



Radiological Toolbox

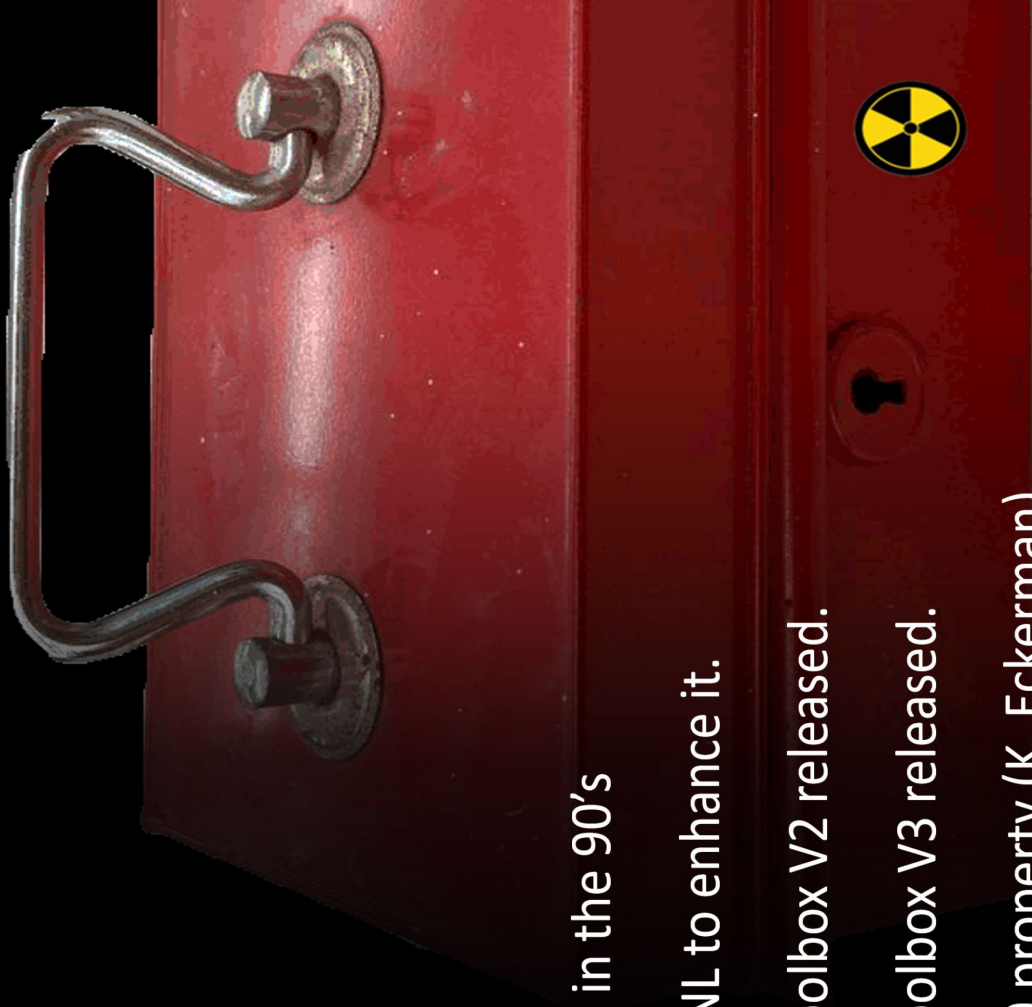
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Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission



October 27 2020

Fall 2020 USERS GROUP Virtual Meeting

Timelines



- “Rad-Toolbox” existed in the 90’s
- 2003 – NRC funds ORNL to enhance it.
- 2007 – Radiological Toolbox V2 released.
- 2013 – Radiological Toolbox V3 released.
- 2019 – Update Pu-240 property (K. Eckerman)

What's in the code?

- **Rad-Toolbox V3.0 (April 2013)**
 - Windows 7 & 10
 - TRM ready for NRC workstations
 - Code has 27 MB in one file.
- **User's Manual (May 2013)**
 - K.F. Eckerman and A.L. Sjoreen
 - In color and PDF searchable
 - References are up to date
 - Built-in under "View-Manual" tab

Something You Should Know about NUREG/CR- 7166

- Abstract and acknowledgement
- Ch.3. How to access Rad-Toolbox features
- User's Guide, PDF: Can be highlighted or add your notes ...
- Knowing bugs: The decay chain graphics have not been tested for all potential parent nuclides.
- The default units of the original data are used.
- Runtime Error '3051' has been received. Your input and feedback are welcome.
- A “note of caution” in Page 10.
- The software can be removed by clicking on the unins000.exe that resides in the Toolbox folder

Must Know the Basic!

$$A = \lambda N$$

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

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

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

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

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

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

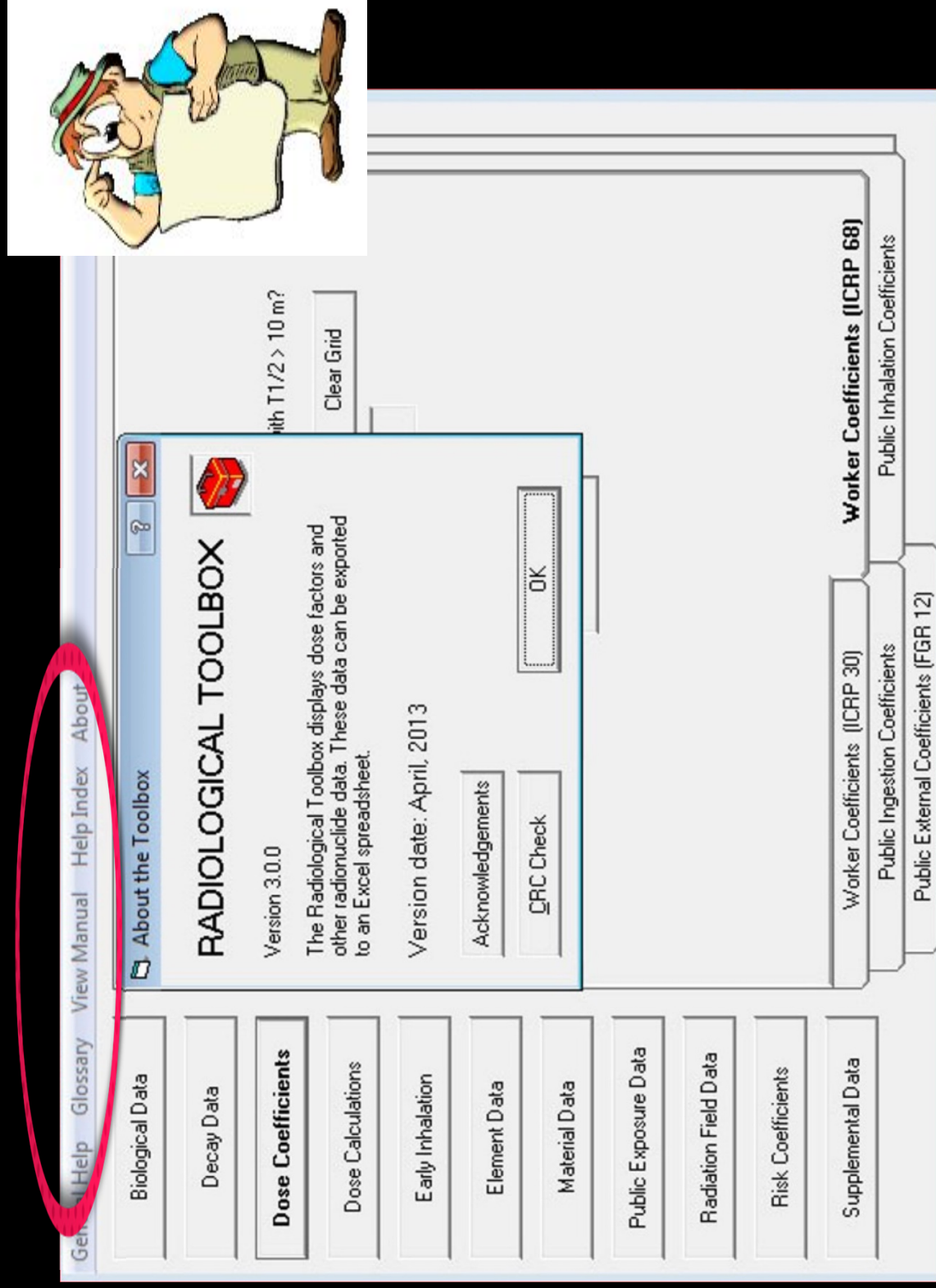
HP Constants

Useful Constants and Conversions

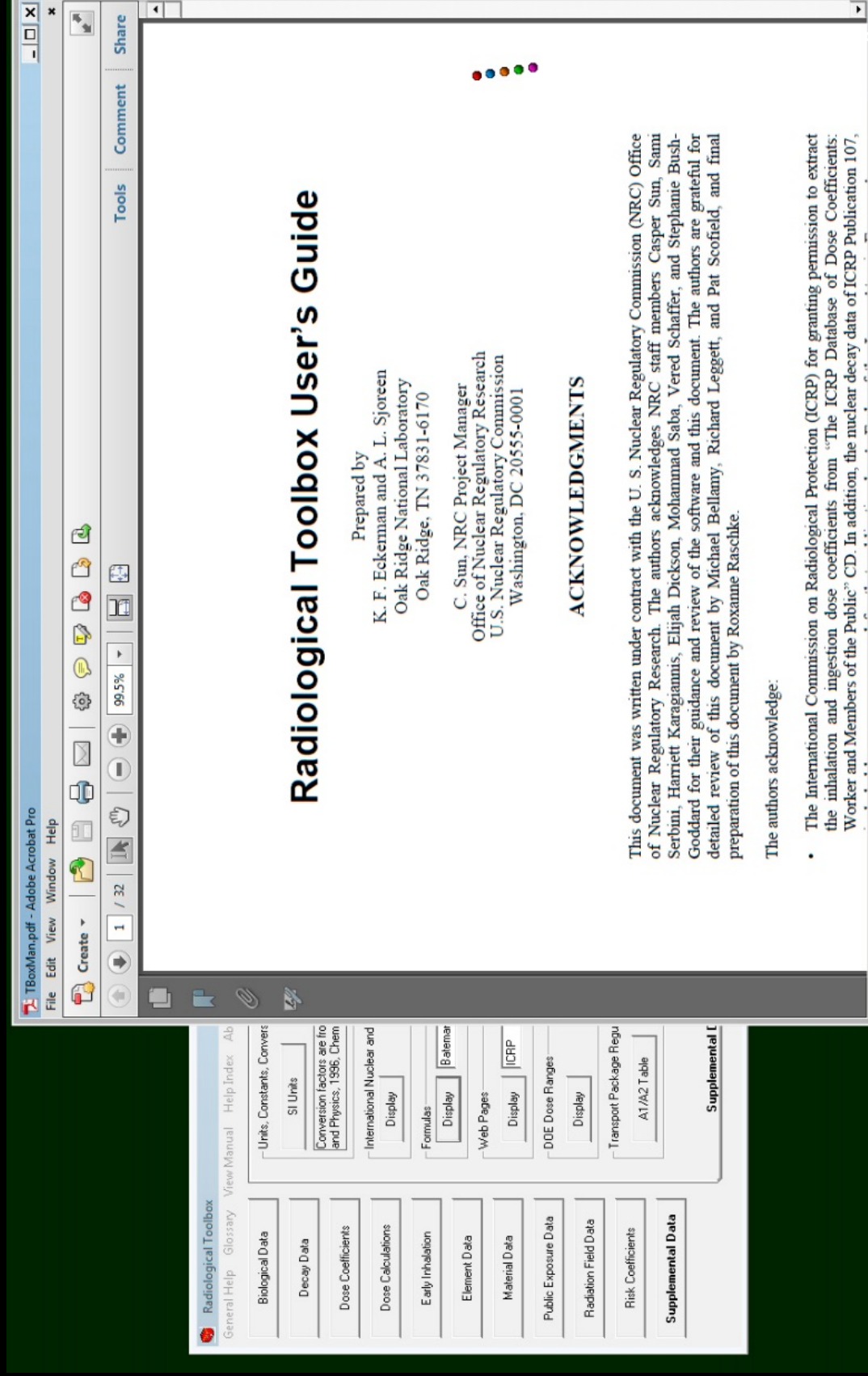
Avogadro's number	$6.023 \times 10^{23} \text{ mol}^{-1}$
Planck's constant	$6.625 \times 10^{-34} \text{ J s}$
volume of ideal gas (STP)	22.4 L mol^{-1}
charge (e^{-1})	$1.602 \times 10^{-19} \text{ C}$
roentgen (STP)	$2.58 \times 10^{-4} \text{ C kg}^{-1}$
1 MeV	$1.602 \times 10^{-13} \text{ J}$
1 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



ABOUT: Menu-Bar



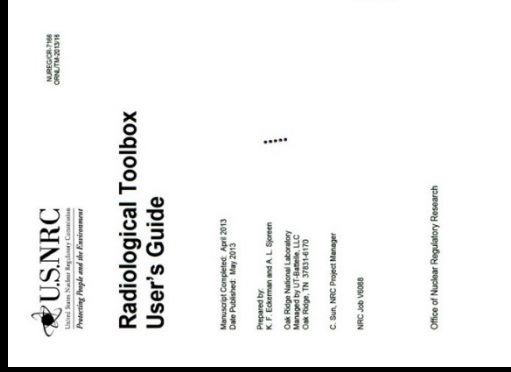
Menu Bar has ...



The 11 Databases (db)

db collection db Description (Table 1.1 from NUREG/CR-7166)

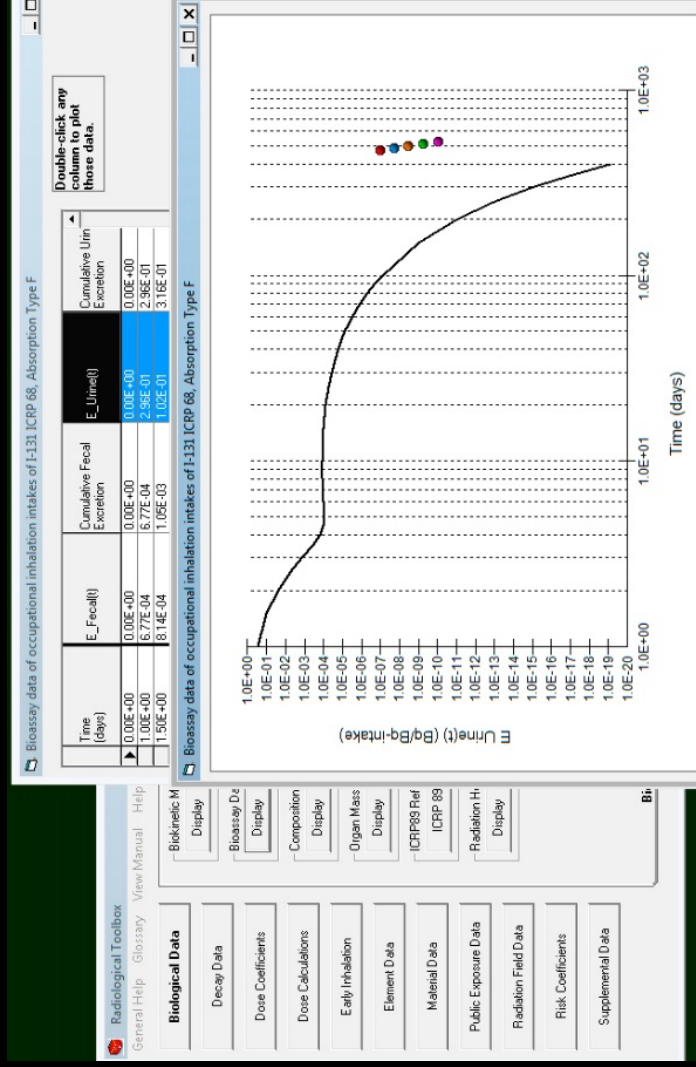
1	Biological Data	Biokinetic models, reference anatomical data, bioassay data, and summary information on radiation health effects
2	Decay Data	Detailed information on the radiations emitted by radionuclides and members of serial decay chains
3	Dose Coefficients	Internal dose coefficients for intakes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





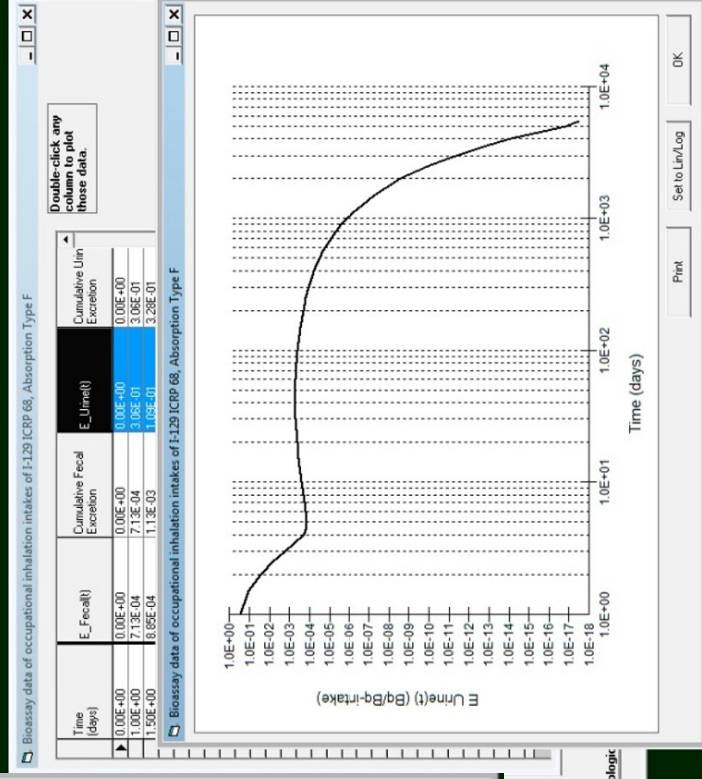
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(db1) Biological Database: I-131 and I-129 Excretions



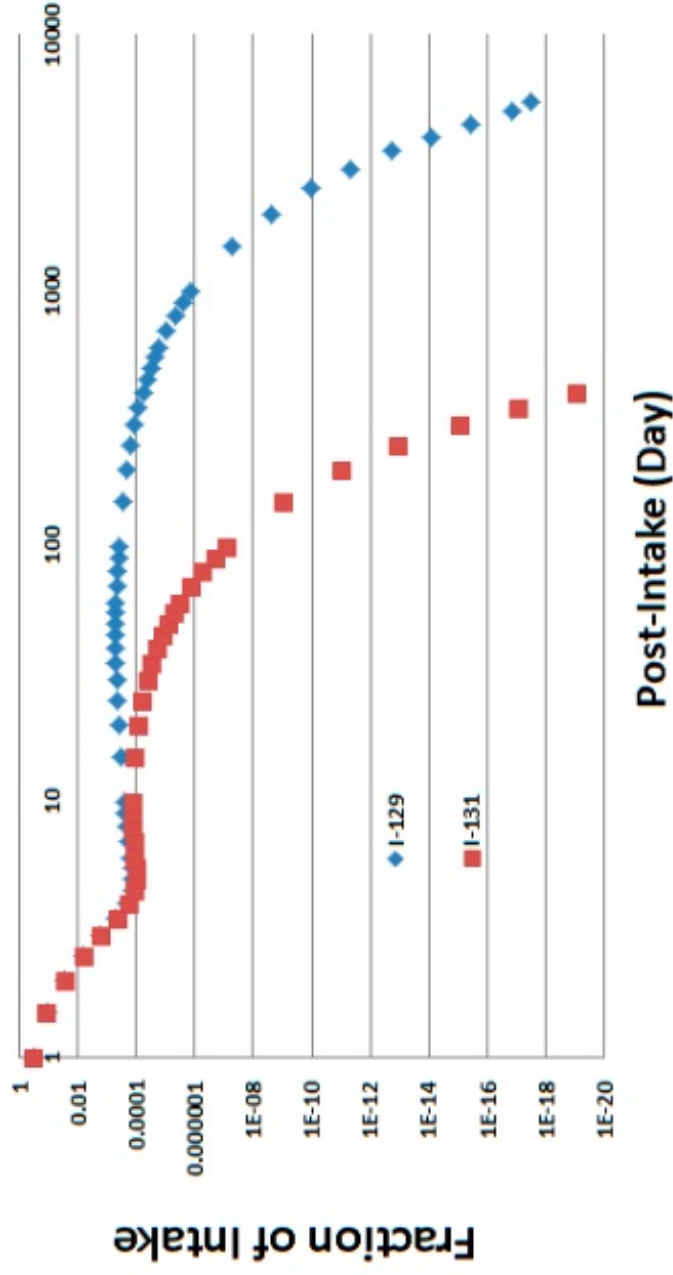
Radioactive Properties of Key Iodine Isotopes						
Isotope	Half-Life	Specific Activity (Ci/g)	Decay Mode	Radiation Energy (MeV)		
				Alpha (α)	Beta (β)	Gamma (γ)
I-129	16 million yr	0.00018	β	-	0.064	0.025
I-131	8.0 days	130,000	β	-	0.19	0.38

EC = electron capture, Ci = curie, g = gram, and MeV = million electron volts; a dash means the entry is not applicable. (See the companion fact sheet on Radioactive Properties, Internal Distribution, and Risk Coefficients for an explanation of terms and interpretation of radiation energies.) Values are given to two significant figures.



Excel plot of Toolbox exported data for “Urine Bioassay Interpretations”

24-h Urine Excretion Function



“Positive”
Bioassay!



"You're fired, Jack. The lab results just came back, and you tested positive for Coke."

(db2) Decay Database

Radiological Toolbox
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Decay Data

Biological Data
Dose Coefficients
Dose Calculations
Early Inhalation
Element Data
Material Data
Public Exposure Data
Radiation Field Data
Risk Coefficients
Supplemental Data

Nuclide: **Ac-223**

Select type of data:
☒ Energy-Intensity Data
☐ Beta Spectrum
☐ Decay Chain Table
☐ Decay Chain Graph
☐ Activity
☐ Summary

Select level of $E \times I$ data to display:
☐ > 20% of all (E^{γ})
☐ > 10% of all (E^{γ})
☐ > 1% of all (E^{γ})
☐ > 0.1% of all (E^{γ})
☒ all radiations

Units: **Bq / kg**

Decay time for activity calculation: **1.0** years

ICRP 107 Data

Display Help

Rel's
Air-Kerma Rate Constants
Periodic Table

Isotopes

(db3) DC for Pu-241 (a)

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Biological Data
Decay Data
Dose Coefficients

Select age:
☐ Newborn
☐ 1 yr-old
☐ 5 yr-old
☐ 10 yr-old
☒ 15 yr-old
☐ Adult

☒ Include daughters with T1/2 > 10 m?

Select Units: **Sv / Bq**
 Display
 Help
 Refs
 Clear Grid

Coefficients
 Public Inhalation Coefficients
 Public Inhalation Coefficients (FGR 12)
 Worker Coefficients (ICRP 30)
 Worker Coefficients (ICRP 68)

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
f1	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
Extrathoracic 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	7.50E-14	7.10E

Pu-241
 Ag-110m
 Ra-226
 Am-241
 Mo-99

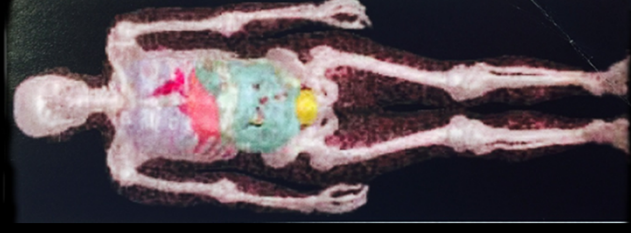
Print
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 OK



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DC for Pu-241 (b)

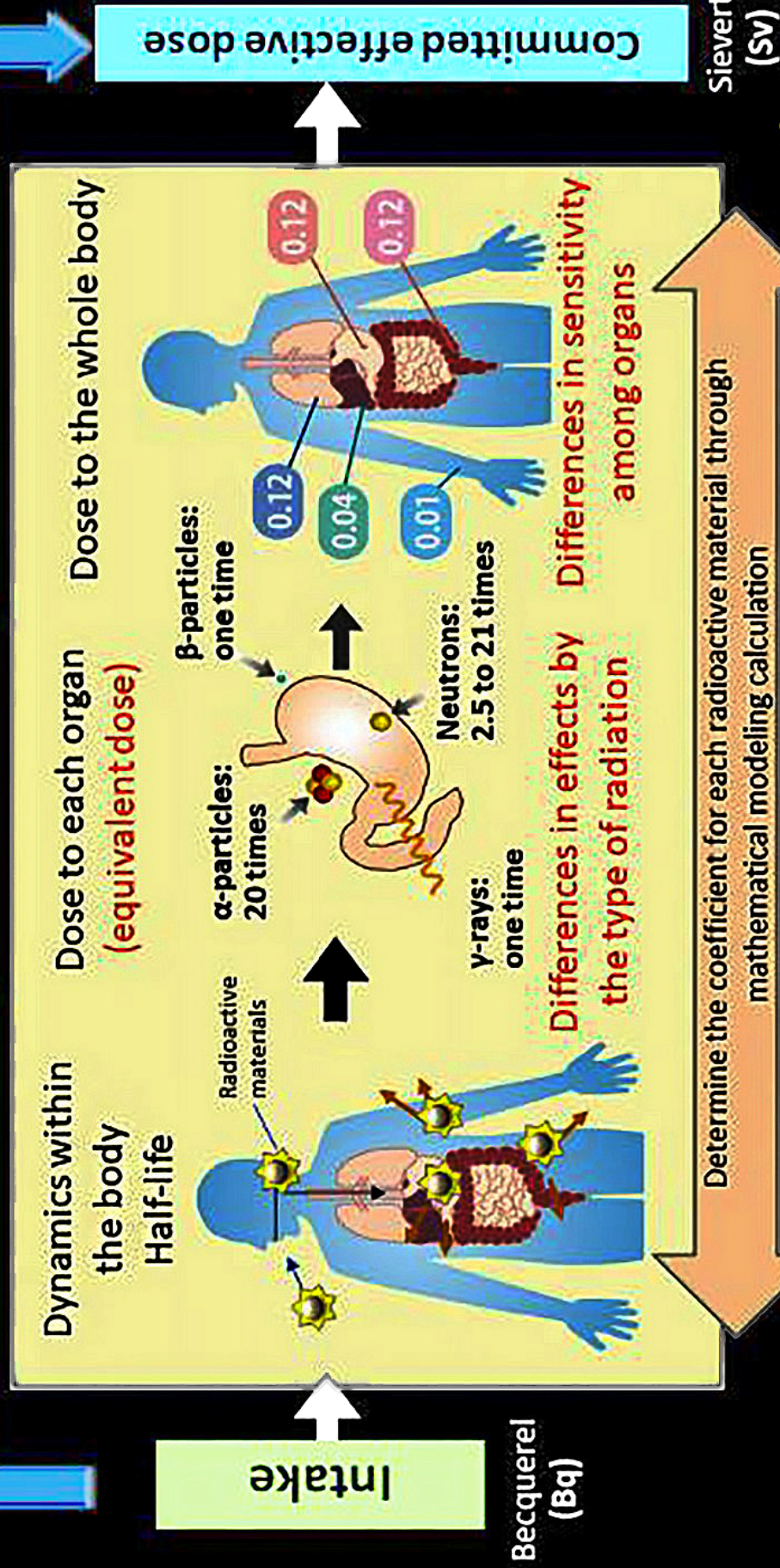
Clipboard		Bluetooth	Font		f _x		Ingestion Adult dose coefficients (Sv / Bq) from ICRP 72		Alignment		Number	
A1												
A	B	C	D	E	F	G	H	I	J	K	L	M
Adult dose coefficients (Sv / Bq) from ICRP 72												
1 Ingestion	Pu-241	Am-241	U-237	Np-237	Pa-233	U-233	Th-229	Ra-225	Ac-225	Bi-213	Pb-209	
2 Nuclide	14.4y	432.2y	6.75d	2.14E6y	27.0d	1.585E5y	7340y	14.8d	10.0d	45.65m	3.253h	
3 Half Life	0.0005	0.0005	0.02	0.0005	0.0005	0.02	0.0005	0.2	0.0005	0.05	0.2	
4 f1	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	
5 Adrenals	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	
6 Urinary Bl	1.6E-07	0.00009	1E-10	5.4E-06	6.6E-11	8.4E-07	0.00023	3.6E-06	4.9E-08	4.6E-12	1.4E-11	
7 Bone Surf	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	
8 Brain	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	
9 Breast	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	
10 Esophagus	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	
11 Stomach	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	
12 Small Inte	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	
13 Upper 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	
14 Lower Lar	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	
15 Colon	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	
16 Kidneys	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	
17 Liver	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	
18 Muscle	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	
19 Ovaries	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	
20 Pancreas	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	
21 Red Marr	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	
22 Extratrach	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	
23 Lungs	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	
24 SKin	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	
25 Spleen	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	
26 Testes	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	
27 Thymus	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	
28 Thyroid	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	
29 Uterus	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	
30 Remainde	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	



Primer for db (4)

Age-related differences are taken into account in calculating committed effective dose coefficients.

Multiply $\times$ Committed effective dose coefficient





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(db4) Dose Calculations

Clipboard Font Alignment Number Cells Editing

A1 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 Nucl
3	Half Life	24065y	703.86y	25.52h	3.276y						
4	f1	0.0005	0.02	0.0005	0.						
5	Adrenals	1.4E-08	2.6E-08	4.8E-13	5						
6	Urinary Bl	1.4E-08	2.6E-08	2.9E-12	4.5						
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	1.2						
12	Small Inte	1.7E-08	2.8E-08	4.4E-10	1.2						
13	Upper Larj	3.3E-08	4.3E-08	1.9E-09	1.5						
14	Lower Larj	6.7E-08	7.8E-08	3.4E-09	1.4						
15	Colon	4.8E-08	5.8E-08	2.5E-09	1.3						
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	4.5						
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 Marrc	3.9E-07	7.6E-08	1.8E-12	2.5						
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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Radiological Toolbox

Biological Data

Decay Data

Dose Coefficients

Dose Calculations

Early Inhalation

Material Data

Public Exposure Data

Radiation Field Data

Risk Coefficients

Supplemental Data

Select intake route: Ingestion Inhalation Paste Decay

Select Units: Ci

Display Help Refs

Ingestion dose coefficients (Sv / Bq) from FGR12

Nuclide	Pu-239	Pu-239	Pu-239	Pu-239	U-235
f1	1.00E-05	1.00E-04	1.00E-03	1.00E-03	2.00E-03
Adrenals	8.28E-14	7.95E-13	7.92E-12	1.05E-10	1.05E-10
Bladder Wall	1.25E-13	7.98E-13	7.52E-12	1.65E-10	1.65E-10
Bone Surface	1.78E-07	1.78E-06	1.78E-05	4.20E-08	4.20E-08
Brain	7.68E-14	7.68E-13	7.68E-12	0.00E+00	0.00E+00
Breast	1.21E-13	8.09E-13	7.68E-12	1.21E-10	1.21E-10
Esophagus	7.54E-14	7.51E-13	7.51E-12	9.81E-11	9.81E-11
Stomach Wall	1.19E-09	1.19E-09	1.20E-09	1.23E-09	1.23E-09
Small Intestine Wall	2.99E-09	2.99E-09	2.99E-09	3.03E-09	3.03E-09
Upper Large Intestine Wall	1.73E-08	1.73E-08	1.73E-08	1.69E-08	1.69E-08
Lower Large Intestine Wall	5.31E-08	5.31E-08	5.30E-08	5.33E-08	5.33E-08
Kidneys	8.78E-14	7.76E-13	7.68E-12	1.73E-08	1.73E-08
Liver	3.14E-08	3.14E-07	3.14E-06	1.14E-10	1.14E-10
Lungs	7.89E-14	7.75E-13	7.74E-12	1.01E-10	1.01E-10
Muscle	1.21E-13	8.09E-13	7.68E-12	1.21E-10	1.21E-10
Ovaries	2.64E-09	2.64E-08	2.64E-07	3.34E-10	3.34E-10
Pancreas	9.99E-14	7.88E-13	7.68E-12	1.23E-10	1.23E-10
Red Marrow	1.41E-08	1.41E-07	1.41E-06	2.78E-09	2.78E-09
Skin	8.17E-14	7.63E-13	7.57E-12	1.04E-10	1.04E-10
Spleen	8.47E-14	7.64E-13	7.55E-12	1.15E-10	1.15E-10
Testes	2.64E-09	2.64E-08	2.64E-07	1.15E-10	1.15E-10
Thyroid	7.50E-14	7.51E-13	7.51E-12	9.81E-11	9.81E-11
Uterus	1.38E-13	8.11E-13	7.54E-12	1.89E-10	1.89E-10
Effective (ICRP 26)	1.40E-08	9.96E-08	9.56E-07	7.22E-09	7.22E-09
Effective (ICRP 60)	1.21E-08	6.20E-08	5.62E-07	7.42E-09	7.42E-09

Worker Coefficients (ICRP 30)

Public Ingestion Coefficients

Public Inhalation Coefficients

Export OK

(db5) ARS: Early Inhalation



Radiological Toolbox

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Biological Data
Decay Data
Dose Coefficients
Dose Calculations
Early Inhalation

Nuclide: I-125
Absorption Type: F
Integration Periods: 10, 2, 5, 0, 7, 0, 10
Units: Gy / Bq
Display: Normal

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

Select units: Gy / Bq

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/calvascular. The neurovascular syndrome occurs at very high absorbed dose (above 10 Gy) and not typically achievable by internal emitters.

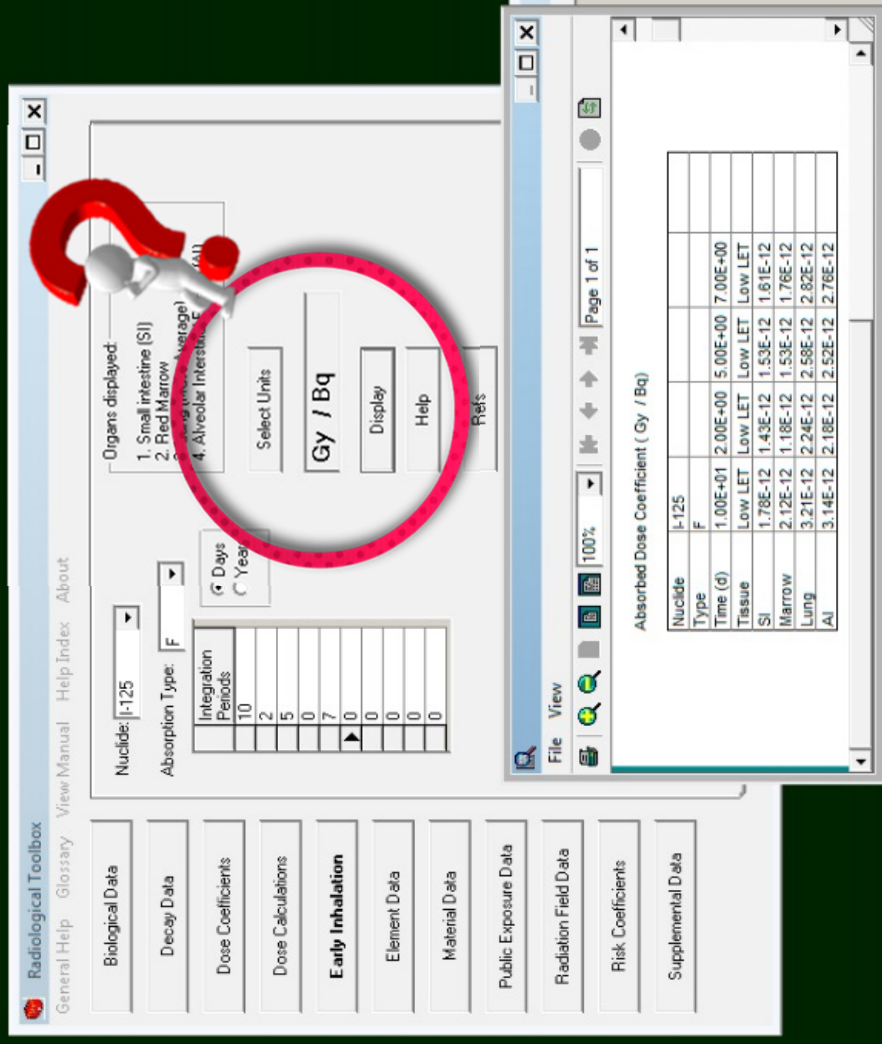
The toolbox addresses 4 tissues: 1) *Red marrow* (hematopoietic syndrome), 2) *Small intestine* (gastrointestinal syndrome), 3) *Lung* (mass average) and 4) *Alveolar Interstitial Region*. The later two are of interest with regard to damage to the respiratory tract. The user can define the time period 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.



(db5) I-125 Dose Coeff.



Radiological Toolbox
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Nuclide: I-125
 Absorption Type: F
 Integration Periods: 10, 2, 5, 0, 7, 0, 0, 0, 0, 0
 Units: Days, Year
 Select Units: Gy / Bq
 Display Help

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

Absorbed Dose Coefficient (Gy / Bq)

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

