# Radiation Regulations, Protection.- Fundamental of Nuclear Pharmacy (*Gopal B. Saha*)

## Radiation Protection;

Because radiation can cause damage in living systems, international and national organizations have been established to set guidelines for the safe handling of radioactive materials.

1- *The International Committee on Radio- logical Protection (ICRP).*
2- *The National Council on Radiation Protection and Measurement (NCRP).*

Their role ;

- They set guidelines for all radiation workers to follow in handling radiations.

## Harmful effects of radiation;

Ionization and excitation of molecule in the body cause abnormal chemical reactions .
e.g.
- Essential enzymes are inactivated proteins are coagulation – nucleic acids in the genetic systems are damaged.
- Histamine like substances are produced.

These effects lead to recognizable sign of radiation damage.

e.g.
500 RAD dose is equal to $LD_{50}$ for man .. why ?

$$1 \text{ rad} = 100 \times 10^{-7} \text{ joules}$$

So, energy produced from 500 rad = $500 \times 100 \times 10^{-7}$ Joule / gm.

- Energy required to produce 1 ion pair in tissue is 34 ev.

>>> N°- of ions produced by above energy =

$$( 500 \times 100 \times 10^{-7} ) \ / \ ( 34 \times 1.6 \times 10^{-19} ) = 0.92 \times 10^{15}$$

- 1gm. Of tissue contains $8 \times 10^{22}$ atom

>>> fraction of atoms ionized= $( 0.92 \times 10^{15} ) \ / \ ( 8 \times 10^{22} ) = 1.15 \times 10^{-8}$

( dose that causes ionization only one molecule in $10^8$ cells )

*(( if possibility of ionization of 1 cell of $10^8$ >> cause death ))*

## Principles of Radiation Protection

- The alpha particle is most damaging due to :its great charge and mass, followed by the β particle and the gamma rays.
- Heavier particles have shorter ranges and therefore deposit more energy per unit length in the absorber, causing more damage. These are called non-penetrating radiations.
- Gamma and X-rays have no charge and mass an therefore have a much longer range in matter. These electromagnetic radiations are called penetrating radiations.

Knowledge of the type and energy of radiations is essential in understanding the principles of radiation protection.

- **The cardinal principles of radiation protection from external sources are based on four factors: time, distance, shielding, and activity.**

## 1-Time:

Radiation exposure to an individual is directly proportional to the time the person is exposed to the radiation source. So, it is wise to spend no more time than necessary near radiation sources.

## 2-Distance:

The intensity of a radiation source, and hence the radiation exposure, varies inversely as the square of the distance ( I α 1 / $distance^2$ ) . It is recommended that an individual remains as far away as possible from the radiation source.

Procedures and radiation areas should be designed such that only minimum exposure takes place to individuals doing the procedures or staying in or near the radiation areas.

The radiation exposure from g- and x-ray emitters can be estimated from :

Exposure dose Roentgen/hour =

( Activity of source in mCi X Exposure rate constant ٦ ) / ( Distances 1 cm $)^2$

**٦ = R – $cm^2$ / mCi – h .**

Exposure due to gamma and x-ray in R/ h from 1mCi of radionuclide at distance of 1cm.

**X = n ٦ / $d^2$**

Where: x : Roentgen / h. - n : mCi - ٦ : constant - $d^2$ : square distance in cm.

$Q_1$ : What is the exposure rate at 30 cm from a vial containing 20 mCi (740 MBq) of $^{131}I$?

Answer : The exposure rate constant $\Gamma^{20}$ for $^{131}I$ is 2.17 R-cm$^2$/mCi-hr at 1 cm

$$X = \frac{20 \times 2.17}{30^2} = 0.048\ \text{R/hr}$$

**$Q_2$ : If a radiation source has an exposure rate of 200 m R /h at one meter (1 m), what is the exposure rate at 5 m away ?**

1- 200 m R / h = (A X Γ) / ( 100 X 100 )

2- x = ( A X Γ ) / ( 500 X 500)

$$\frac{200}{x} = \frac{A \times \Gamma \times 500 \times 500}{100 \times 100 \times A \times \Gamma}$$ =>> 200 / x = 25/ 1 =>> x = 200 / 25

**$Q_3$ : If a source of radioactivity shown an exposure rate of 50 R/h at 4 meters from the source , thus the exposure rate at 2 meters from the source is ??**

50 mR/h / x = ( 200 X 200 ) / ( 400 X 400)

## 3-Shielding:

Various high atomic number N°- materials that absorb radiations can be used to provide radiation protection.

- Alpha and beta particles are short in matter, the containers themselves act as shields for these radiations.
- Gamma radiations are highly penetrating, and therefore highly absorbing material must be used for shielding of g-emitting sources.

  >> lead is most commonly used for this purpose. Why ? for economic reasons.
- The concept of half-value layer (HVL) of an absorbing material for penetrating radiations is important in the design of shielding for radiation protection.
- ( HVL ) define as the thickness of shielding that reduces the exposure from a radiation source by one half.

  E.x. HVL of an absorber placed around a source of radiation with an exposure rate of 100 mR/hr will reduce the exposure rate to 50 mR/hr.

- The HVL of absorber is dependent on both the energy of the radiation and the atomic number of the absorbing material.
- The HVL value is greater for high-energy radiations and smaller for high Z materials.

- The greater the HVL of any material for a radiation, the larger the amount of material necessary to shield the radiation.

**So, shielding is an important means of protection from radiation.so,**

1- Radionuclides should be stored in a shielded area.
2- Injection dosages for patients should be carried in shielded syringes.

- Radionuclides emitting b particles should be stored in containers of low Z material such as aluminum and plastic because in high Z material such as lead they produce highly penetrating bremsstrahlung radiation.
- For example, $^{32}P$ emit beta radiation should be stored in plastic containers instead of lead containers.

**4-Activity:**

Radiation hazard increases with the intensity of the radioactive source.

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- Nuclear Pharmacist work with large quantities of radioactive materials on day to day basis , but by using simple techniques , the amount of radiation exposure to the nuclear pharmacist is very low.
- Most radiopharmaceuticals are available as " kit" formulations.
- All materials necessary for preparation are available in non radioactive kit with the exception of the radioactive isotope. When the radioactive isotope is added to the kit, the chemical reactions required for binding the isotope occur within the vial.
- In most cases , when tagging reaction is complete , the final product will be ready for quality verification and unit dose dispensing .
- Prior to dispensing any individual dose, simple instant thin layer chromatography tests quickly and accurately provide information on the radiochemical composition of the kit that was prepared.
- When the radiochemical purity of the compounded product is verified, it can be dispensed for use in patient.
- Most radiopharmaceutical doses are delivered to the end user in unit dose syringe form.

**Questions: ( from book )**

Q. What are the cardinal rules of protection from external sources of radiation?

Q. If a source of radioactivity shows an exposure rate of 50 mR/hr at 4 m from the source, calculate the exposure rate at (a) 3 m from the source and (b) 6 m from the source.

Answer;

$I_1$ 50mR / $I_2$ = $d_2$ / $d_1$ =>> ( 3X3 / 4X4 ) $I_2$

= 50X4X4 /3X3

= $(d_2/d_1)$ X ( $50/d_2$)

=(6 X 6)/ (4 X 4).

Q. What will be the exposure rate in percent of a radioactive sample surrounded by an HVL of absorbing material? Calculate the exposure rate if the source exposure rate is 75 mR/hr.