UNIT III

Interaction of radiation with matter lipids

Attenuation of γ-Radiations

- Attenuation is the removal of photons from a beam of x- or gamma rays as it passes through matter. Attenuation is caused by both absorption and scattering of the primary photons.
- At low photon energies (<26 keV), the photoelectric effect dominates the attenuation processes in soft tissue.
- However, photoelectric absorption is highly dependent on photon energy and the atomic number of the absorber.

- When higher energy photons interact with low Z materials (e.g., soft tissue), Compton scattering dominates.
- Only at very high photon energies (>1.02 MeV), well beyond the range of diagnostic and nuclear radiology, does pair production contribute to attenuation.

Linear and Mass Attenuation Coefficients

- γ-ray and x-ray photons are either attenuated or transmitted as they travel through an absorber.
- Attenuation results from absorption by the photoelectric effect, Compton scattering, and pair production at higher energies.
- Depending on the photon energy and the density and thickness of the absorber, some of the photons may pass through the absorber without any interaction leading to the transmission of the photons.
- Attenuation of g-radiations is an important factor in radiation protection.

- If a photon beam of initial intensity I_0 passes through an absorber of thickness x, then the transmitted beam I_t is given by the exponential equation

$$I_t = I_0 e^{-\mu x}$$

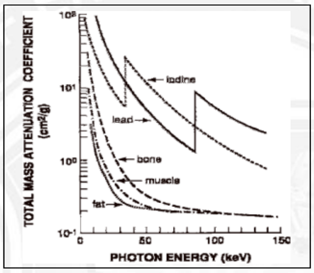
where μ is the linear attenuation coefficient of the absorber for the photons of interest and has the unit of cm^{-1}.

- The factor $e^{-\mu x}$ represents the fraction of the photons transmitted. Because attenuation is primarily due to photoelectric, Compton, and pair production interactions, the linear attenuation coefficient μ is the sum of photoelectric coefficient (τ), Compton coefficient(σ), and pair production coefficient (κ). Thus,

$$\mu = \tau + \sigma + \kappa$$

Linear attenuation coefficients normally decrease with the energy of the γ-ray or x-rayphotons and increase with the atomic number and density of the absorber.

- An important quantity, mm, called the mass attenuation coefficient, is given by the linear attenuation coefficient divided by the density r of the absorber.
- The mass attenuation coefficient μ_m has the unit of cm^2/g or cm^2/mg. The mass attenuation coefficients for fat, bone, muscle, iodine, and lead are given in the figure below.



Half-Value Layer

- The concept of half-value layer (HVL) of an absorbing material for g- or x-radiationsis important in the design of shielding for radiation protection.
- It is defined as the thickness of the absorber that reduces the intensity of a photonbeam by one-half.
- Thus, an HVL of an absorber around a source of g-radiations with an exposure rate of150 mR/hr will reduce the exposure rate to 75mR/hr.
- The HVL depends on the energy of the radiation and the atomic number of theabsorber.
- It is greater for high-energy photons and smaller for high-Z materials.
- For monoenergetic photons, the HVL of an absorber is related to its linear attenuation coefficient as follows:

$$\text{HVL} = \frac{0.693}{\mu}$$

- Because m has the unit of cm^{-1}, the HVL has the unit of cm.
- Another important quantity, tenth-value layer (TVL), is the thickness of an absorberthat reduces the initial beam by a factor of 10. It is given by

$$\text{TVL} = -\frac{\ln(0.1)}{\mu}$$

$$= \frac{2.30}{\mu}$$

$$= 3.32 \text{ HVL}$$