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Radiation Protection Course

Lecturer

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Chapter Three

Radiation Measurement Units & International SI Units

1. Activity
2. Exposure
3. Absorbed dose
4. Kerma
5. Equivalent dose
6. Effective dose
7. Committed Equivalent & effective dose

1- Activity: is the measure of the rate at which radioactive materials decay and emit ionizing radiation. It is typically expressed in units(SI) such as becquerels (Bq) or curies (Ci) and indicates how many radioactive decays occur per unit of time, commonly per second. This activity can be natural or human-made and is important in various fields, including medicine, industry, and nuclear science.

Becquerel (Bq): The Becquerel is the SI unit for radioactivity (activity), counts how many particles or photons (in the case of wave radiation) are emitted per second by a source.

It represents the rate of radioactive decay of a substance. One Becquerel is equal to one decay per second. It is named after Henri Becquerel, who discovered radioactivity. The activity depends only on the number of decays per second, not on the type of decay, the energy of the decay products,

2- Exposure: The concept of exposure defined only for (x-rays and gamma rays). We begin by considering the passage of x-rays and gamma-rays photons through air. The photons interact many times with atoms in the air, each of which creates a free electron. These secondary electrons can themselves produce ionization (and additional electrons). The total electric charge Q on the ions produced in a given mass (m) of air it is called the exposure X. Exposure measure the number of ionization in air. The exposure is

$X = Q/m$, and is measured in the SI units of Coulomb per Kilogram. The historical unit has been the roentgen (R). The two units are related by $1R = 2.58\times10^{4}\ C/Kg$

One Roentgen (R) is defined as the amount of radiation that produces one electrostatic unit of charge (1 esu $=3.336 \times 10^{10}$ C) in one cubic centimeter (cm^3) of dry air at standard atmospheric conditions with $m = 0.001293$gm . This definition provides a standardized way to measure exposure to x-rays and gamma rays.

If we assume that we have a volume of air of one cubic centimeter under standard conditions and this volume is exposed to radiation, and assuming that the entire amount of radiation is absorbed to form an electrical charge of (1 esu), then the amount of exposure is equal to

$$\frac{\Delta Q}{\Delta m} = \frac{3.34\times10^{-10}C}{0.001293\ gm/cm^3\times1cm^3\times10^{-3}Kg/gm} = 2.58\times\frac{10^{-4}c}{Kg} = 1R$$

3- **Absorbed dose**: The absorbed dose in radiation refers to the amount of energy deposited by ionizing radiation in a given material, typically biological tissue. It measures the energy absorbed per unit mass of the material. The unit for absorbed dose is the gray (Gy), where 1 gray represents the absorption of 1 joule of energy per kilogram of the material.

$$D = \frac{E}{m} = \frac{J}{Kg} \qquad 1\ Gy = 1\ J/kg$$

Problem: If a dose of 0.05 Gy is delivered uniformly to a patient during a diagnostic x-ray examination, how energy is absorbed by each gram of that patient.

$$D = \frac{E}{m} \Longrightarrow E = Dm = 0.05 \times 10^{-3} joule$$

Problem : A radiographic exposure results in 0.015J energy absorbed by the liver. If the liver weighs 0.0Kg, what is the total absorbed dose to the liver.

$$D = \frac{E}{m} = \frac{0.015J}{0.9Kg} = \frac{0.0167J}{Kg} = 0.0167\ Gy$$

4- **KERMA**: is defined as the sum of the initial kinetic energies of all charged particles liberated by ionizing radiation (e.g., X-rays, gamma rays, or other forms of ionizing radiation) per unit mass of the irradiated material. It is denoted by the symbol "K" and is typically measured in units of joules per kilogram (J/kg) or gray (Gy).

KERMA accounts for energy transferred to charged particles through various mechanisms, including Compton scattering, photoelectric effect, and electron-positron pair production.

5- Equivalent dose: in radiation refers to a measure of the biological effect of ionizing radiation on living tissue. It takes into account not only the absorbed dose of radiation (the energy deposited per unit mass of tissue) but also the type and energy of the radiation, as different types of radiation have varying degrees of biological impact. Equivalent dose is typically expressed in sieverts (Sv) and is used to assess the potential harm to human tissues or organs exposed to radiation, by accounting for the relative biological effectiveness of different types of radiation. Sievert (Sv):

The Sievert is the SI unit for the biological effect of ionizing radiation, taking into account the type of radiation and its impact on living tissue. It is used to express radiation dose in terms of its potential harm to humans.

Equivalent dose H (Sv) = Absorbed Dose (D Gy) × radiation weighting factor (w_R)

Problem: A radiation worker received a gonadal dose of 25 mGy over the course of a year . If 100% of this dose was from x-rays, what is the equivalent dose.

$$H = D \times w_R = 25 \times 1 = 25mSv$$

Q) In 1 year a worker receives a γ dose of 0.01 Gy, a thermal neutron (Ns) dose of 0.002 Gy and a fast neutron dose (Nf) of 0.0002 Gy. What is his total equivalent dose? (Take the radiation weighting factor for fast neutrons as 20.)

Solution:

Equivalent dose, γ = 0.01 × 1 = 0.01 Sv

Equivalent dose, N_s = 0.002 × 2.5 = 0.005 Sv

Equivalent dose, N_f = 0.0002 × 20 = 0.004 Sv

Total equivalent dose = 0.019 Sv

Type of radiation	*Weighting factor, w_R*
X-rays	1
gamma rays	1
beta particles	1
slow neutrons	5
fast neutrons	10
alpha particles	20

6- **Effective dose**: The effective dose in radiation, often expressed in units of sieverts (Sv), is a measure that takes into account both the amount of radiation absorbed by a specific tissue or organ in the body and the biological sensitivity of that tissue to radiation. It provides a way to assess the overall risk of harm from exposure to ionizing radiation. In brief, the effective dose represents the weighted sum of the equivalent doses to various organs and tissues, with each tissue's contribution weighted by its radiation sensitivity. This allows for a more comprehensive evaluation of the potential health effects of radiation exposure.

effective dose, E, and is obtained by summing the equivalent doses to all tissues and organs of the body multiplied by a weighting factor w_T for each tissue or organ. This is written as follows:

$$E = \sum H_T w_T$$

Problem: The thyroid a radiation worker is exposed to an absorbed dose of 10mGy from an alpha emitting radionuclide. Calculate the effective dose.

$$E = D \times w_R \times w_T = 10 \times 20 \times 0.04 = 8mSv$$

During an AP scoliosis x-ray, the breast, gonads and stomach of patient receive a dose of 3mGy. What is the total effective dose?

a. 0.32 mSv
b. 0.0035 mSv
c. 0.96 mSv

$$E = D \times w_R \times w_T = 3mGy \times 1 \times (0.12 + 0.8 + 0.12) = 0.96mSv$$

Tissue	Weighting factor
Gonads	0.8
Bone marrow	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Breast	0.12
Remainder tissues*	0.12
Bladder	0.04
Oesophagus	0.04
Liver	0.04
Thyroid	0.04
Bone surface	0.01
Brain	0.01
Salivary glands	0.01
Skin	0.01

7- **Committed Equivalent Dose and Effective Dose**: are concepts used in the field of radiological protection to assess and quantify the health risks associated with exposure to ionizing radiation. Here's a brief overview of each:

- **Committed Equivalent Dose** (CED):
  CED is a measure of the radiation dose that an individual is expected to receive over a specified time period following the intake or ingestion of a radioactive material. It takes into account the type of radiation (e.g., alpha, beta, gamma), the radionuclide involved, and the organ or tissue where the radioactive material is deposited. CED is typically expressed in units of sieverts (Sv) or millisieverts (mSv). The calculation of CED considers factors such as the biological half-life of the radionuclide in the body and the radiation weighting factor (WR) to account for the relative biological effectiveness of different types of radiation.

- **Committed Effective Dose** is a concept used to assess the overall radiation dose to an individual from multiple sources of ionizing radiation exposure. It takes into account both external exposures (e.g., from x-rays or gamma rays) and internal exposures (e.g., from radioactive materials that have been ingested, inhaled, or deposited in the body). ED is calculated by summing the products of the equivalent dose (HT) for each exposed organ or tissue and the tissue weighting factor (WT) for each organ. This accounts for the varying sensitivity of different organs and tissues to radiation. Effective Dose is expressed in sieverts (Sv) and provides a more comprehensive estimate of the radiation risk to the whole body. It is often used in radiation protection standards and guidelines to establish permissible exposure limits and to assess the potential health risks associated with radiation exposure scenarios.

In summary, Committed Equivalent Dose (CED) is specific to internal exposures and accounts for the dose received from a particular radionuclide over time in specific organs or tissues. On the other hand, Effective Dose (ED) is a broader concept that considers both internal and external radiation exposures, providing a more comprehensive assessment of the overall radiation risk to the whole body. These concepts are crucial in the field of radiation protection to ensure that exposure to ionizing radiation is kept within safe limits to minimize health risks.