Radiation: What’s in you today?

Annual Exposure Expressed in “Effective Dose Equivalent”

<table>
<thead>
<tr>
<th>Source</th>
<th>mrem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural</td>
<td>200</td>
</tr>
<tr>
<td>Radon</td>
<td>100</td>
</tr>
<tr>
<td>Other</td>
<td>0.90</td>
</tr>
<tr>
<td>Occupational</td>
<td>0.05</td>
</tr>
<tr>
<td>Nuclear Fuel Cycle</td>
<td>16,000</td>
</tr>
<tr>
<td>Tobacco</td>
<td>5 - 13</td>
</tr>
<tr>
<td>Other Environmental Sources</td>
<td>0.06</td>
</tr>
<tr>
<td>Medical:</td>
<td>14</td>
</tr>
<tr>
<td>Diagnostic X-rays</td>
<td>39</td>
</tr>
<tr>
<td>Nuclear Medicine</td>
<td>14</td>
</tr>
<tr>
<td>Approximate Total:</td>
<td>360</td>
</tr>
</tbody>
</table>

Source: U.S. NRC, NCRP Report 393, 1997

NATURAL 82%

MANUFACTURED 18%

<table>
<thead>
<tr>
<th>Source</th>
<th>mrem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical X-rays (11%)</td>
<td>11</td>
</tr>
<tr>
<td>Nuclear Medicine (4%)</td>
<td>4</td>
</tr>
<tr>
<td>Consumer Products (3%)</td>
<td>3</td>
</tr>
<tr>
<td>Other (15%)</td>
<td>15</td>
</tr>
<tr>
<td>Occupational</td>
<td>0.3</td>
</tr>
<tr>
<td>Fallout</td>
<td>0.3</td>
</tr>
<tr>
<td>Nuclear Fuel Cycle</td>
<td>0.1</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Note: Discrepancies, math errors, etc., even when the values are supposedly based on the same source (such as the nuclear fuel cycle values shown above) are not uncommon in science.

The longer you live, the more radiation your body must endure. Radiation is everywhere. But nevertheless, the less you get, the better.

To some extent, and maybe to a large extent, your cumulative dose determines your risk.

Natural radioactive “hits” per second: ~15,000*

Cumulative over 80 years: ~38,000,000,000,000

“Hits” per second in your body allowed by U.S. EPA from tritium alone: 29,600

Cumulative over 80 years: ~75,000,000,000,000

From a “typical” medical x-ray: >1,000,000,000,000*

From one CT-Scan: ~500,000,000,000,000

The risk of cancer from one CT Scan is currently estimated at about one in one thousand -- but even after all these years, nobody really knows.

* Source Coding: The Nuclear Energy Option, Chapter 5

Pathways to Ingestion:

<table>
<thead>
<tr>
<th>Source</th>
<th>mrem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radon</td>
<td>55%</td>
</tr>
<tr>
<td>Medical Products</td>
<td>3%</td>
</tr>
<tr>
<td>Other</td>
<td>1%</td>
</tr>
</tbody>
</table>

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Biological Half-life

The biological half-life of an element (the point in time when half of a foreign substance once in the body is no longer in the body) is NOT the same as the radiological half-life. After 20 radiological half-lives, only 2^-20 of a substance will remain (about one millionth of the original amount). But when, for example, tritium poisons the body, some of it will bind “permanently” masquerading as a stable, useful hydrogen atom, until the moment of radioactive decay.
High-energy, high-speed emissions, such as alpha (α) and beta (β) particles, neutrons, protons, x-rays and gamma (γ) rays, penetrate the human body and other things, causing biological, chemical, and/or physical damage. Energy of emissions is usually measured in megavolts (MeV). The biological half-life will be the same for all isotopes of a substance but will not always be the same for all organs. In any case, the biological half-life should be taken with a large “grain of salt” since some portion of any biological assault usually remains permanently in your body. Short radiological half-lives have no biological half-life listed; the assumption is that they will probably decay internally before the body might expel them.

**Key Symbol**

- **Atomic weight**: emission type [max. MeV] (2nd type), half life / biological half-life (2nd component)

**BRAIN**

- **A-21** α [5.87 MeV], 7 h

**SKIN**

- **S-35** β [0.16 MeV], 87.4 d / 623 d (90 d)

- If you are contaminated with beta emitters on your skin:
  - “First, decontaminate yourself. Flush with plain soap and water (no scrub-brush!).
  - Remove any contaminated clothing.”

**THYROID** (Source: Duke U.)

- **Te-99** β [0.29 MeV], 211,000 y / 12 h
- **I-131** β [0.97 MeV] (γ), 8 d / 110 d
- **I-132** β [1.12 MeV] (γ), 2.3 h
- **I-133** β [1.27 MeV] (γ), 20.8 h
- **I-135** β [1.63 MeV] (γ), 6.6 h

**LIVER**

- **Mn-56** β [3.70 MeV] (γ), 2.6 h / 4 d (40 d)
- **Ca-45** β [0.32 MeV] (γ), 5.72 d / 6 d (60 d)
- **Ca-44** β [0.58 MeV] (γ), 32.5 d / 9 y
- **Ca-444** β [0.1 MeV] (γ), 285 d
- **Pr-143** β [0.93 MeV] (γ), 13.5 d
- **Pr-146** β [1.99 MeV] (γ), 0.3 h
- **Nd-145** β [0.90 MeV] (γ), 11 d
- **Pu-242** α [4.98 MeV], 373,300 y / 82 y

**PANCREAS**

- **H-3** β [0.02 MeV], 12.3 y

**OVARIIES**

- **K-42** β [3.62 MeV] (γ), 12.56 h
- **K-43** β [0.67 MeV] (γ), 10.72 y
- **Ca-40** β [1.28 MeV] (γ), 5.27 y
- **Ca-44** β [1.06 MeV] (γ), 2.1 y
- **I-131** β [0.97 MeV] (γ), 8 d / 4 d
- **Pu-241** α [4.90 MeV] (β, γ), 14.1 y / 80 y

**MUSCLE**

- **K-42** β [3.52 MeV] (γ), 12.36 h
- **Ca-128** β [0.21 MeV], 2,300,000 y / 70 d

**WHOLE BODY**

- **H-3** β [0.02 MeV], 12.3 y / 9.4 d
- **C-14** β [0.16 MeV], 5,715 y / 12 d
- **P-32** β [0.71 MeV], 143.4 d / 257 d
- **Ca-137** β [0.18 MeV] (γ), 30 y / 70 d
- **Ce-144** β [0.31 MeV] (γ), 285 d / 9 y
- **Pu-238** α [5.17 MeV] (γ), 6,563 y / 175 y

**LUNGS**

- **Kr-85** β [0.67 MeV] (γ), 10.72 y
- **Ce-141** β [0.31 MeV] (γ), 285 d / 180 d
- **Rn-222** α [0.59 MeV] (γ), 3.8 d / 10 y
- **U-238** α [4.2 MeV] (γ), 4,500,000,000 y / 3.8 y
- **Pu-238** α [5.0 MeV] (γ), 87.5 y / 1.5 y

**SPLEEN**

- **Po-210** α [4.88 MeV] (γ), 103 y / 50 d
- **Po-211** α [5.31 MeV] (γ), 138.4 d

**KIDNEYS**

- **Ru-106** β [0.04 MeV], 372 d / 7.2 d
- **....and everything else...**

**BLADDER**

- **Po-210** α [5.31 MeV] (γ), 138.4 d
- **....and everything else...**

**BONE**

- **P-32** β [0.71 MeV], 143.4 d / 7.3 y
- **Ca-45** β [0.26 MeV], 163 d
- **Mn-56** β [3.70 MeV] (γ), 2.6 h / 40 d
- **Sr-90** β [0.166 MeV] (γ), 85.6 d / 40 d
- **Sr-90** β [0.55 MeV] (γ), 29 y
- **Y-90** β [1.27 MeV] (γ), 64.1 h
- **Y-91** β [1.35 MeV] (γ), 58.8 d
- **Ba-141** β [1.02 MeV] (γ), 12.7 d
- **La-140** β [3.76 MeV] (γ), 40.3 h
- **Ce-144** β [0.31 MeV] (γ), 285 d / 9 y
- **Nd-147** β [1.90 MeV] (γ), 11 d
- **Ra-226** α [4.78 MeV] (γ), 1,600 y / 10 y
- **U-235** α [4.82 MeV] (γ), 160,000,000 y / 200 y
- **U-238** α [4.70 MeV] (γ), 710,000,000 y
- **Pu-239** α [5.15 MeV] (γ), 24,131 y / 200 y

“All reproductive organs are attacked by radiation. Many isotopes cross the placenta. Plutonium also concentrates in the gonads. Radiation causes birth defects, mutations and miscarriages in the first and/or successive generations after exposure. A fetus is much more vulnerable to radiation than an adult. Girls are more vulnerable than boys. Women are more vulnerable than men. Nevertheless, radiation “safety” standards are based mainly on adult male resistance levels. Cancers, leukemia, heart failure, amnesia, neuromuscular diseases, and many other health effects may take years to develop. There is no minimum dose; any dose can be fatal and any dose causes some amount of damage.”

-- W. O. Caster, From Bomb to Man ( Fallout, Basic Books, 1960, p 41)