Ionizing Radiation

Dose Ranges

( Rem )

**Medical Intervention**

Whole body acute: G-I destruction; lung damage; cognitive dysfunction (death certain in 5 to 12 days)*

Whole body acute: circulating blood cell death; moderate G-I damage (death probable 2-3 wks)*

Whole body, acute: marked G-I and bone marrow damage (death probable in 1-2 wks)*

*Note: Whole body acute prognoses assume no medical intervention (G-I = gastrointestinal)

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### Cancer Radiotherapy

**Total doses to tumor**

Whole body, acute: cerebral/vascular breakdown (death in 0-5 days)*

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### Acute Radiation Syndromes

**Human LD50 range acute exposure with medical intervention**

(chronic = hours, days, years)

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### Cancer Epidemiology

**Estimated dose for 3-yr Mars mission (current shielding)**

Evidence for small increases in human cancer above 10 rem acute exposure or 20 rem chronic exposure

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### Radiation Protection Units

- **Dose Equivalent**: 100 rem = 1 Sievert
  - Dose Equivalent = (absorbed dose x radiation quality)
  - LD50 = Lethal Dose to 50%
  - LD50 = 50% of exposed individuals in 30-60 days

- **Absorbed Dose**: 100 rad = 1 Gray
  - Absorbed Dose = (energy deposited in tissue or organ) / mass of exposed tissue

- **Natural background, USA average**
  - Approximately 310 mrem/yr (includes radon)

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### Medical Diagnostics

**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

**Radiotracers 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

**Medical Diagnostics (A-O)**

- DOE, NRC dose limit for workers: 5 rem/yr (50 mSv/yr)

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### Regulations & Guidelines

**Regulatory Agencies**

- NRC: Nuclear Regulatory Commission
- EPA: Environmental Protection Agency
- DOE: Department of Energy

**TIPS**: Transjugular Intrahepatic Portosystemic Shunt

- DOE/BER: “Orders of Magnitude” revised June 2010
  - 1 rem = 1 rad for x- and gamma-rays
  - “≈” stands for “approximately equal to”

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**Chart compiled by NF Metting, Office of Science, U.S. Department of Energy**

http://www.lowdose.energy.gov/ober/

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**Sources**

- Office of Biological and Environmental Research (BER), Office of Science, U.S. Department of Energy
- NRC Low Dose Program

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**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 equivalents” 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)

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**DOE Low Dose Program**

- Typical mission doses on International Space Station (ISS)
- Typical added annual dose for commercial airline flight crews
- Typical round-trip Los Angeles – New York ≈ 3.7 mrem

**DOE facility releases**

- EPA dose limit for public drinking water systems: 4 mrem/yr
- EPA dose limit from release in air: 10 mrem/yr

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**Human LD50 range acute exposure with medical intervention**

(Death certain in 5 to 12 days)*

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**Transmitting Agency**

Office of Biological and Environmental Research (BER), Office of Science, U.S. Department of Energy

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**Interplanetary Space**

- High natural bkg/yr
- Natural background, USA average ≈ 310 mrem/yr

**Medical Diagnostics (A-O)**

- DOE, NRC dose limit for the public: 100 mrem/yr (1 mSv/yr)

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**Charged particle event**

(Solar flare) dose on moon, no shielding

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**White body, acute**

- Whole body acute: G-I destruction; lung damage; cognitive dysfunction (death certain in 5 to 12 days)*

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**Whole body acute**

- Circulating blood cell death; moderate G-I damage (death probable 2-3 wks)*

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**Whole body acute**

- Marked G-I and bone marrow damage (death probable in 1-2 wks)*

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**Whole body acute**

- Cerebral/vascular breakdown (death in 0-5 days)*

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**Whole body acute**

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

**Dose Ranges**

(Sievert)

**Life Span Study**
(A-bomb survivor epidemiology)

**Total Body Irradiation**
(TBI) Therapy

**Acute Radiation Syndromes**

Whole body, acute: marked G-I and bone marrow damage
(death probable in 1-2 wks)*

Whole body, acute: cerebral/vascular breakdown
(death in 0-5 days)*

Whole body, acute: G-I destruction; lung damage; cognitive dysfunction
(death certain in 5 to 12 days)*

**Medical Diagnostics**

<table>
<thead>
<tr>
<th>mGy</th>
<th>X-ray films</th>
<th>A – Chest (PA &amp; Lat)</th>
<th>0.14</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B – Dental Panoramic</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C – Lumbar-Sacral Spine</td>
<td>2 – 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D – Mammogram</td>
<td>2 – 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>E – Heart Stress (Tc-99m)</td>
<td>6 – 12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F – Bone (Tc-99m)</td>
<td>4 – 15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G – Dual Isotope Stress Test</td>
<td>40 – 45</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H – PET: F-18 FDG (bladder)</td>
<td>55 – 80</td>
<td></td>
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</tbody>
</table>

**Radiotracer Imaging**

<table>
<thead>
<tr>
<th>mSv</th>
<th>DOE Low Dose Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>L – Full Body CT</td>
</tr>
<tr>
<td>20</td>
<td>I – Chest CT</td>
</tr>
<tr>
<td>30</td>
<td>J – Head CT</td>
</tr>
<tr>
<td>40</td>
<td>K – Abdominal CT</td>
</tr>
<tr>
<td>50</td>
<td>M – Barium Contrast G.I.</td>
</tr>
<tr>
<td>60</td>
<td>N – Cardiac Catheterization</td>
</tr>
<tr>
<td>70</td>
<td>O – TIPS Procedure</td>
</tr>
<tr>
<td>80</td>
<td>DOE, NRC dose limit for public relocation: 20 mSv/yr (2 rem/yr)</td>
</tr>
<tr>
<td>90</td>
<td>Guinea, Brazil high natural bkg/yr</td>
</tr>
<tr>
<td>100</td>
<td>DOE, NRC dose limit for workers: 50 mSv/yr (5 rem/yr)</td>
</tr>
<tr>
<td>200</td>
<td>DHS emergency guideline to save a life: 250 mSv</td>
</tr>
<tr>
<td>400</td>
<td>Interplanetary Space natural bkg/yr</td>
</tr>
<tr>
<td>600</td>
<td>DOE, NRC dose limit for site decommissioning / unrestricted use: 0.25 mSv/yr</td>
</tr>
<tr>
<td>800</td>
<td>Yangjiang, China high natural bkg/yr</td>
</tr>
<tr>
<td>1000</td>
<td>Medical Diagnostics (A-O) see chart &gt;&gt;</td>
</tr>
</tbody>
</table>

**Regulations & Guidelines**

<table>
<thead>
<tr>
<th>mSv</th>
<th>DOE, NRC dose limit for the public: 1 mSv/yr (100 mrem/yr) (ICRP, NCRP)</th>
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<tbody>
<tr>
<td>0</td>
<td>EPA dose limit public drinking water systems: 0.04 mSv/yr</td>
</tr>
<tr>
<td>0.1</td>
<td>EPA dose limit from release in air: 0.1 mSv/yr</td>
</tr>
<tr>
<td>0.2</td>
<td>NRC cleanup criteria for site decommissioning / unrestricted use: 0.25 mSv/yr</td>
</tr>
<tr>
<td>0.3</td>
<td>DOE facility releases</td>
</tr>
<tr>
<td>0.4</td>
<td>Round-trip Los Angeles – New York (≈ 0.037 mSv)</td>
</tr>
<tr>
<td>0.5</td>
<td>Natural background, USA average ≈ 3.1 mSv/yr (includes radon)</td>
</tr>
<tr>
<td>0.6</td>
<td>Yangjiang, China high natural bkg/yr</td>
</tr>
<tr>
<td>0.7</td>
<td>DOE, NRC dose limit for site decommissioning / unrestricted use: 0.25 mSv/yr</td>
</tr>
<tr>
<td>0.8</td>
<td>DOE facility releases</td>
</tr>
<tr>
<td>0.9</td>
<td>DOE facility releases</td>
</tr>
<tr>
<td>1</td>
<td>EPA dose limit public drinking water systems: 0.04 mSv/yr</td>
</tr>
</tbody>
</table>

**Cancer Radiotherapy**

**total doses to tumor**

**Acute Radiation**

Syndromes

Note: Whole body acute: all at once; chronic = hours, days, years

**Medical Diagnostics**

(Estimated maximum organ dose)

**Fractions**

1. **Medical Diagnostics**

   - **X-ray films**
     - A – Chest (PA & Lat) 0.14
     - B – Dental Panoramic 0.7
     - C – Lumbar-Sacral Spine 2 – 3
     - D – Mammogram 2 – 4
     - E – Heart Stress (Tc-99m) 6 – 12
     - F – Bone (Tc-99m) 4 – 15
     - G – Dual Isotope Stress Test 40 – 45
     - H – PET: F-18 FDG (bladder) 55 – 80
   - **Radiotracer Imaging**
     - E – Heart Stress (Tc-99m) 6 – 12
     - F – Bone (Tc-99m) 4 – 15
     - G – Dual Isotope Stress Test 40 – 45
     - H – PET: F-18 FDG (bladder) 55 – 80
     - I – Chest CT 20 – 30
     - J – Head CT 30 – 50
     - K – Abdominal CT 22 – 60
     - L – Full Body CT 50 – 100
   - **Fluoroscopy/Procedures**
     - M – Barium Contrast G.I. 10 – 22
     - N – Cardiac Catheterization 12 – 40
     - O – TIPS Procedure 400 – 1400

**Acute Exposure**

= all at once; chronic = hours, days, years

**Dose Equivalent**

1 Sievert = 100 rem

= (absorbed dose x radiation quality)

**Absorbed Dose**

1 Gray = 100 rad

1 Sv ≈ 1 Gy for x- and gamma-rays

(“≈” stands for “approximately equal to”)