Module 2
Fundamentals of Basic Radiation
Topics Covered in This Module

• Radiation Found in the Environment,
• Types of Radiation,
• Exposure, Absorbed Dose, and Dose Equivalent.
Radiation Found in the Environment
Natural Sources of Radiation

- Cosmic,
- Terrestrial,
- Internal,
- Inhaled.
Cosmic Radiation

- High energy particles and photons from the sun and other sources outside the earth’s atmosphere:
  - Our atmosphere provides shielding from cosmic radiation.
  - An increase in altitude results in an increase in exposure.
    - For example, at sea level, average exposure is 26 mrem/year but in Denver, Colorado, the average exposure is 50 mrem/year.
Terrestrial Radiation

• Radiation from radioactive materials occurring naturally in the earth’s crust.

• In the United States, highest radiation levels found on the eastern slope of the Rockies in Colorado Plateau Area Range 75 to 140 mrem/year and average 90 mrem/year.

• In the United States, lowest radiation levels found on the Atlantic Coast in the Atlantic and Gulf Coastal Plain Range 15 to 35 mrem/year and average 23 mrem/year.
Inhaled Radiation

• Primarily from Radon ($^{222}$Rn) and its daughters.

• $^{222}$Rn is released from the soil as Radium-226 ($^{226}$Ra) and then it decays to Radon.
  • Radium is part of the Uranium-238 ($^{238}$U) decay chain.

• Levels vary widely from area to area,
  • Average dose is 200 mrem/year.

• Dose may be enhanced by poor ventilation or the use of uranium containing building materials.
Internal Radiation

• Radiation from radioactive materials incorporated in the human body:
  • Carbon-14 (\(^{14}\text{C}\)),
  • Potassium-40 (\(^{40}\text{K}\)),
    • Total dose of 39 mrem/year (due mostly to \(^{40}\text{K}\)).
Types of Radiation
What is Radiation?

• Radiation is the emission of energy as electromagnetic waves or as moving subatomic particles through space or through a material.

• Radiation is often categorized as either ionizing or non-ionizing depending on the energy of radiated particles or waves.

• Ionizing radiation carries more than 10 eV, which is enough to ionize atoms and molecules and break chemical bonds.
Particulate Radiation Vs. Electromagnetic Radiation

• Particulate Radiation:
  • Alpha Particle,
  • Beta Particle,
  • Neutron.

• Electromagnetic Radiation:
  • Photon,
  • Gamma.
Electromagnetic Radiation

• Oscillating electric and magnetic fields that transfer energy to matter via photon or wave interactions.

• Electromagnetic radiation includes radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays.
Charged Radiation Vs. Uncharged Radiation

• Charged Radiation:
  • Alpha Particle,
  • Beta Particle.

• Uncharged Radiation:
  • Photon,
  • Neutron.
Ionizing Radiation Vs. Non-Ionizing Radiation

• Ionizing Radiation:
  • Has enough energy to completely remove an electron from an atom.
  • Alpha, beta, gamma, neutron, and X-rays.

• Non-Ionizing Radiation:
  • Not enough energy to completely remove an electron from an atom.
  • Visible light, Ultra-Violet, infrared, microwaves, and radio waves.
Exposure, Absorbed Dose and Dose Equivalent
Exposure

- The sum of the charges of one sign produced by photons in a given mass of air.
- The SI unit of exposure is the Coulomb/kilogram (C/kg).
- The traditional unit is the roentgen (R).
- 1 R = 2.58 \times 10^{-4} \text{ C/kg}.
  - This unit is only defined for photons of less than 3 MeV energy in air.
Absorbed Dose

- The energy deposited in or absorbed by an object per unit mass.
- Applies to all radiation at all energies in all absorbers.
- The SI unit of absorbed dose is the Gray (Gy).
- The traditional unit is the rad.
- $100 \text{ rad} = 1 \text{ Gy} = 1 \text{ J/kg}$.
- Symbol is $D$. 
Dose Equivalent

• The energy deposited in an object per unit mass (D) multiplied by a “quality factor” (Q, quality factor accounts for the different biological effectiveness of different types of radiation).

• The SI unit of dose equivalent is the Sievert (Sv).

• The traditional unit is the rem.

• 100 rem = 1 Sv.

• Symbol is H, H = D x Q.
# Recommended Quality Factors

<table>
<thead>
<tr>
<th>Radiation Type</th>
<th>QF</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-Ray, Gammas, and betas</td>
<td>1</td>
</tr>
<tr>
<td>Neutrons</td>
<td>2-11</td>
</tr>
<tr>
<td>Neutrons with unknown energy</td>
<td>10</td>
</tr>
<tr>
<td>High Energy photon</td>
<td>10</td>
</tr>
<tr>
<td>Alpha particles, fission fragments, heavy nuclei</td>
<td>20</td>
</tr>
</tbody>
</table>
Conversion

• For the purpose of radiation protection, it is assumed that 1 R = 1 rad = 1 rem.
  • R is only defined for photons,
  • The quality factor is 1 for photons,
  • The actual “conversion” factor is dependent on the absorber,
  • 1 R is actually less than 1 rad (1 R = 0.97 rad for tissue).