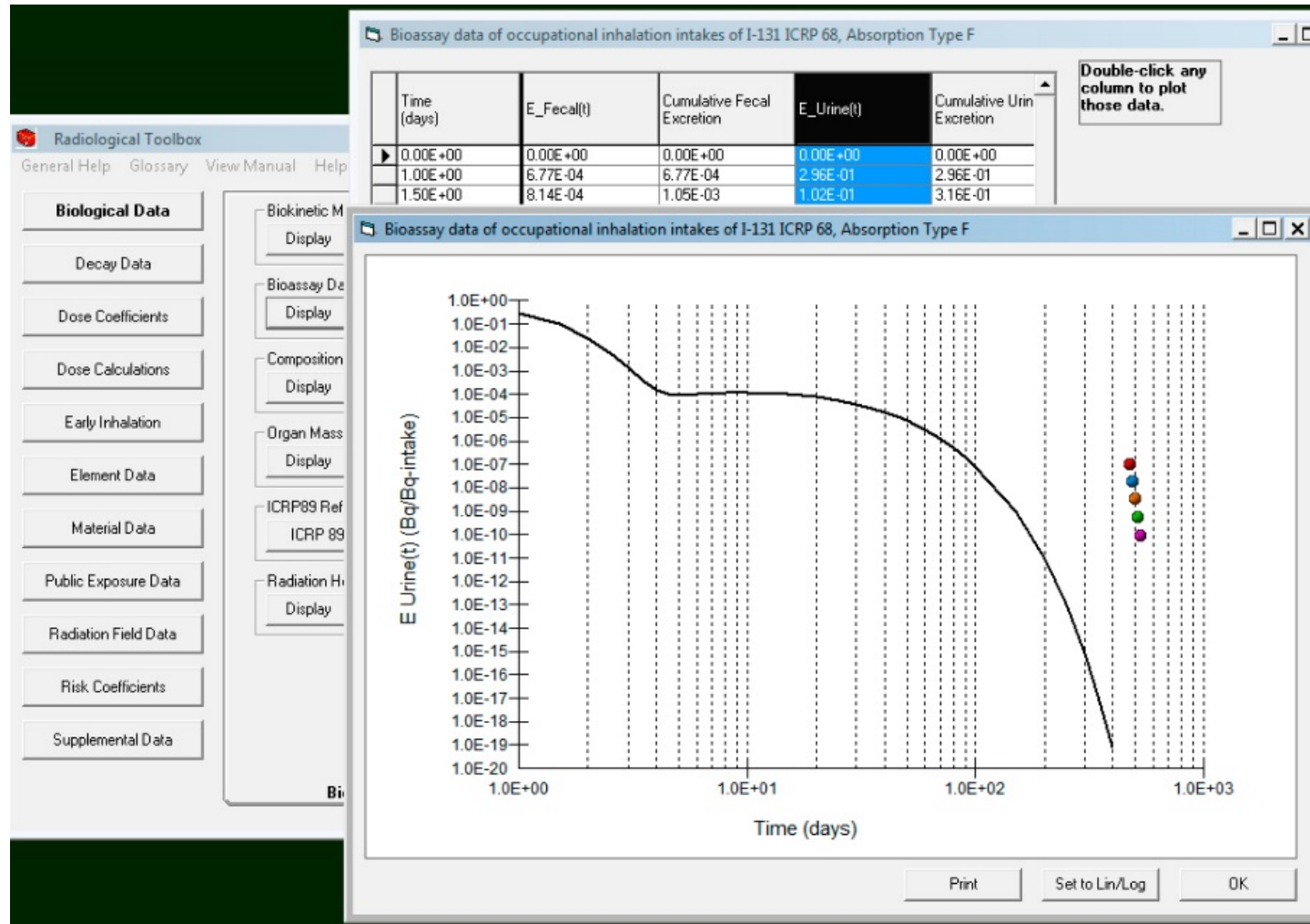
At the bottom of the window, there are four tabs for different coefficient sets:

- Worker Coefficients (ICRP 30)** (selected)
- Worker Coefficients (ICRP 68)**
- Public Ingestion Coefficients**
- Public Inhalation Coefficients**
- Public External Coefficients (FGR 12)**

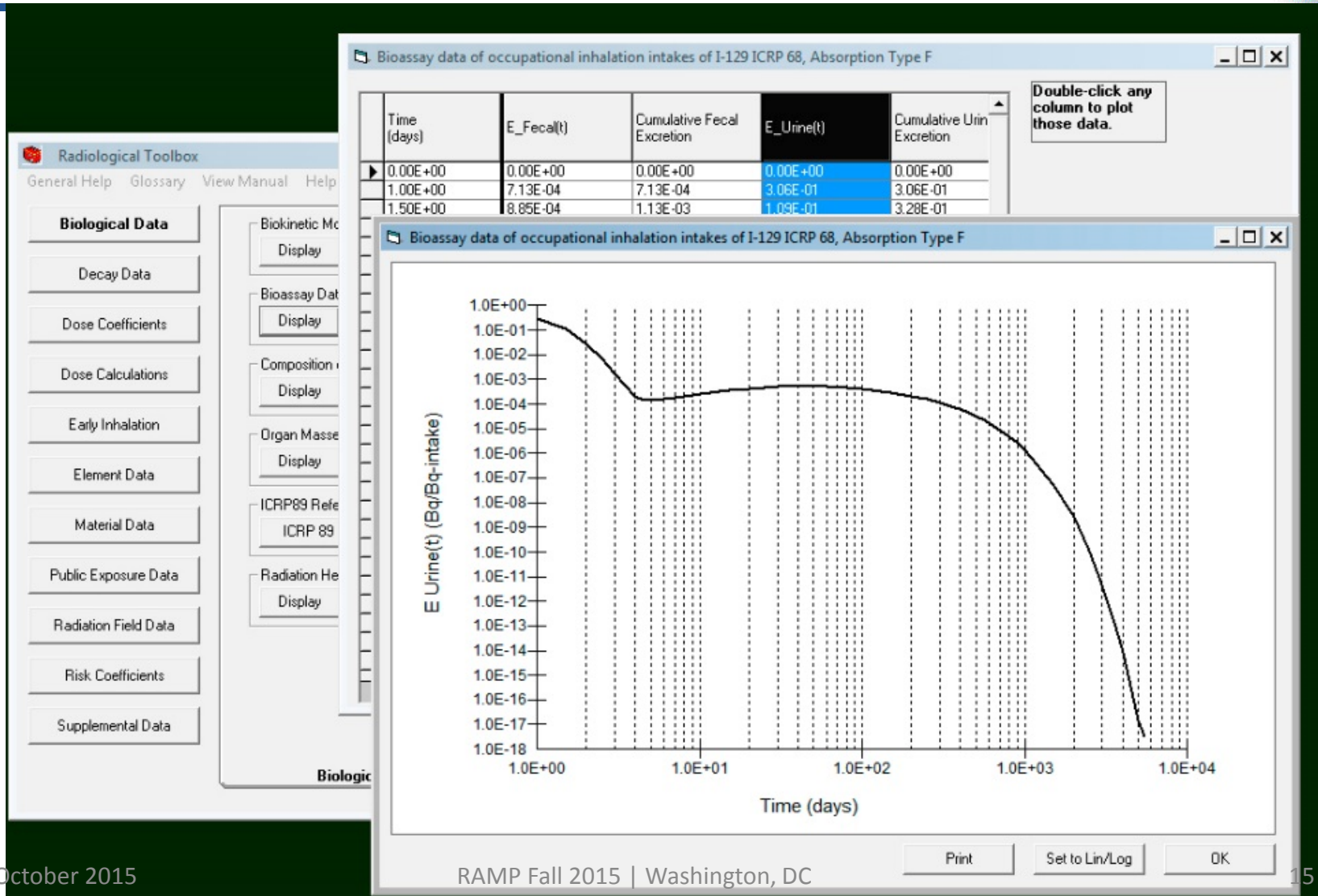
(1) Biological Data



(1) I-131

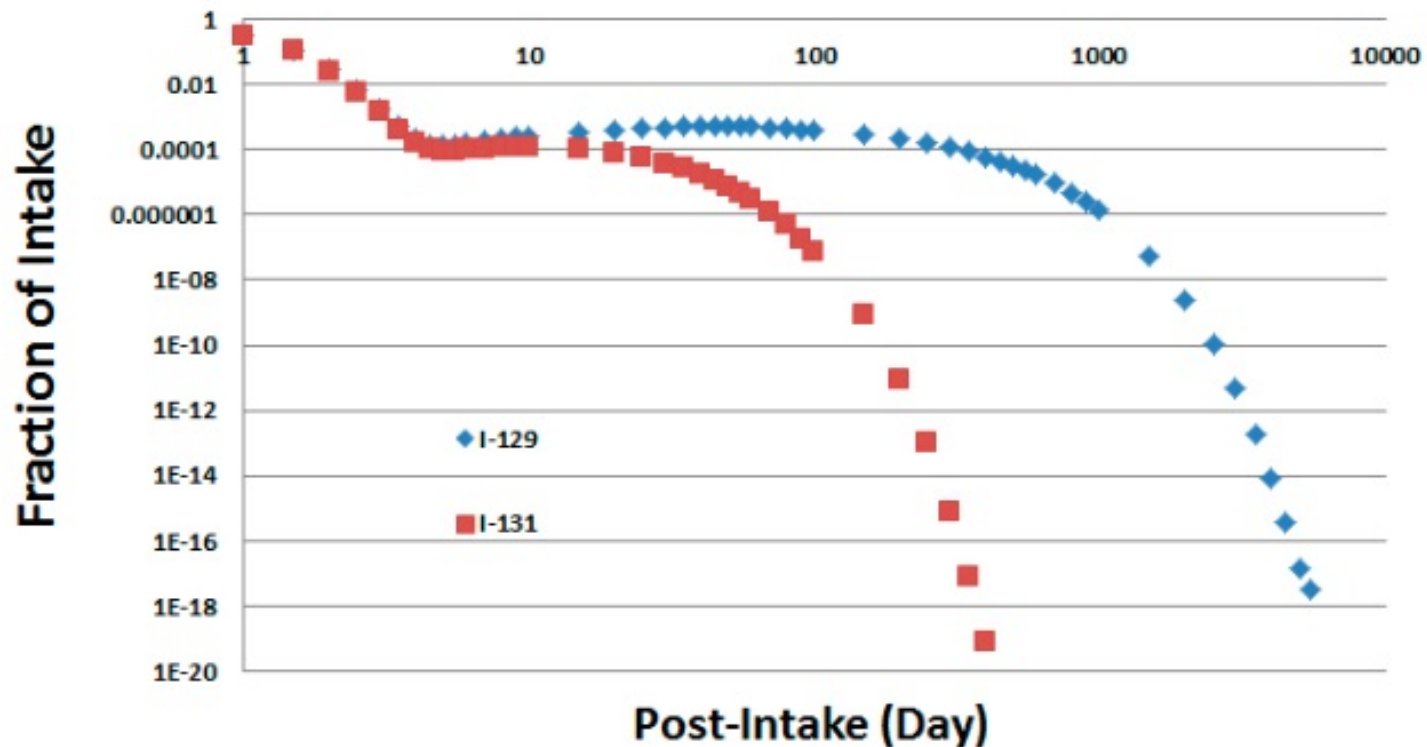


(1) I-129

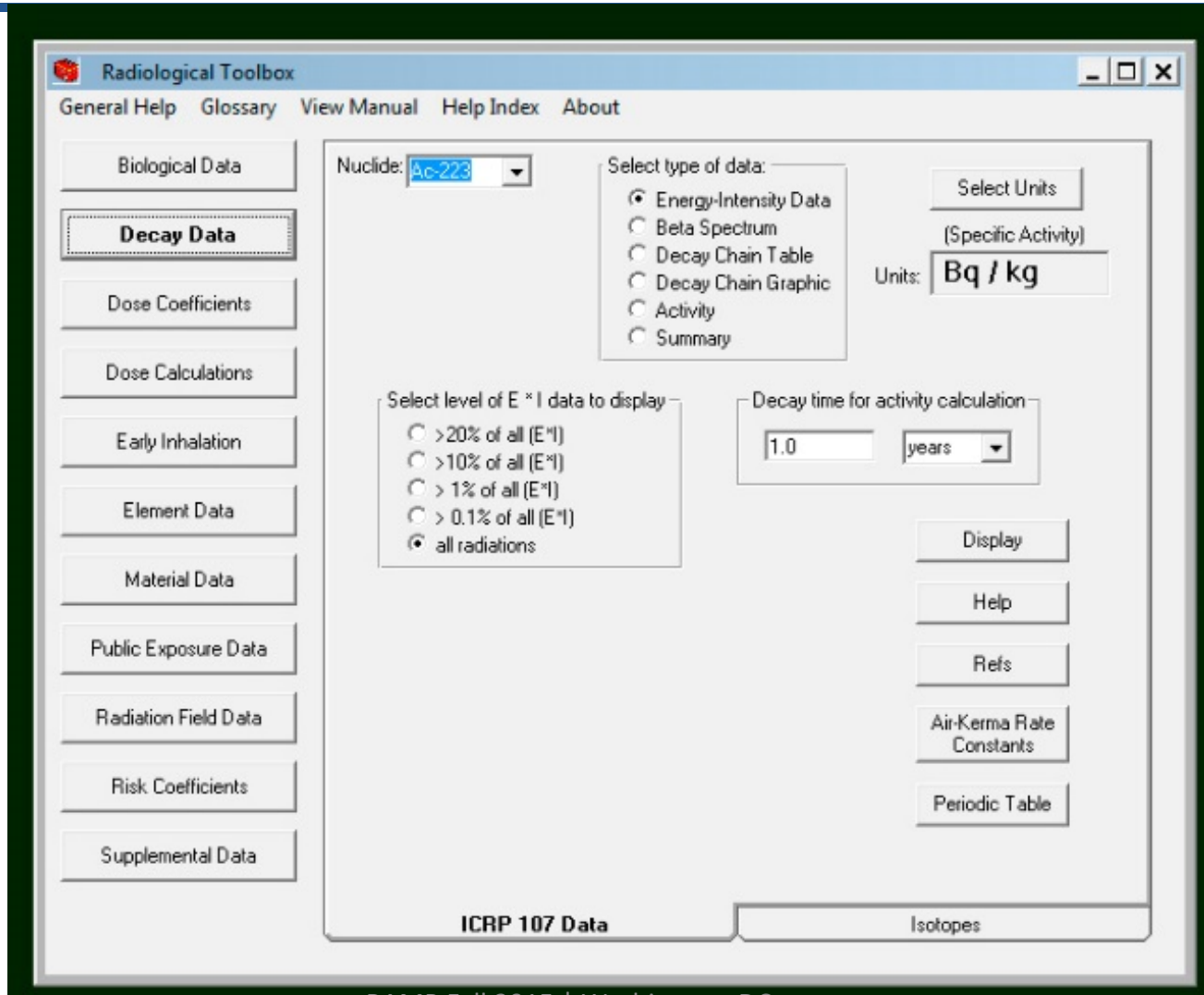


(1) Bioassay Application

24-h Urine Excretion Function



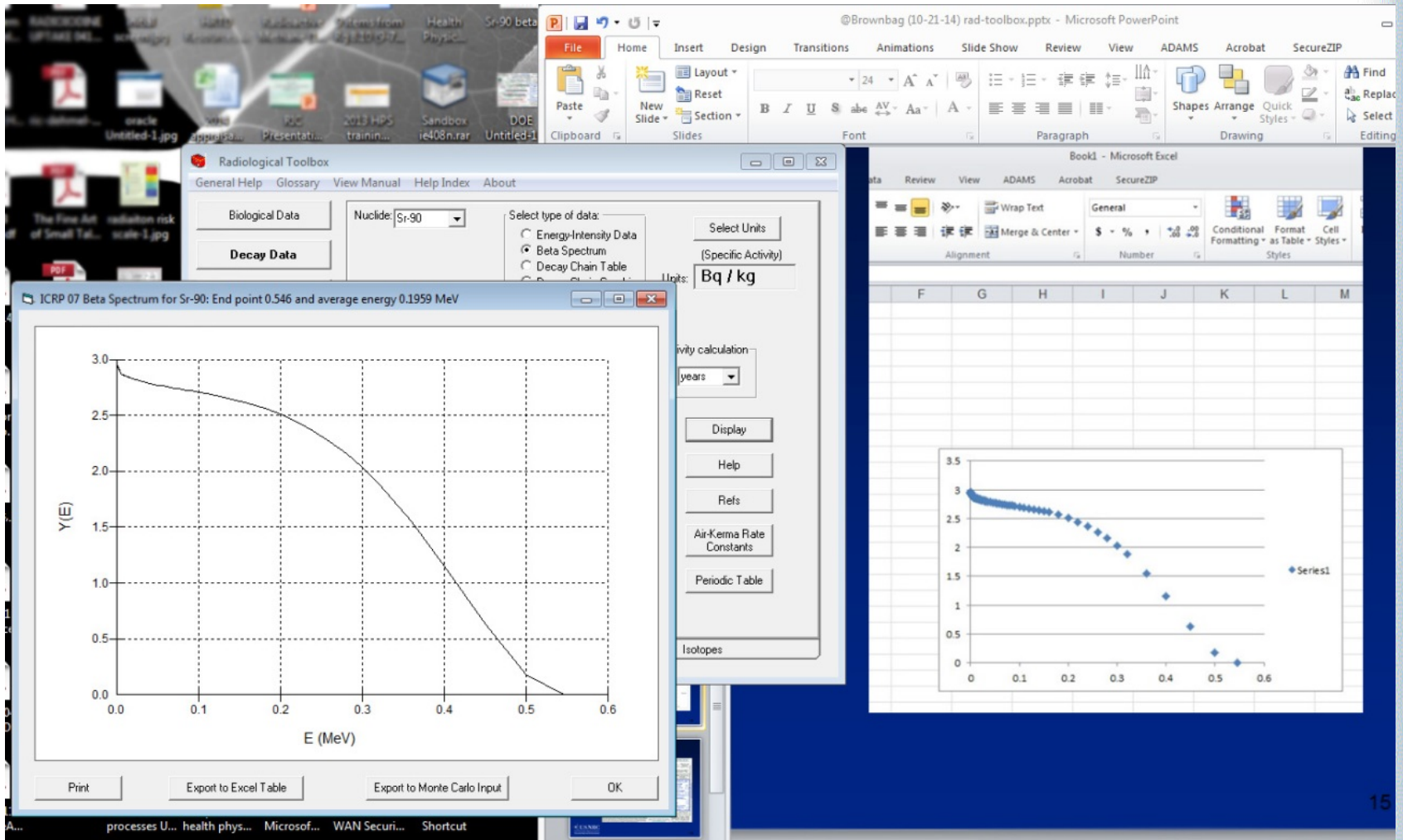
(2) Decay Data



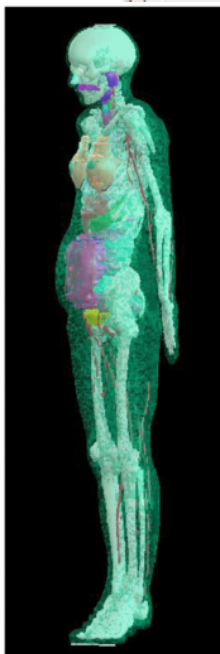
The screenshot shows the "Radiological Toolbox" application window. The "Decay Data" button is highlighted in the left sidebar. The main panel is configured as follows:

- Nuclide:** A dropdown menu showing "Ac-223".
- Select type of data:** A group box containing five radio buttons: "Energy-Intensity Data" (selected), "Beta Spectrum", "Decay Chain Table", "Decay Chain Graphic", "Activity", and "Summary".
- Select Units:** A button labeled "Select Units" with "(Specific Activity)" below it. The "Units:" label is followed by a text box containing "Bq / kg".
- Select level of E * I data to display:** A group box containing five radio buttons: ">20% of all (E*I)", ">10% of all (E*I)", "> 1% of all (E*I)", "> 0.1% of all (E*I)", and "all radiations" (selected).
- Decay time for activity calculation:** A text box containing "1.0" followed by a dropdown menu set to "years".
- Buttons:** "Display", "Help", "Refs", "Air-Kerma Rate Constants", and "Periodic Table".
- Footer:** Two tabs labeled "ICRP 107 Data" and "Isotopes".

(2) Sr-90 Beta Spec.



(3) Dose Coefficients



Radiological Toolbox

General Help Glossary View Manual Help Index About

Biological Data

Decay Data

Dose Coefficients

Nuclide

Select intake mode:
☒ Ingestion
☐ Inhalation

☐ Include daughters with T1/2 > 10 m?

Select Units Clear Grid

Sv / Bq

Display

Help

Refs

Worker Coefficients (ICRP 30)

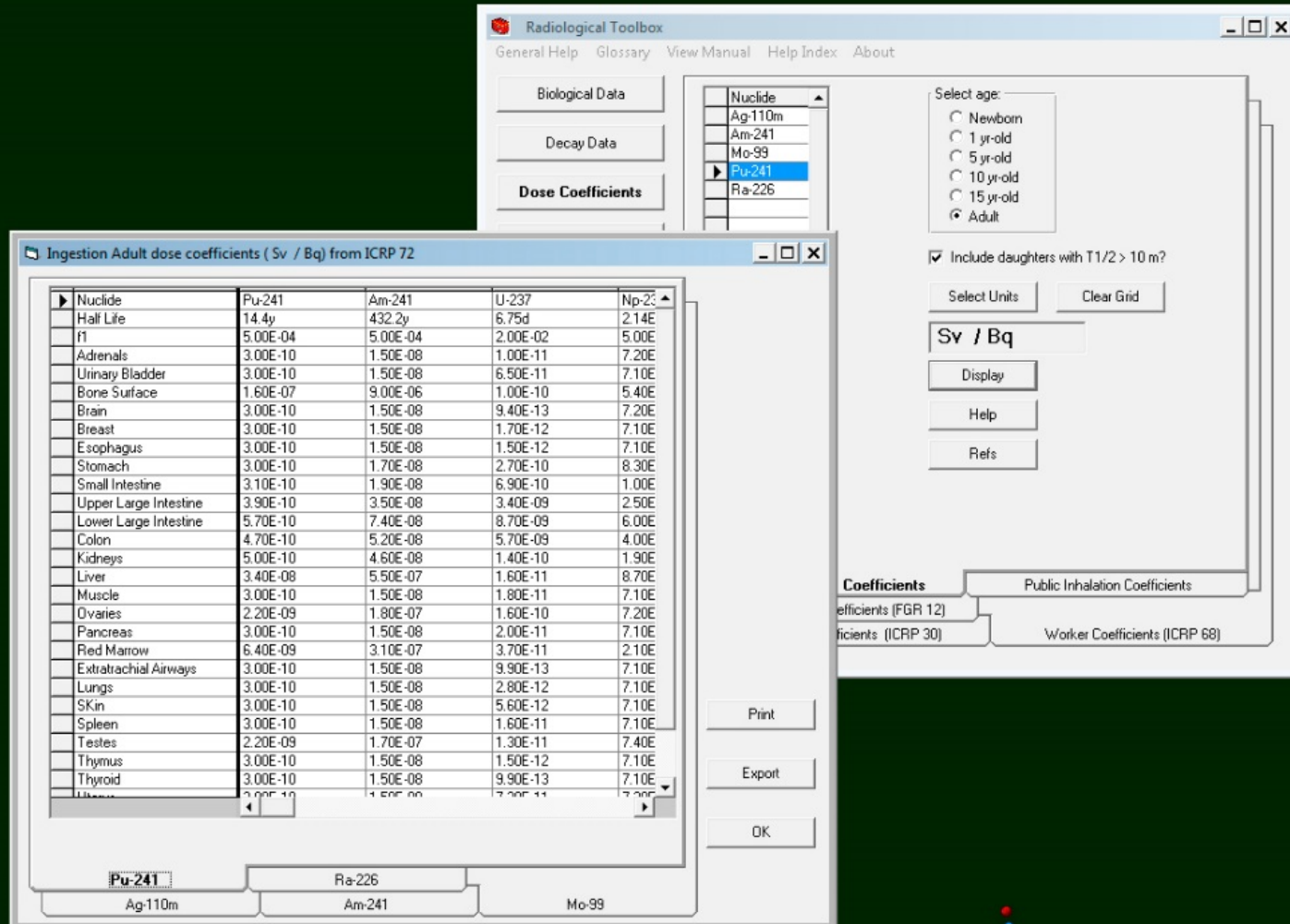
Public Ingestion Coefficients

Public External Coefficients (FGR 12)

Worker Coefficients (ICRP 68)

Public Inhalation Coefficients

(3) Pu-241; Adult



The screenshot displays the 'Radiological Toolbox' application window. The 'Dose Coefficients' tab is active, showing a table of ingestion adult dose coefficients for various nuclides. The 'Pu-241' nuclide is selected in the list on the left. The table displays coefficients for Pu-241, Am-241, U-237, and Np-237 across various organs and tissues. The 'Select age' dropdown is set to 'Adult'. The 'Include daughters with T1/2 > 10 m' checkbox is checked. The 'Sv / Bq' units are selected. The 'Display' button is highlighted.

Table: Ingestion Adult dose coefficients (Sv / Bq) from ICRP 72

Nuclide	Pu-241	Am-241	U-237	Np-237
Half Life	14.4y	432.2y	6.75d	2.14E
ti	5.00E-04	5.00E-04	2.00E-02	5.00E
Adrenals	3.00E-10	1.50E-08	1.00E-11	7.20E
Urinary Bladder	3.00E-10	1.50E-08	6.50E-11	7.10E
Bone Surface	1.60E-07	9.00E-06	1.00E-10	5.40E
Brain	3.00E-10	1.50E-08	9.40E-13	7.20E
Breast	3.00E-10	1.50E-08	1.70E-12	7.10E
Esophagus	3.00E-10	1.50E-08	1.50E-12	7.10E
Stomach	3.00E-10	1.70E-08	2.70E-10	8.30E
Small Intestine	3.10E-10	1.90E-08	6.90E-10	1.00E
Upper Large Intestine	3.90E-10	3.50E-08	3.40E-09	2.50E
Lower Large Intestine	5.70E-10	7.40E-08	8.70E-09	6.00E
Colon	4.70E-10	5.20E-08	5.70E-09	4.00E
Kidneys	5.00E-10	4.60E-08	1.40E-10	1.90E
Liver	3.40E-08	5.50E-07	1.60E-11	8.70E
Muscle	3.00E-10	1.50E-08	1.80E-11	7.10E
Ovaries	2.20E-09	1.80E-07	1.60E-10	7.20E
Pancreas	3.00E-10	1.50E-08	2.00E-11	7.10E
Red Marrow	6.40E-09	3.10E-07	3.70E-11	2.10E
Extratracheal Airways	3.00E-10	1.50E-08	9.90E-13	7.10E
Lungs	3.00E-10	1.50E-08	2.80E-12	7.10E
SKin	3.00E-10	1.50E-08	5.60E-12	7.10E
Spleen	3.00E-10	1.50E-08	1.60E-11	7.10E
Testes	2.20E-09	1.70E-07	1.30E-11	7.40E
Thymus	3.00E-10	1.50E-08	1.50E-12	7.10E
Thyroid	3.00E-10	1.50E-08	9.90E-13	7.10E
Uterus	3.00E-10	1.50E-08	7.20E-11	7.20E

At the bottom of the window, there are tabs for different nuclides: Pu-241, Am-241, Ra-226, and Mo-99. The 'Pu-241' tab is currently selected.

(3) Pu-241

Clipboard		Bluetooth		Font		Alignment		Number					
A1		Ingestion Adult dose coefficients (Sv / Bq) from ICRP 72											
	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Ingestion	Adult dose coefficients (Sv / Bq) from ICRP 72											
2	Nuclide	Pu-241	Am-241	U-237	Np-237	Pa-233	U-233	Th-229	Ra-225	Ac-225	Bi-213	Pb-209	
3	Half Life	14.4y	432.2y	6.75d	2.14E6y	27.0d	1.585E5y	7340y	14.8d	10.0d	45.65m	3.253h	
4	f1	0.0005	0.0005	0.02	0.0005	0.0005	0.02	0.0005	0.2	0.0005	0.05	0.2	
5	Adrenals	3E-10	1.5E-08	1E-11	7.2E-09	1.3E-11	2.8E-08	7.6E-08	1.1E-08	3.2E-11	5.1E-12	5.5E-13	
6	Urinary Bl	3E-10	1.5E-08	6.5E-11	7.1E-09	7.5E-11	2.8E-08	7.6E-08	1.1E-08	9.3E-11	8.2E-12	2.5E-12	
7	Bone Surf	1.6E-07	0.000009	1E-10	5.4E-06	6.6E-11	8.4E-07	0.000023	3.6E-06	4.9E-08	4.6E-12	1.4E-11	
8	Brain	3E-10	1.5E-08	9.4E-13	7.2E-09	1.5E-13	2.8E-08	7.6E-08	1.1E-08	2E-11	4.3E-12	5.5E-13	
9	Breast	3E-10	1.5E-08	1.7E-12	7.1E-09	2E-12	2.8E-08	7.6E-08	1.1E-08	2.2E-11	4.5E-12	5.5E-13	
10	Esophagu:	3E-10	1.5E-08	1.5E-12	7.1E-09	1.5E-12	2.8E-08	7.6E-08	1.1E-08	2.1E-11	4.4E-12	5.5E-13	
11	Stomach	3E-10	1.7E-08	2.7E-10	8.3E-09	2.9E-10	2.9E-08	7.8E-08	1.1E-08	5.3E-09	1.3E-09	1.9E-10	
12	Small Inte	3.1E-10	1.9E-08	6.9E-10	1E-08	7.7E-10	3.1E-08	8E-08	1.2E-08	1.7E-08	7.4E-10	2.2E-10	
13	Upper Lar	3.9E-10	3.5E-08	3.4E-09	2.5E-08	3.7E-09	4.5E-08	9.7E-08	1.8E-08	1E-07	4.4E-10	3.5E-10	
14	Lower Lar	5.7E-10	7.4E-08	8.7E-09	6E-08	1E-08	7.7E-08	1.4E-07	4.7E-08	2.8E-07	1E-10	1.7E-10	
15	Colon	4.7E-10	5.2E-08	5.7E-09	4E-08	6.5E-09	5.9E-08	1.2E-07	3E-08	1.8E-07	2.9E-10	2.7E-10	
16	Kidneys	5E-10	4.6E-08	1.4E-10	1.9E-08	3.3E-11	2.9E-07	3E-07	3.7E-08	5E-11	6.1E-10	7.1E-12	
17	Liver	3.4E-08	5.5E-07	1.6E-11	8.7E-08	2.1E-11	1.1E-07	1.1E-06	1.9E-07	1.3E-08	4.9E-12	2.7E-12	
18	Muscle	3E-10	1.5E-08	1.8E-11	7.1E-09	2.6E-11	2.8E-08	7.6E-08	1.1E-08	4.6E-11	4.8E-12	5.5E-13	
19	Ovaries	2.2E-09	1.8E-07	1.6E-10	7.2E-08	2.3E-10	2.8E-08	1.7E-07	1.3E-08	7.9E-10	6.6E-12	5.5E-13	
20	Pancreas	3E-10	1.5E-08	2E-11	7.1E-09	2.7E-11	2.8E-08	7.6E-08	1.1E-08	4.4E-11	7.3E-12	5.5E-13	
21	Red Marr	6.4E-09	3.1E-07	3.7E-11	2.1E-07	4.6E-11	8.4E-08	1.1E-06	3.5E-07	4E-09	4.9E-12	1.8E-12	
22	Extratrach	3E-10	1.5E-08	9.9E-13	7.1E-09	3.4E-13	2.8E-08	7.6E-08	1.1E-08	2E-11	4.3E-12	5.5E-13	
23	Lungs	3E-10	1.5E-08	2.8E-12	7.1E-09	3.4E-12	2.8E-08	7.6E-08	1.1E-08	2.3E-11	4.6E-12	5.5E-13	
24	SKin	3E-10	1.5E-08	5.6E-12	7.1E-09	8.3E-12	2.8E-08	7.6E-08	1.1E-08	2.8E-11	4.5E-12	5.5E-13	
25	Spleen	3E-10	1.5E-08	1.6E-11	7.1E-09	2.1E-11	2.8E-08	7.3E-08	1.1E-08	3.9E-11	6.2E-12	5.5E-13	
26	Testes	2.2E-09	1.7E-07	1.3E-11	7.4E-08	2.1E-11	2.9E-08	1.8E-07	1.3E-08	5.8E-10	4.4E-12	5.5E-13	
27	Thymus	3E-10	1.5E-08	1.5E-12	7.1E-09	1.5E-12	2.8E-08	7.6E-08	1.1E-08	2.1E-11	4.4E-12	5.5E-13	
28	Thyroid	3E-10	1.5E-08	9.9E-13	7.1E-09	3.4E-13	2.8E-08	7.6E-08	1.1E-08	2E-11	4.3E-12	5.5E-13	
29	Uterus	3E-10	1.5E-08	7.3E-11	7.2E-09	1.1E-10	2.8E-08	7.6E-08	1.1E-08	1.2E-10	6.1E-12	5.5E-13	
30	Remainde	3E-10	1.6E-08	3.3E-11	7.3E-09	4.1E-11	3.1E-08	7.9E-08	1.2E-08	3.9E-10	2.6E-11	5.3E-12	
31	Effective (4.8E-09	2E-07	7.6E-10	1.1E-07	8.7E-10	5.1E-08	4.9E-07	9.9E-08	2.4E-08	2E-10	5.7E-11	
32													

(4) Dose Calculations

Clipboard Bluetooth Font Alignment Number Cells Editing

A1 fx Ingestion Adult dose coefficients (Sv / Bq) from ICRP 72

	A	B	C	D	E	F	G	H	I	J	K
1	Ingestion Adult dose coefficients (Sv / Bq) from ICRP 72										
2	Nuclide	Pu-239	U-235	Th-231	Pa-231	Ac-227	Th-227	Fr-223	Ra-223	Pb-211	Inge
3	Half Life	24065y	703.8E6y	25.52h	3.276E4y	41.8E3y	4.7E3y	21.5d	11.43d	36.1m	Nucl
4	f1	0.0005	0.02	0.0005	0.						
5	Adrenals	1.4E-08	2.6E-08	4.8E-13	9.						
6	Urinary Bl	1.4E-08	2.6E-08	2.9E-12	4.9						
7	Bone Surf	8.2E-06	7.4E-07	5.8E-12	0.00						
8	Brain	1.4E-08	2.6E-08	1.8E-14	5.4						
9	Breast	1.4E-08	2.6E-08	6E-14	2.6						
10	Esophagus	1.4E-08	2.6E-08	4.3E-14	3.6						
11	Stomach	1.6E-08	2.7E-08	1.9E-10	1.3						
12	Small Inte	1.7E-08	2.8E-08	4.4E-10	3.2						
13	Upper Lar	3.3E-08	4.3E-08	1.9E-09	1.5						
14	Lower Lar	6.7E-08	7.8E-08	3.4E-09	5.4						
15	Colon	4.8E-08	5.8E-08	2.5E-09	3.4						
16	Kidneys	3.4E-08	2.7E-07	1.4E-12	3.4						
17	Liver	1.7E-06	1E-07	9.9E-13	2.2						
18	Muscle	1.4E-08	2.6E-08	1.4E-12	4.9						
19	Ovaries	1.1E-07	2.6E-08	1.9E-11	1.3						
20	Pancreas	1.4E-08	2.6E-08	1.5E-12	5.8						
21	Red Marro	3.9E-07	7.6E-08	1.8E-12	2.9						
22	Extratrach	1.4E-08	2.6E-08	2E-14	4						
23	Lungs	1.4E-08	2.6E-08	1.2E-13	4.7						
24	SKin	1.4E-08	2.6E-08	2.9E-13	3						
25	Spleen	1.4E-08	2.6E-08	9.6E-13	4.1						
26	Testes	1.1E-07	2.6E-08	5.6E-13	2.5						
27	Thymus	1.4E-08	2.6E-08	4.3E-14	3.6						
28	Thyroid	1.4E-08	2.6E-08	2E-14	4						
29	Uterus	1.4E-08	2.6E-08	4.9E-12	6.8						
30	Remainde	1.5E-08	2.8E-08	1E-11	1.5						
31	Effective (2.5E-07	4.7E-08	3.4E-10	7.1E-07	1.1E-06	8.8E-09	2.4E-09	1E-07	1.8E-10	
32											
33											

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- Dose Calculations**
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- Supplemental Data

Worker Coefficients (ICRP 30)
Public Ingestion Coefficients
Public External Coefficients (FGR 12)

Worker Coefficients (ICRP 68)
Public Inhalation Coefficients

Ingestion dose coefficients (Sv / Bq) from FGR12

Nuclide	Pu-239	Pu-239	Pu-239	U-235
r1	1.00E-05	1.00E-04	1.00E-03	2.00E-03
Adrenals	8.28E-14	7.95E-13	7.92E-12	1.09E-10
Bladder Wall	1.25E-13	7.98E-13	7.52E-12	1.69E-10
Bone Surface	1.76E-07	1.76E-06	1.76E-05	4.20E-08
Brain	7.66E-14	7.66E-13	7.66E-12	0.00E+00
Breast	1.21E-13	8.09E-13	7.69E-12	1.21E-10
Esophagus	7.54E-14	7.51E-13	7.51E-12	9.81E-11
Stomach Wall	1.19E-09	1.19E-09	1.20E-09	1.23E-09
Small Intestine Wall	2.99E-09	2.99E-09	2.99E-09	3.03E-09
Upper Large Intestine Wall	1.73E-08	1.73E-08	1.73E-08	1.69E-08
Lower Large Intestine Wall	5.31E-08	5.31E-08	5.30E-08	5.33E-08
Kidneys	8.78E-14	7.76E-13	7.66E-12	1.73E-08
Liver	3.14E-08	3.14E-07	3.14E-06	1.14E-10
Lungs	7.89E-14	7.75E-13	7.74E-12	1.01E-10
Muscle	1.21E-13	8.09E-13	7.69E-12	1.21E-10
Ovaries	2.64E-09	2.64E-08	2.64E-07	3.34E-10
Pancreas	9.95E-14	7.89E-13	7.68E-12	1.23E-10
Red Marrow	1.41E-08	1.41E-07	1.41E-06	2.78E-09
Skin	8.17E-14	7.63E-13	7.57E-12	1.04E-10
Spleen	8.47E-14	7.64E-13	7.55E-12	1.15E-10
Testes	2.64E-09	2.64E-08	2.64E-07	1.15E-10
Thymus	7.54E-14	7.51E-13	7.51E-12	9.81E-11
Thyroid	7.50E-14	7.49E-13	7.49E-12	9.82E-11
Uterus	1.38E-13	8.11E-13	7.54E-12	1.89E-10
Effective (ICRP 26)	1.40E-08	9.96E-08	9.56E-07	7.22E-09
Effective (ICRP 60)	1.21E-08	6.20E-08	5.62E-07	7.42E-09

Pu-239 U-235

Print
Export
OK

(5) Early Inhalation



Biological Data

Decay Data

Dose Coefficients

Dose Calculations

Early Inhalation

Nuclide: I-125

Absorption Type: F

Integration Periods

10

2

5

0

7

0

0

Organs displayed:

1. Small intestine (SI)

2. Red Marrow

3. Lung (Mass Average)

4. Alveolar Interstitial Region (AI)

Select Units

Gy / Bq

Display

Days

Years

Acute Absorbed Dose Coefficients (Gy/Bq- inhaled)

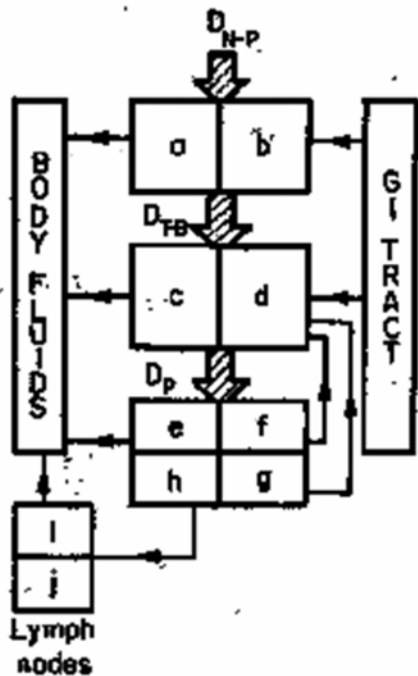
For a selected set of radionuclides the toolbox contains information on the low and high LET absorbed dose rate as a function of time post an acute inhalation intake for tissues of the body subject to acute radiation syndrome (ARS). ARS is classically divided into three main presentations: hematopoietic, gastrointestinal and neurological/vascular. The neurovascular syndrome occurs at very high absorbed dose (above 10 Gy) and not typically achievable by internal emitters.

The toolbox addresses 4 tissues: 1) *Red marrow* (hematopoietic syndrome), 2) *Small intestine* (gastrointestinal syndrome), 3) *Lung* (mass average) and 4) *Alveolar Interstitial Region*. The later two are of interest with regard to damage to the respiratory tract. The user can define the time period over which the absorbed dose rate is to be integrated. In results of the integration are given for both the low and high [LET](#) components to which the user can then apply as suitable [RBE](#) if desired.

The absorbed dose rate data file was assembled during the preparation of [Federal Guidance Report 13](#). The toolbox only addresses inhalation intakes. An acute dose calculator which considers intakes by ingestion and inhalation (referred to as a Acute Dose Calculator) is available from [EPA](#).

Note: The tabulated dosimetric quantity is absorbed dose and thus no modifying factor (RBE or w_R) has been applied to the numerical values of the low and high LET components. The user may apply a suitable RBE and sum the resultant values.

(5) I-125



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Nuclide: I-125
Absorption Type: F

Integration Periods
10
2
5
0
7
0
0
0
0
0

Days
Years

Organs displayed:
1. Small intestine (SI)
2. Red Marrow
3. Lung (Mass Average)
4. Alveolar Interstitial Region (AI)

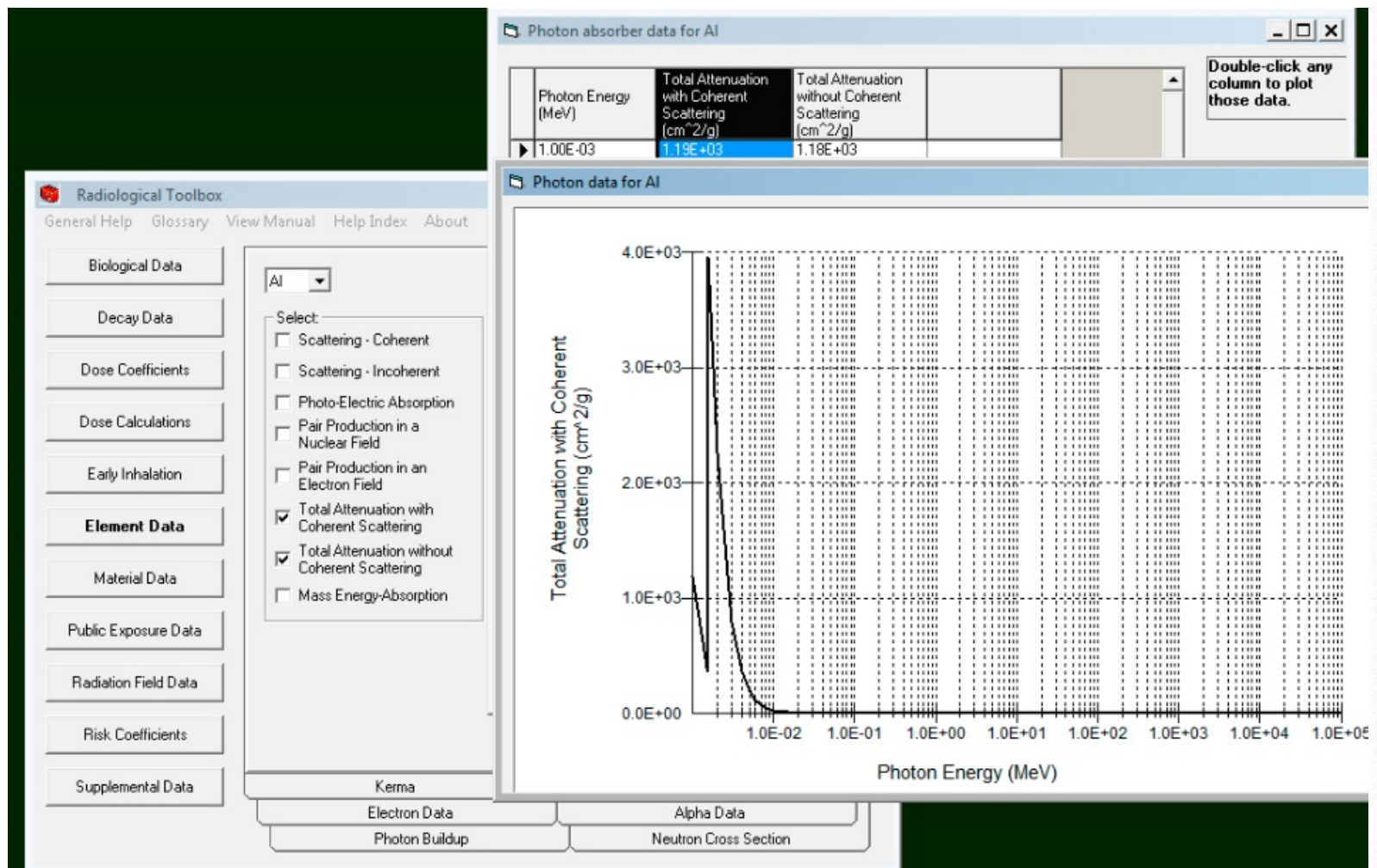
Select Units
Gy / Bq
Display
Help
Refs

Absorbed Dose Coefficient (Gy / Bq)

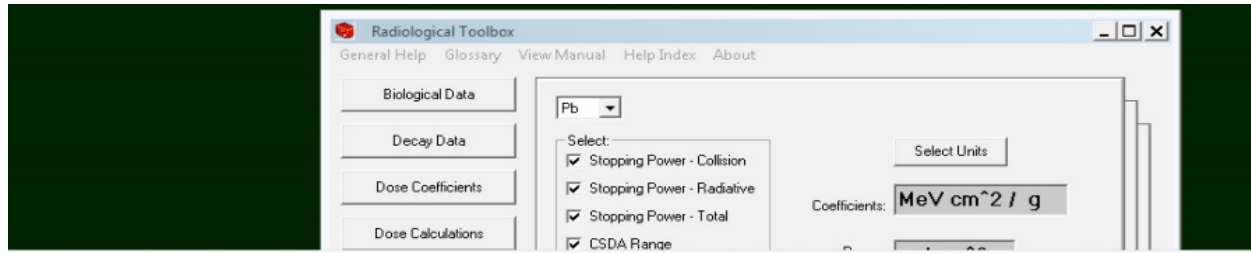
Nuclide	I-125				
Type	F				
Time (d)	1.00E+01	2.00E+00	5.00E+00	7.00E+00	
Tissue	Low LET	Low LET	Low LET	Low LET	
SI	1.78E-12	1.43E-12	1.53E-12	1.61E-12	
Marrow	2.12E-12	1.18E-12	1.53E-12	1.76E-12	
Lung	3.21E-12	2.24E-12	2.58E-12	2.82E-12	
AI	3.14E-12	2.18E-12	2.52E-12	2.76E-12	

Export
Print
OK

(6) Element Data (Al)



(6) Element Data (Pb)



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Pb

Select:

- ☒ Stopping Power - Collision
- ☒ Stopping Power - Radiative
- ☒ Stopping Power - Total
- ☒ CSDA Range

Select Units

Coefficients: MeV cm² / g

Element Data: Properties

This section of the toolbox contains data for various types of radiations.

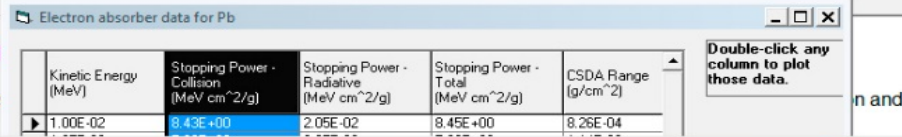
Atomic mass: Information on the atomic mass, properties and elemental composition of the element.

Interaction Coefficients: Coefficients for the interaction of radiation with matter, available for display, export, and calculation.

Kerma coefficients for photon and neutron interactions.

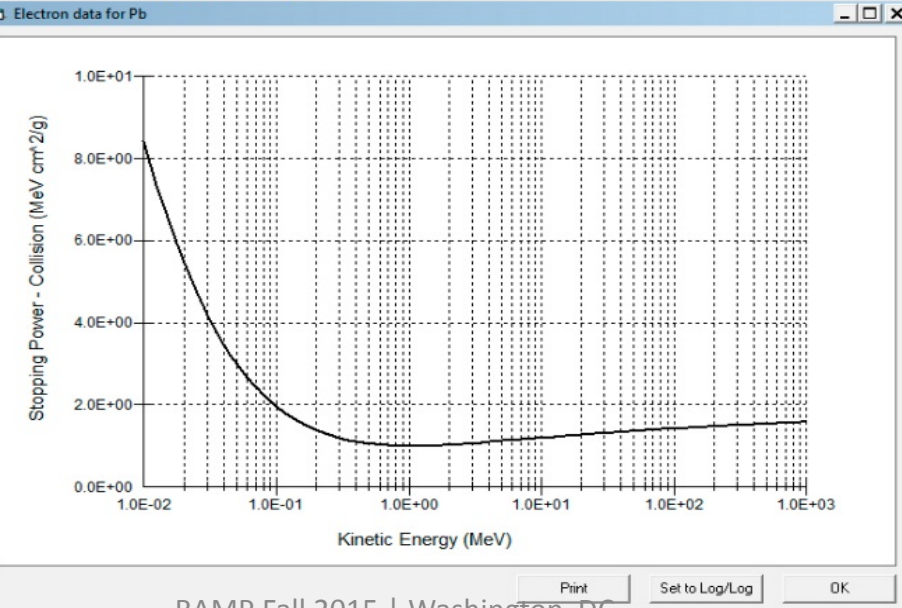
Neutron Activation Cross Sections: Neutron activation cross sections for various isotopes of the element. See [Mughabghab](#) for more information.

Photon Buildup: The Geometric Factor (GF) and its values can be calculated using the procedures implemented in the toolbox.



Kinetic Energy (MeV)	Stopping Power - Collision (MeV cm ² /g)	Stopping Power - Radiative (MeV cm ² /g)	Stopping Power - Total (MeV cm ² /g)	CSDA Range (g/cm ²)
1.00E-02	8.43E+00	2.05E-02	8.45E+00	8.26E-04

Double-click any column to plot those data.



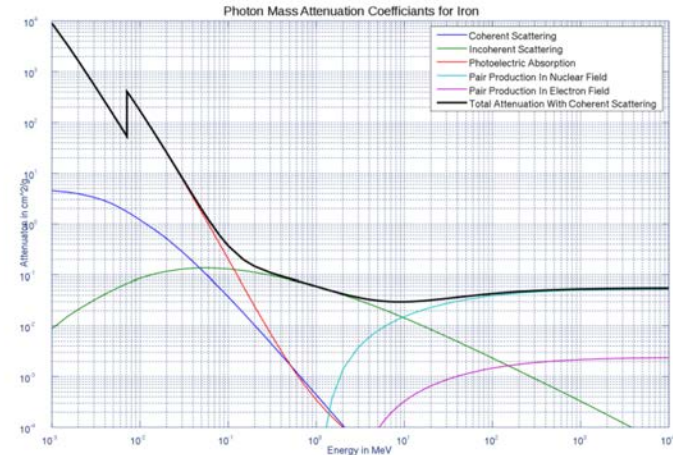
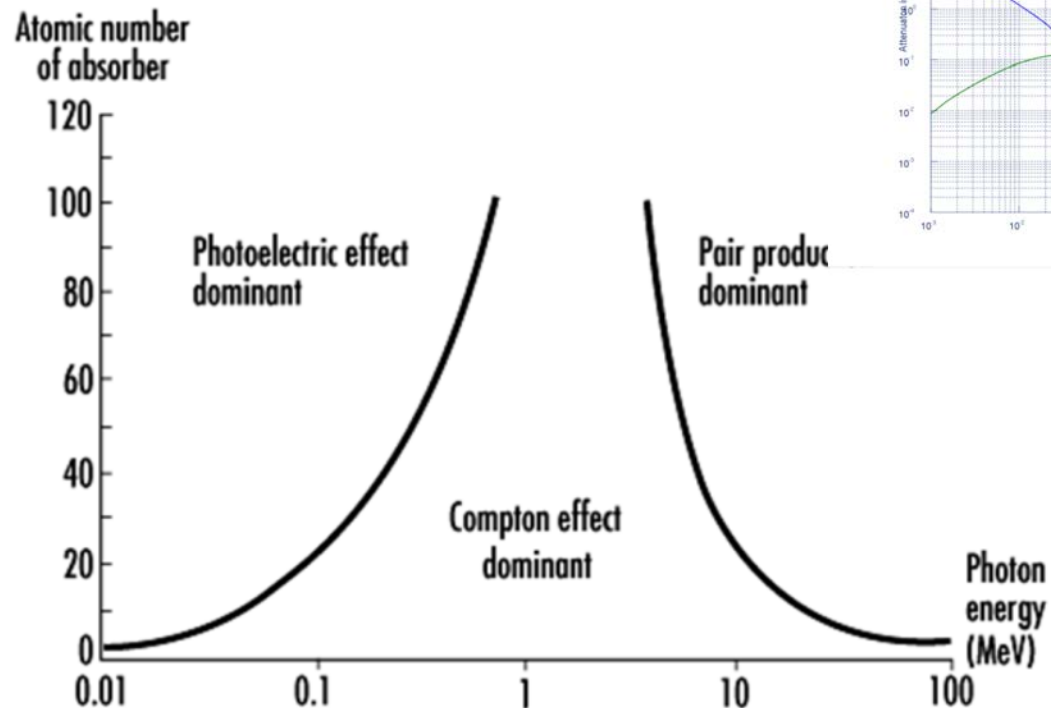
Electron data for Pb

Stopping Power - Collision (MeV cm²/g)

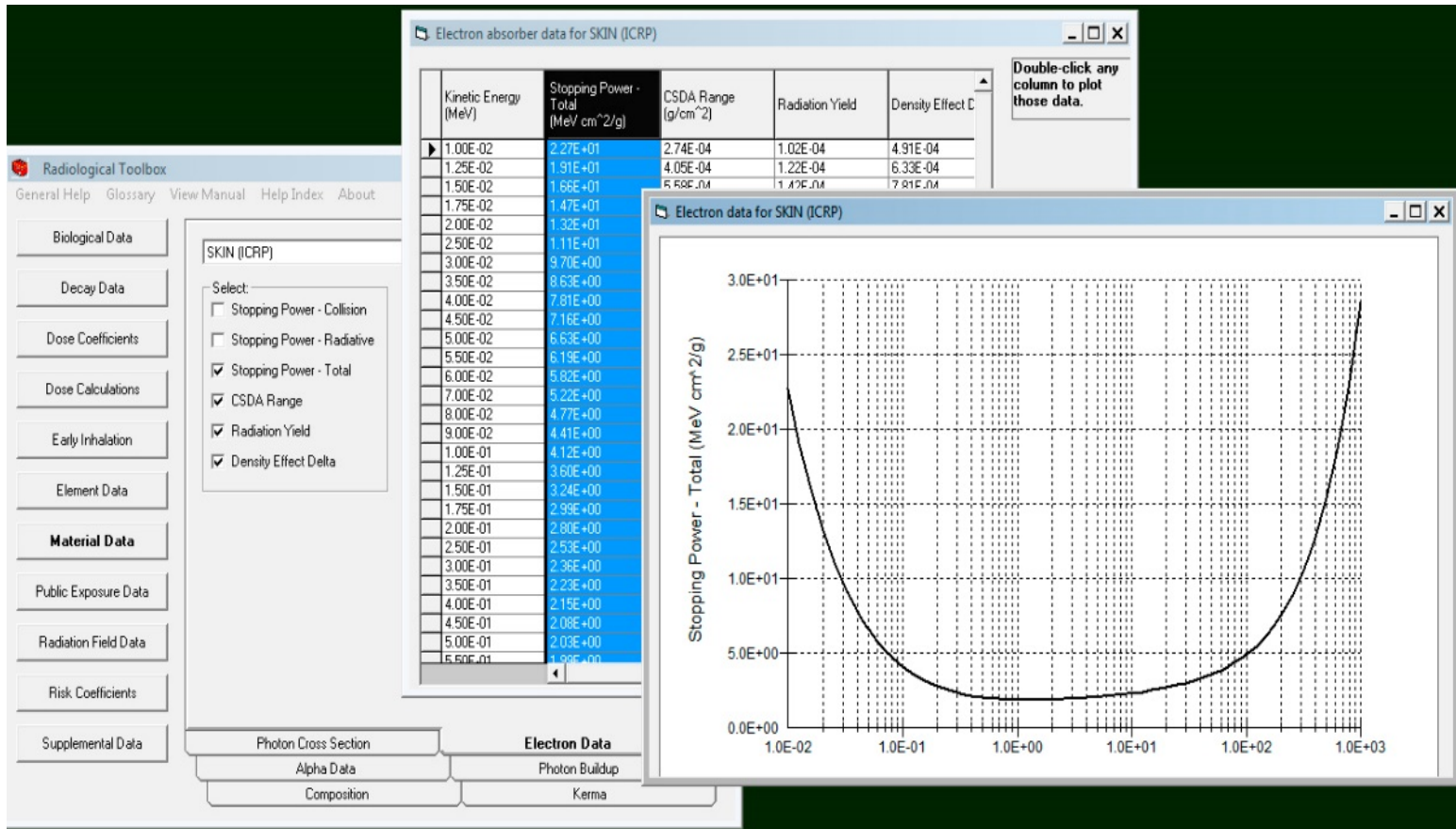
Kinetic Energy (MeV)

Print Set to Log/Log OK

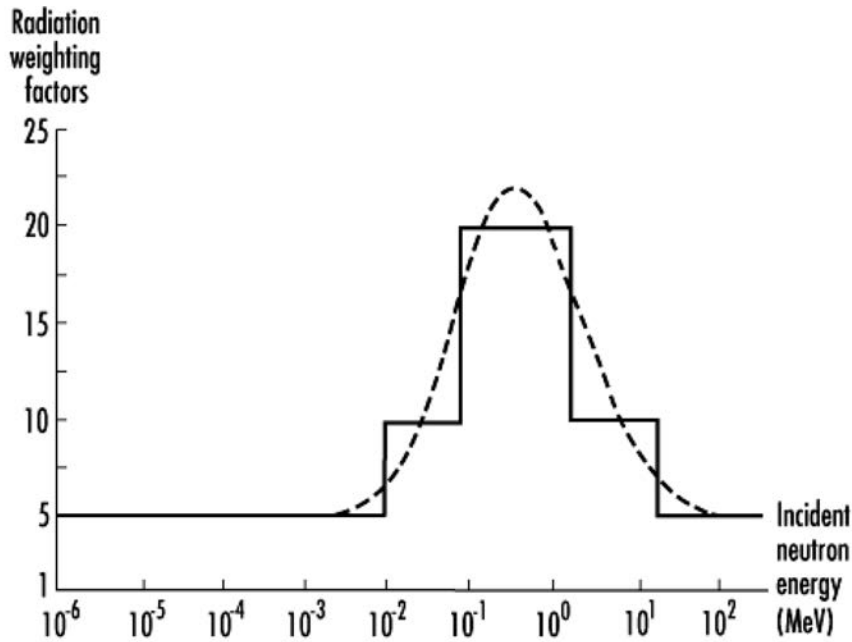
(6) Element Data (Fe)



(7) Material Data (Skin)

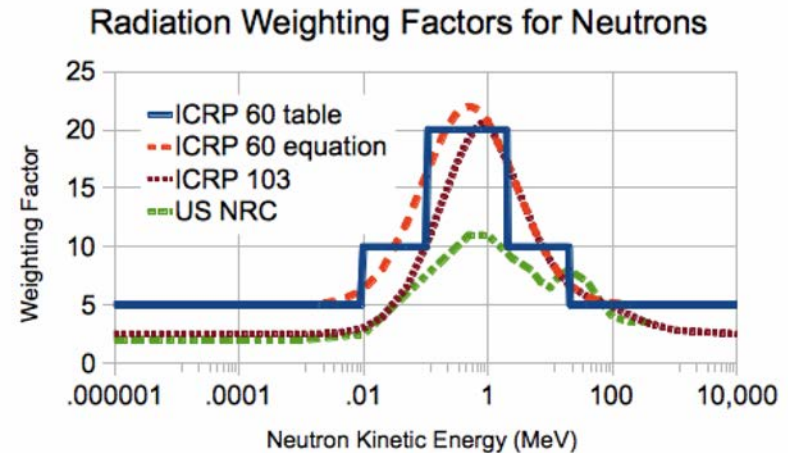


(7) Neutron “ w_R ”



$$w_R = \begin{cases} 2.5 + 18.2e^{-[\ln(E_n)]^2/6}, & E_n < 1 \text{ MeV} \\ 5.0 + 17.0e^{-[\ln(2E_n)]^2/6}, & 1 \text{ MeV} \leq E_n \leq 50 \text{ MeV} \\ 2.5 + 3.25e^{-[\ln(0.04E_n)]^2/6}, & E_n > 50 \text{ MeV} \end{cases}$$

ICRP 60 Radiation Weighting Factors	
Radiation type and energy	Weighting Factor w_R
Photons, all energies	1
Electrons, all energies	1
Neutrons, energy < 10 keV	5
10 - 100 keV	10
100 - 2000 keV	20
2 - 20 MeV	10
> 20 MeV	5
Protons, energy > 2 MeV	5
Alpha, fission fragments	20



(8) Public Exposure Data

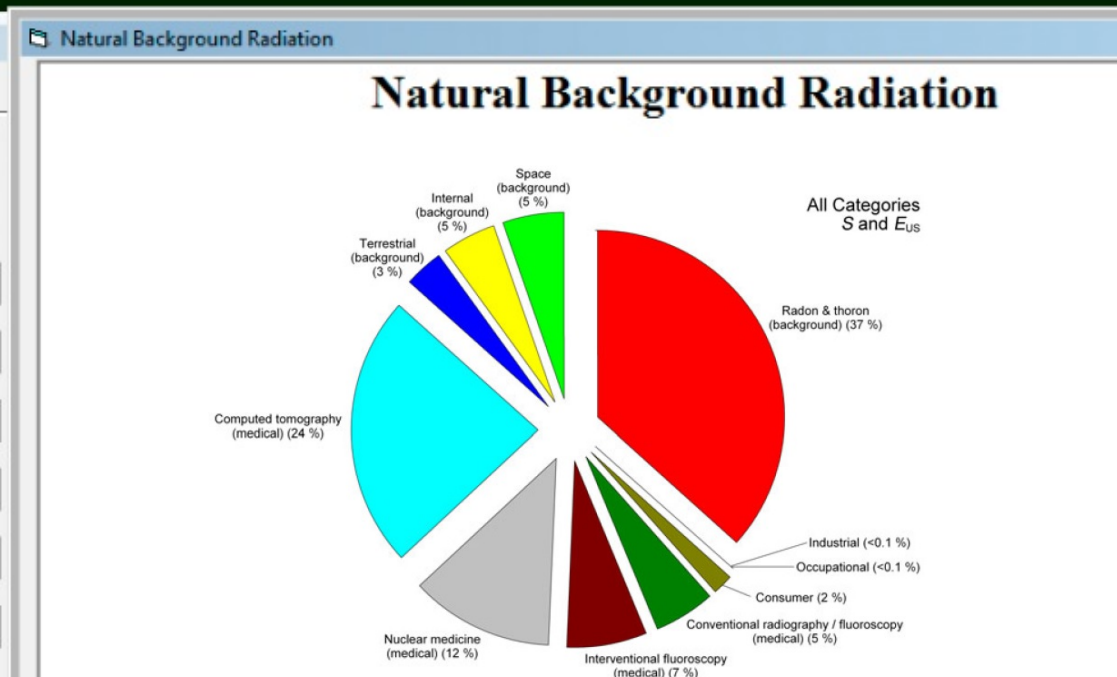
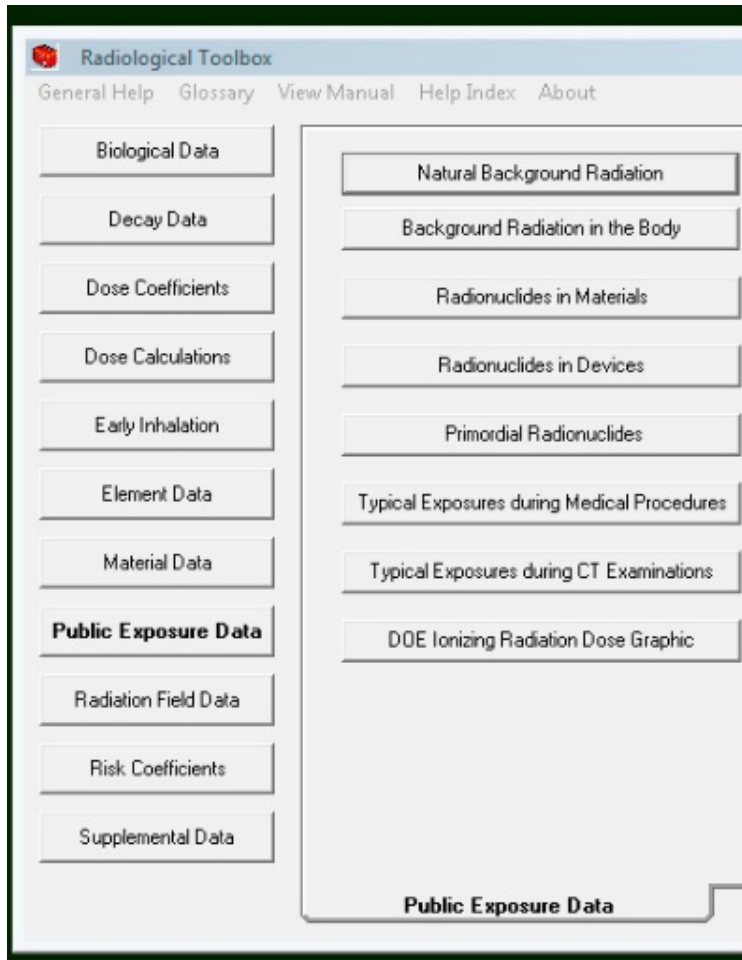


Fig. 1.1. Percent contribution of various sources of exposure to the total collective effective dose (1,870,000 person-Sv) and the total effective dose per individual in the U.S. population (6.2 mSv) for 2006. Percent values have been rounded to the nearest 1 %, except for those <1 % [see Table 1.1 for the values of S (person-sievert) and E_{US} (millisievert)].

(8) Basic NORM

Natural Occurring Radionuclides in Body		
Nuclide	Mass	Activity
Uranium	90 µg	1.1 Bq
Thorium	30 µg	0.11 Bq
Potassium 40	17 mg	4.4 kBq
Radium	31 pg	1.1 Bq
Carbon 14	22 ng	3.7 kBq
Tritium	0.06 pg	23 Bq
Polonium	0.2 pg	37 Bq



Radionuclides in Oceans	
Nuclide	Concentration
Uranium	33 mBq/L
Potassium 40	11 Bq/L
Tritium	0.6 mBq/L
Carbon 14	5 mBq/L
Rubidium 87	1.1 mBq/L

Radionuclides in Food		
Food	K-40 (pCi/kg)	Ra-226 (pCi/kg)
Banana	3520	1
Brazil nuts	5600	1000-7000
Carrots	3400	0.6 - 2
Potatoes	3400	1 - 2.5
Beer	390	-
Red meat	3000	0.5
Lima beans	4640	2 - 5
Drinking water	-	0 - 0.17

(8) Medical Exposures

Dose from Medical Diagnostic Procedures		
Procedure	Dose (rem)	Dose (mSv)
Chest x-ray (1 film)	0.01	0.1
Dental x-ray	0.16	1.6
Mammogram	0.25	2.5
Lumbosacral spine	0.32	3.2
Bone scan (Tc-99m)	0.44	4.4
Cardiac (Tc-99m)	0.75	7.5
Cranial CT	5	50
GI fluoroscopy (barium)	8.5	85
Spiral CT	3-10	30 - 100



Computed tomography examinations

Effective dose per CT scans	
Examination	Dose (mSv)
Head	2
Chest	7
Abdomen/pelvis	10
Extremity	0.1
CT angiography: heart	20
CT angiography: head	5
Spine	10
Interventional	0.1
Whole-body screening	10
Calcium scoring	2
Cardiac	20
Virtual colonography	10
Miscellaneous	5

(9) Radiation Field Data

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Select:

- ☒ Operational quantities
- ☐ AP - Antero-posterior geometry
- ☐ PA - Postero-anterior geometry
- ☐ LLAT - Left lateral geometry
- ☐ RLAT - Right lateral geometry
- ☐ ROT - Rotational geometry
- ☐ ISO - Isotropic geometry

Select Units

pSv cm²

Sv / Gy

Display Help

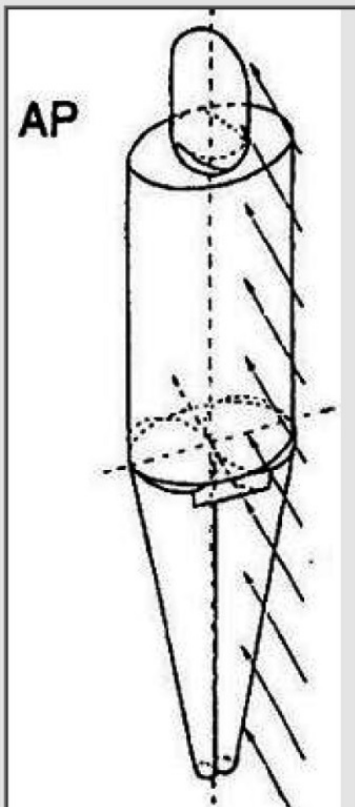
Refs

Note: For gamma constants, go the Decay Data / Summary display.

Photon Radiation Field (ICRP 74)

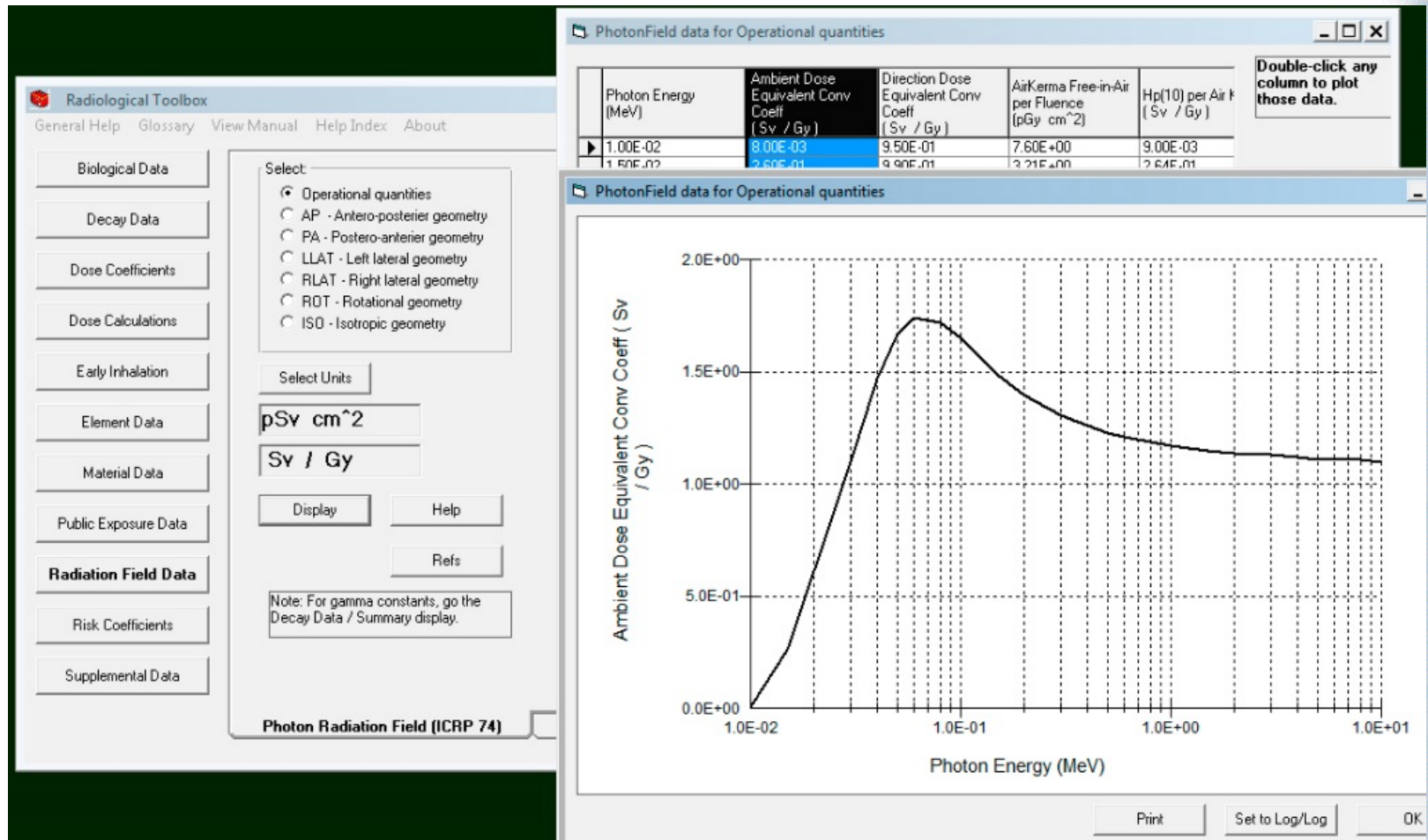
Neutron Radiation Field (ICRP 74)

AP

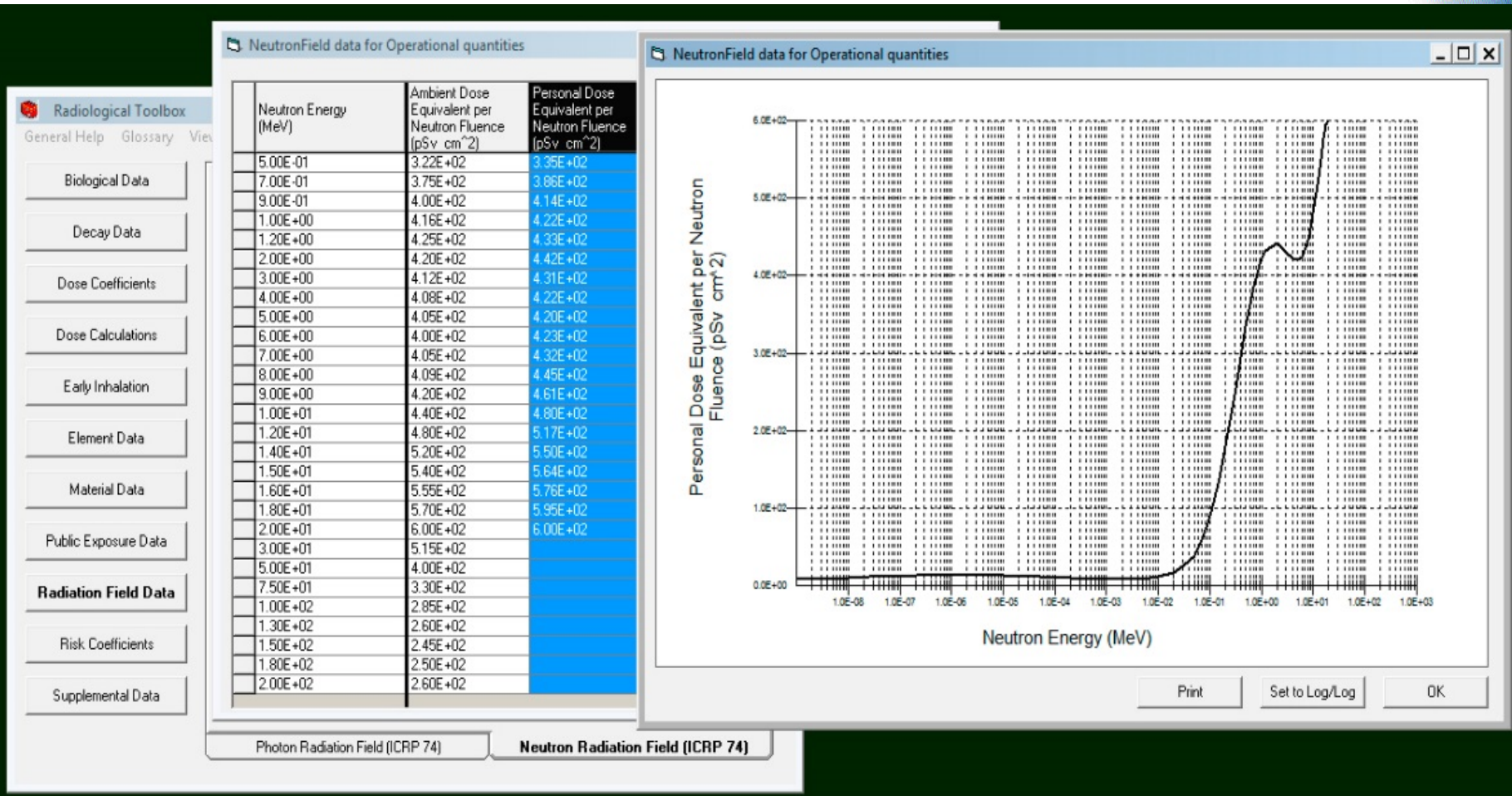


The diagram shows a human figure in an antero-posterior (AP) geometry. A dashed line represents the radiation beam entering from the front and exiting from the back. The beam is shown as a cylinder at the top and a cone at the bottom, with arrows indicating the direction of radiation. The label 'AP' is placed to the left of the figure.

(9) Operational (γ)



(9) Operational (n)



(10) Risk Coefficients



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Nuclide
C-14
I-131

Select intake mode:
☐ Ingestion
☐ Inhalation
☒ Air Submersion
☐ Ground Plane
☐ Soil Layer
☐ Include daughters?

rad_toolbox

 I-131 is not a valid nuclide name. Please use the choice list to enter names.

OK

Risk Coefficients (FGR 13)

(10) C-14 and I-131

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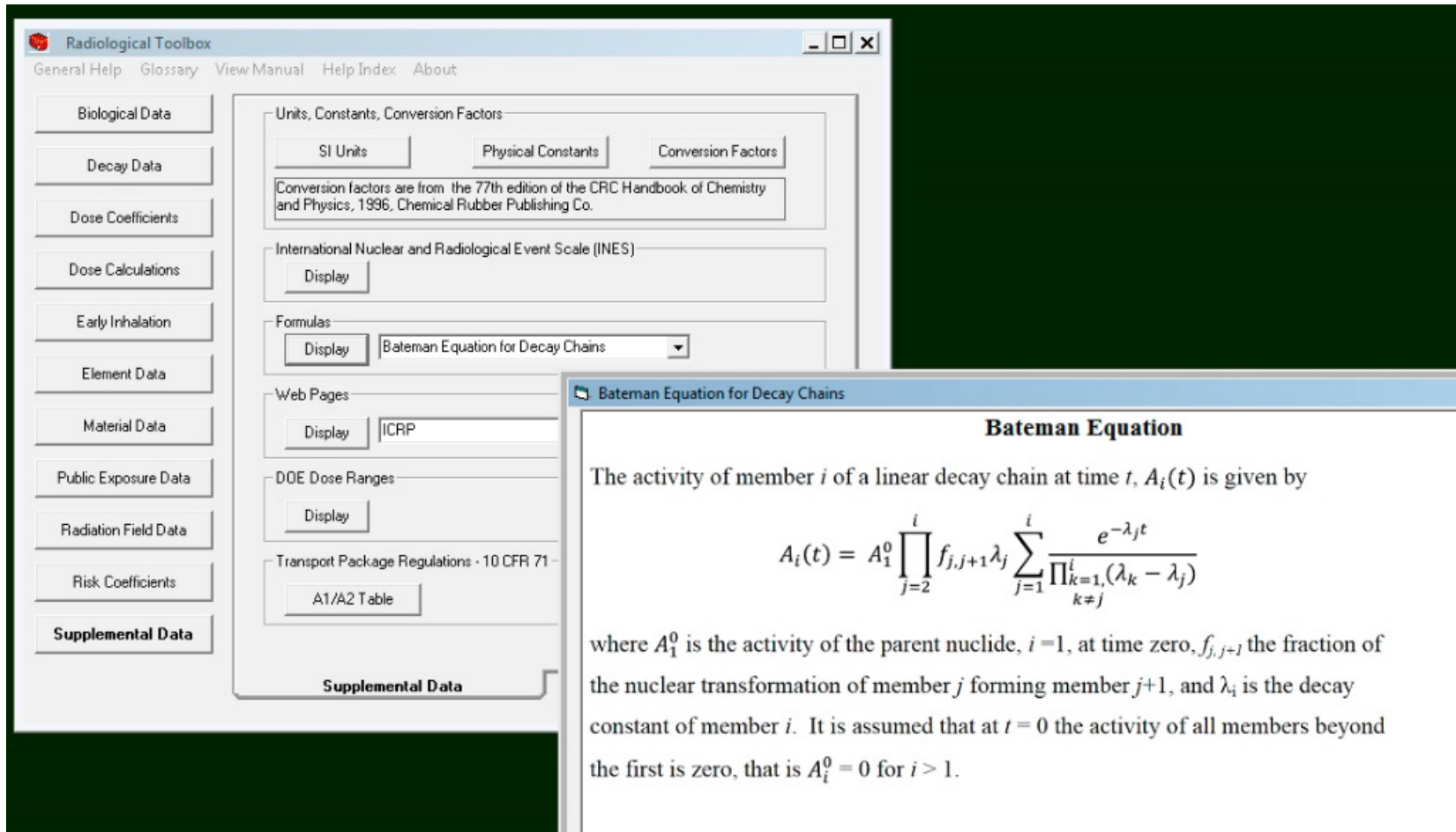
Nuclide: C-14, I-131
Select intake mode:
☒ Ingestion
☐ Inhalation
☐ Air Submersion
☐ Ground Plane
☐ Soil Layer

Ingestion risk coefficients (/ Bq) from

Nuclide	C-14
F1	1.00E+00
Intake	D Water
Cancer	mortality
esophagus	6.23E-13
stomach	2.20E-12
colon	4.88E-12
liver	8.86E-13
lung	4.94E-12
bone	5.41E-14
skin	5.13E-14
breast	2.13E-12
ovary	7.04E-13
bladder	1.47E-12
kidney	3.03E-13
thyroid	1.52E-13
leukemia	3.33E-12
residual	7.21E-12
Total	2.89E-11

Ingestion risk coefficients (/ Bq) from FGR 13									
	A	B	C	D	E	F	G	H	I
1	Ingestion risk coefficients (/ Bq) from FGR 13								
2	Nuclide	C-14		C-14		I-131		I-131	
3	F1	1.00E+00		1.00E+00		1.00E+00		1.00E+00	
4	Intake	D Water		Diet		D Water		Diet	
5									
6	Cancer	mortality	morbidity	mortality	morbidity	mortality	morbidity	mortality	morbidity
7	esophagu	6.23E-13	6.92E-13	7E-13	7.78E-13	2.22E-13	2.47E-13	2.75E-13	3.06E-13
8	stomach	2.2E-12	2.45E-12	2.93E-12	3.25E-12	1.28E-12	1.42E-12	1.75E-12	1.95E-12
9	colon	4.88E-12	8.87E-12	6.85E-12	1.25E-11	1.83E-12	3.32E-12	2.76E-12	5.01E-12
10	liver	8.86E-13	9.32E-13	9.89E-13	1.04E-12	8.67E-14	9.12E-14	1.02E-13	1.07E-13
11	lung	4.94E-12	5.2E-12	6.08E-12	6.4E-12	1.13E-12	1.18E-12	1.47E-12	1.54E-12
12	bone	5.41E-14	7.73E-14	6E-14	8.56E-14	1.3E-14	1.86E-14	1.46E-14	2.09E-14
13	skin	5.13E-14	5.13E-14	6.43E-14	6.43E-14	7.08E-15	7.08E-15	9.18E-15	9.18E-15
14	breast	2.13E-12	4.27E-12	2.86E-12	5.71E-12	3.24E-13	6.48E-13	4.58E-13	9.16E-13
15	ovary	7.04E-13	1.01E-12	7.97E-13	1.14E-12	7.46E-14	1.07E-13	8.91E-14	1.27E-13
16	bladder	1.47E-12	2.94E-12	1.58E-12	3.17E-12	2.01E-12	4.01E-12	2.18E-12	4.35E-12
17	kidney	3.03E-13	4.67E-13	3.41E-13	5.25E-13	2.76E-14	4.25E-14	3.25E-14	5.01E-14
18	thyroid	1.52E-13	1.52E-12	1.99E-13	1.99E-12	1.22E-10	1.22E-09	1.73E-10	1.73E-09
19	leukemia	3.33E-12	3.36E-12	3.62E-12	3.66E-12	6.17E-13	6.23E-13	6.83E-13	6.9E-13
20	residual	7.21E-12	1.02E-11	9.74E-12	1.37E-11	1.27E-12	1.78E-12	1.77E-12	2.49E-12
21	Total	2.89E-11	4.2E-11	3.68E-11	5.4E-11	1.31E-10	1.23E-09	1.85E-10	1.75E-09
22									
23									
24									

(11) Supplemental Data



The screenshot shows the 'Radiological Toolbox' application window. On the left is a sidebar with various data categories. The main window is divided into several sections: 'Units, Constants, Conversion Factors', 'International Nuclear and Radiological Event Scale (INES)', 'Formulas', 'Web Pages', 'DOE Dose Ranges', and 'Transport Package Regulations - 10 CFR 71'. The 'Supplemental Data' section is highlighted at the bottom of the main window. A pop-up window titled 'Bateman Equation for Decay Chains' is open, displaying the Bateman Equation and its components.

Bateman Equation

The activity of member i of a linear decay chain at time t , $A_i(t)$ is given by

$$A_i(t) = A_1^0 \prod_{j=2}^i f_{j,j+1} \lambda_j \sum_{j=1}^i \frac{e^{-\lambda_j t}}{\prod_{k=1, k \neq j}^i (\lambda_k - \lambda_j)}$$

where A_1^0 is the activity of the parent nuclide, $i=1$, at time zero, $f_{j,j+1}$ the fraction of the nuclear transformation of member j forming member $j+1$, and λ_i is the decay constant of member i . It is assumed that at $t = 0$ the activity of all members beyond the first is zero, that is $A_i^0 = 0$ for $i > 1$.



U.S. NRC
United States Nuclear Regulatory Commission

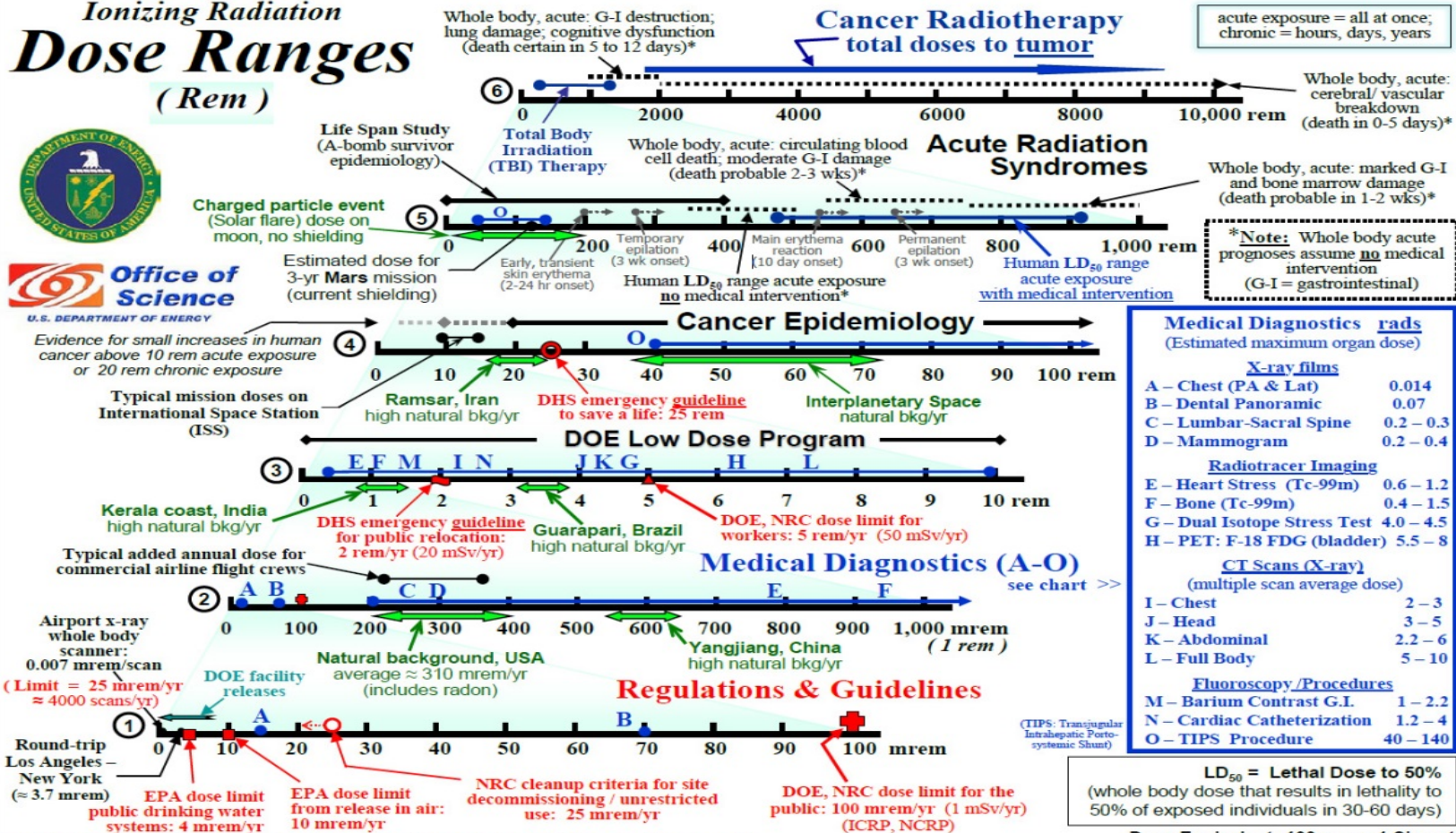
Protecting People and the Environment

(11) Supplemental Data

Ionizing Radiation Dose Ranges (Rem)



Office of Science
U.S. DEPARTMENT OF ENERGY



Medical Diagnostics rads (Estimated maximum organ dose)

X-ray films

A - Chest (PA & Lat)	0.014
B - Dental Panoramic	0.07
C - Lumbar-Sacral Spine	0.2 - 0.3
D - Mammogram	0.2 - 0.4

Radiotracer Imaging

E - Heart Stress (Tc-99m)	0.6 - 1.2
F - Bone (Tc-99m)	0.4 - 1.5
G - Dual Isotope Stress Test	4.0 - 4.5
H - PET: F-18 FDG (bladder)	5.5 - 8

CT Scans (X-ray)

(multiple scan average dose)

I - Chest	2 - 3
J - Head	3 - 5
K - Abdominal	2.2 - 6
L - Full Body	5 - 10

Fluoroscopy/Procedures

M - Barium Contrast G.I.	1 - 2.2
N - Cardiac Catheterization	1.2 - 4
O - TIPS Procedure	40 - 140

LD₅₀ = Lethal Dose to 50%
(whole body dose that results in lethality to 50% of exposed individuals in 30-60 days)

Dose Equivalent: 100 rem = 1 Sievert
= (absorbed dose x radiation quality)

Absorbed Dose: 100 rad = 1 Gray
1 rem ≈ 1 rad for x- and gamma-rays

("≈" stands for "approximately equal to")

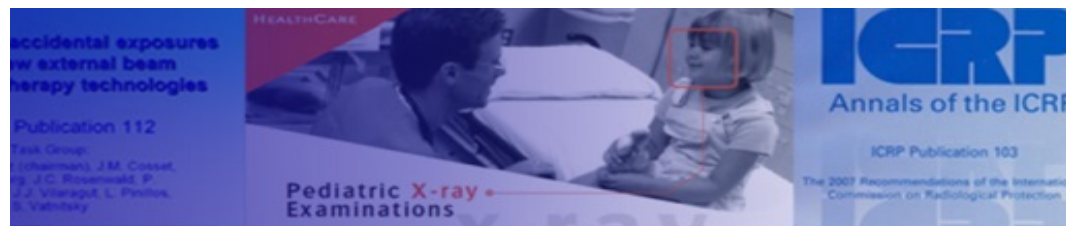
NOTE: This chart was constructed with the intention of providing a simple, user-friendly, "order-of-magnitude" reference for radiation exposures of interest to scientists, managers, and the general public. In that spirit, most quantities are expressed as "dose equivalent" in the more commonly used radiation protection units, the rem and Sievert. Medical diagnostics are expressed as estimated maximum organ dose, as they are not in "effective dose" they do not imply an estimation of risk (no tissue weighting). Dose limits are in effective dose, but for most radiation types and energies the difference is numerically not significant within this context. It is acknowledged that the decision to use these units is a simplification, and does not address everyone's needs. (NRC = Nuclear Regulatory Commission; EPA = Environmental Protection Agency; DHS = Department of Homeland Security) Disclaimer: Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information disclosed.

Chart compiled by NF Metting, Office of Science,
DOE/BER. "Orders of Magnitude" revised June 2010
<http://www.lowdose.energy.gov/>

Source: Office of Biological and Environmental Research (BER), Office of Science, U.S. Department of Energy
<http://www.science.doe.gov/ober/>

NUREG/CR-7166: Ch.3. HOW TO ACCESS RAD TOOLBOX FEATURES

- 1. Use Of The Nuclide Input Grid In Requesting Dose Coefficients**
- 2. Use Of The Choice Lists In Requesting Nuclide, Element, And Material Data**
- 3. How to Export Data**
- 4. Use The Activity Feature In Dose Calculations For A Decay Chain**
- 5. How to Define a Material and Calculate its Interaction Coefficients**
- 6. How to Generate Histogram Representation of Beta Spectra**
- 7. How to Check the Integrity of the Rad Toolbox Data Files**



Freebie:

In footnote of Page 9:
 “The numbers of nuclides differ between FGR 12 and **ICRP Publications 30, 68, and 72** as the latter set of publications **do not consider the intake of radionuclides of half-life less than 10 minutes.** The ICRP Database of Dose Coefficients: Workers and Members of the Public; Ver. 3.0 is now available as a free educational download;
<http://www.icrp.org/page.asp?id=145>.

Educational CD Downloads

Free Educational CD Downloads

The following files are downloadable installation files for CDs of dose coefficients available here at no cost. They can be used by teachers, students, and those interested in radiological protection together with their parent ICRP Publications. Please note that while we encourage you to download and use these CDs, ICRP retains copyright and you must not edit or attempt to repack these materials for sale.

These downloads replace ICRP [CD1](#), [CD2](#) and [CD3](#) which are now out of print. These free downloads are for Windows operating systems, including Win 7, on 32 and 64 bit machines.

ICRP Database of Dose Coefficients: Workers and Members of the Public; Ver. 3.0

Available as a Windows setup file named [ICRPDOSE_setup.exe](#).

ICRP Database of Dose Coefficients: Embryo and Fetus; Ver. 2.0

Available either as a Windows setup file named [ICRPCD2_setup.exe](#) or as a selfextracting file named [ICRPCD2_SelfExtract.exe](#).

ICRP Database of Dose Coefficients: Radionuclides in Mother's Milk; Ver. 2.0

Available either as a Windows setup file named [ICRPCD3_setup.exe](#) or as a selfextracting file named [ICRPCD3_SelfExtract.exe](#).

If the Help utility is not available for CD2 and CD3 it may be necessary to download from a program from Microsoft. See the ReadMe.txt file in the installation folder after installing these databases.

Please note that the dose coefficients in the first of the downloadable CDs listed above are the same as those in [ICRP Publication 119 "Compendium of Dose Coefficients based on ICRP Publication 60"](#). Although the downloadable CDs will be of practical use, the above-noted ICRP Publication will be the definitive and reference able compendium of these coefficients.

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Freebie:

NUREG-1350: ML15254A321.pdf

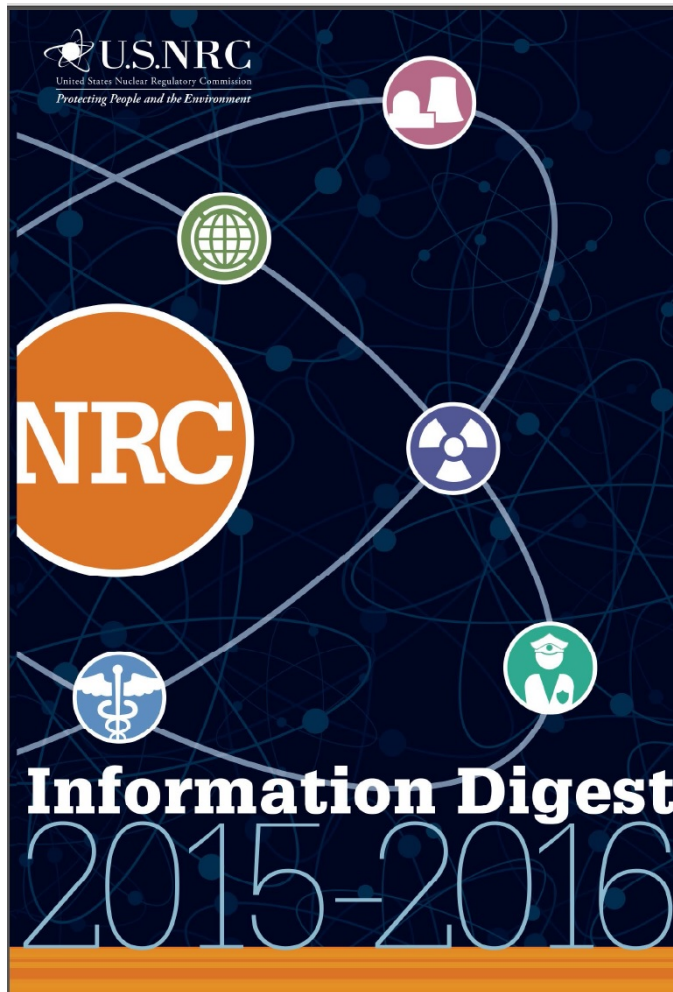
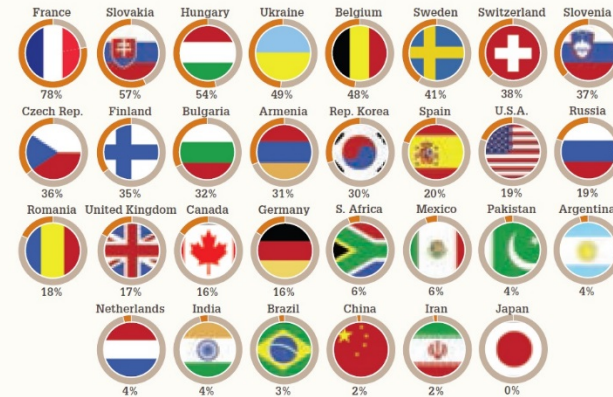
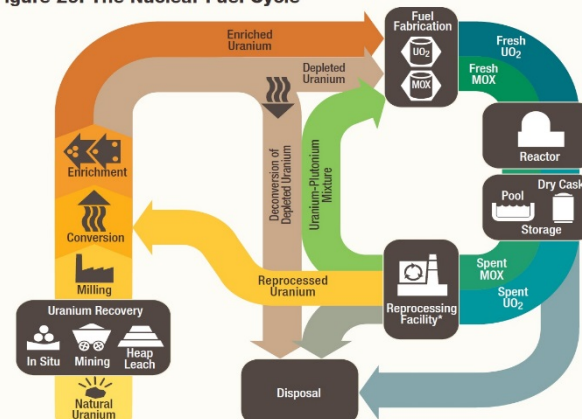


Figure 8. Nuclear Share of Electricity Generated by Country



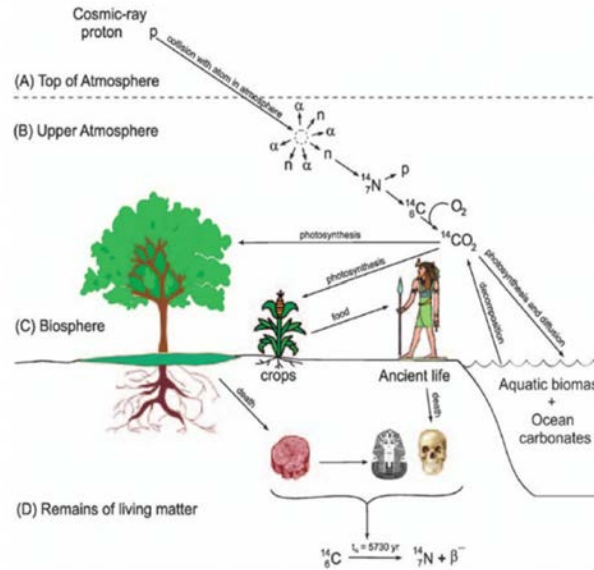
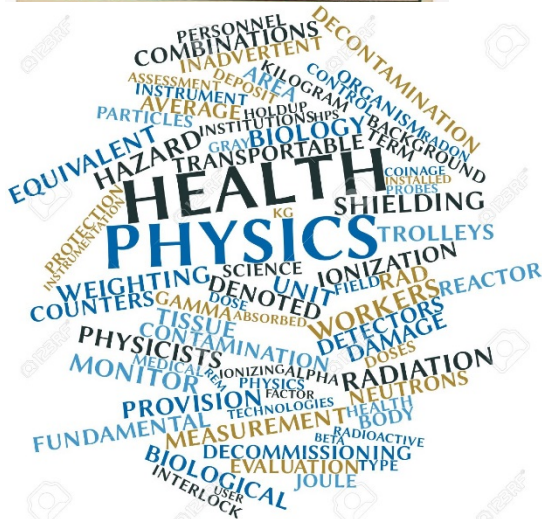
Note: The country's short-form name is used.
Source: IAEA, Power Reactor Information System database, as of May 2015

Figure 29. The Nuclear Fuel Cycle



* Reprocessing of spent nuclear fuel, including mixed-oxide (MOX) fuel is not practiced in the United States.
Note: The NRC has no regulatory role in mining uranium.

More Database?



$$C(x, y, z, t) = \frac{Q}{2\pi\mu\sigma_1\sigma_2} \cdot \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \left[\exp\left(-\frac{(z-H_0)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z+H_0)^2}{2\sigma_z^2}\right) \right]$$



United States Nuclear Regulatory Commission

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