SNS COLLEGE OF TECHNOLOGY

(AN AUTONOMOUS INSTITUTION)

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Department of Biomedical Engineering

Course Name: 19BME301 – Medical Physics

III Year : V Semester

Unit V – BASIC RADIATION QUANTITIES

Activity (A)

- How much radioactivity we have in a source. The main unit we use for this is called the Becquerel (Bq)
- Bq is that quantity of radioactive material in which one atom is transformed per second OR number of nuclear transformation (or disintegration) per second.

- Unit : Becquerel (Bq)
- 1 Bq = 1 transformation per second
- = 1 dps
- Old unit : Curie (Ci) {activity of 1 g of Ra-226}
- 1 Ci = 3.7×10^{10} transformation per second
- = 3.7×10^{10} Bq

  = 37×10^{9} Bq

  = 37 GBq

Exposure (X)

- It is a measure of amount of photons (x-rays or gamma rays) present in a location of interest.
- Exposure unit is a measure of the photon flux and is related to the amount energy transferred from the photon field to a unit mass of air.
- A quantity used to indicate the amount of ionization in air produced by x- or gamma-ray radiation
- Exposure: Quantity of photons that produces in air ions carrying 1 Coulomb of charge per 1 kg of air.
- 1 X unit : 1 C/kg air

Exposure (X)

- Old unit : Roentgen (R)
- 1 R = $\frac{\text{1electrostatic unit of charge (ESU)}}{\text{1 cc of air at (STP)}}$
- 1 X unit = 3881 R OR
- 1 R = 2.58×10^{-4} C/kg
- Energy absorption per unit mass of air for

  1 X unit = 34 Gy (air) and 1 R ~ 87.7 ergs/g (air)

KERMA

- KERMA- Kinetic Energy Released in the Medium.
- It is a measure of amount of total energy transferred by photons (x-rays or gamma rays) interacting in the medium.
- Kerma is defined as the sum of the initial kinetic energies of all charged particles liberated by uncharged particle (γ or n) in material of mass 1 Kg.
- Unit : Joule per kg (J/kg)
- SI Unit : Gray (Gy)
- When the reference material is air, the quantity is called air kerma

1 air kerma (Gy) = 114 R

- Air kerma due to an exposure of

  1 R = 87.6 ergs/g or

  1 J/kg (Gy) = 114 R

- 1 Gy air kerma is resulted by an exposure of 114 R

- Air Kerma decreases continuously with increasing depth in an absorbing medium.

Absorbed dose (D)

- Our bodies absorb energy when exposed to ionizing radiation. The 'energy absorbed per unit mass' is called:

ABSORBED DOSE

- The *UNIT* of absorbed dose is the *JOULE PER KILOGRAM*
- The unit of absorbed dose is given a special name: ***GRAY (Gy).***

1 GRAY = 1 J/kg

- Dose of 1 Gy corresponds to energy absorption of 1 Joule per kilogram of the irradiated material.

- **This is a useful unit because we know that the greater the absorbed dose a person receives, the greater the damage or the risk of damage from the radiation exposure.**

UNITS OF ABSORBED DOSE

Old unit : rad(Radiation Absorbed Dose)

1 rad = 100 ergs / gm = 10^{-2} Gy

1 Gy=100 rad

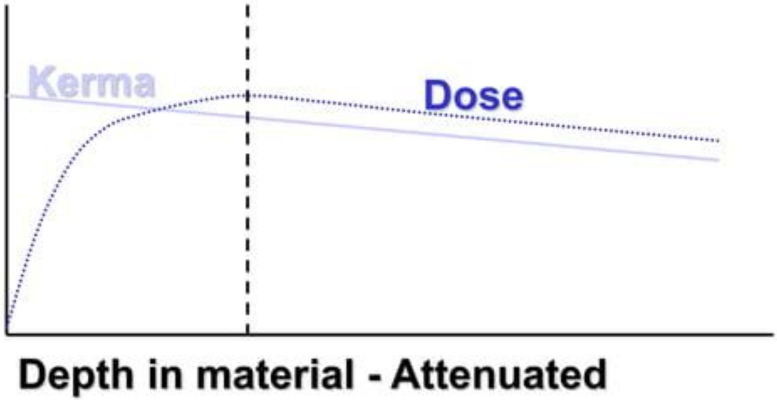
1 R exposure ~ 87.7 ergs/g of air

~ 95 ergs/g muscle tissue

1 rad ~ tissue dose of 100 ergs/gm

1 Roentgen = 1 RAD

KERMA AND ABSORBED DOSE



Kerma represents the transference of energy from the photons (or neutrons) to the directly ionizing particles. The subsequent transferrence of energy from these directly ionizing particles to the medium (e.g. air or tissue) is represented by the absorbed dose.

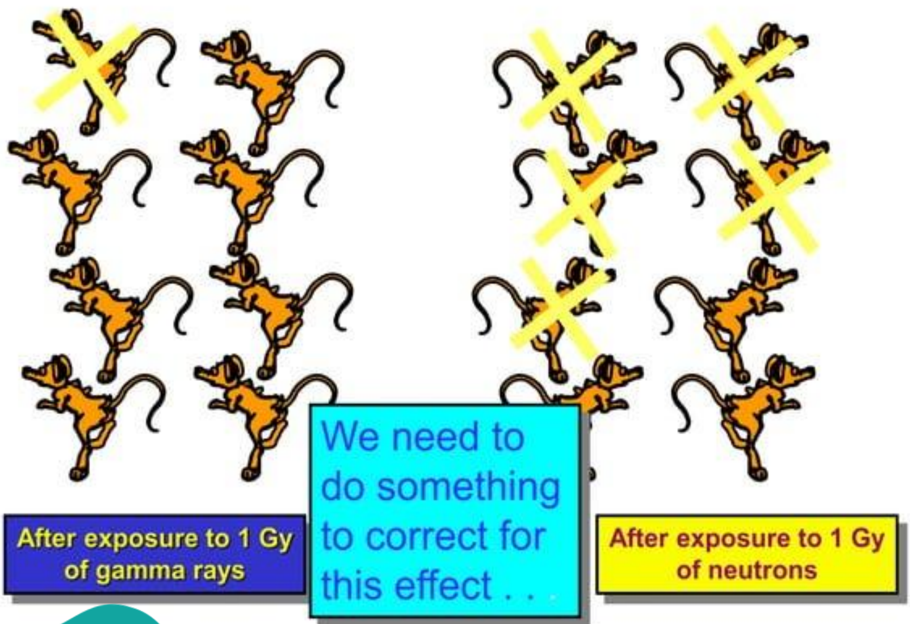
Equivalent Dose (H_T)

1 Gray from alpha particles is more harmful than 1 Gray from gamma rays

The different radiations are not all equally dangerous. We think this is because they deposit their energy in our bodies in different ways.

The different radiations have a different 'relative biological effectiveness'

Relative Biological Effectiveness



Equivalent dose

- We calculate equivalent dose by multiplying the absorbed dose by a 'radiation weighting factor':

This will enable us to account for the fact that different ionising radiations cause different amounts of biological harm for the same absorbed dose.

Equivalent Dose

SI UNIT NAME → **Sievert**

SYMBOL → **Sv (Joule/kg)**

The older unit is the rem

1 Sv = 100 rem

Equivalent Dose = Absorbed Dose x W_R

Sv (rem) = Gy (rad) x W_R

Radiation Weighting Factors

Published by the International Commission for Radiological Protection (ICRP) - Publication 60, 1990

RADIATION TYPE	RADIATION WEIGHTING FACTOR
X/GAMMA RADIATION	1
BETA RADIATION	1
NEUTRON RADIATION	
< 10 keV	5
10 keV - 100 KeV	10
100 keV - 2 MeV	20
2 MeV - 20 MeV	10
ALPHA RADIATION	20

Equivalent Dose

- The equivalent dose in tissue T is given by the expression:
- $$H_T = \sum W_R \ D_{T,R}$$
- where $D_{T,R}$ is the absorbed dose averaged over the tissue or organ T, due to radiation R

Again, however, there are problems . . .

Some tissues in the body are more easily damaged by radiation than others: we say that the cells are more 'radiosensitive'. The effect of radiation exposure of individual tissues contributes differently to the total health of the exposed person, depending upon the seriousness of the damage in individual tissues and its treatability.

This is not a problem in all cases, but it causes serious errors when trying to assess the risk from internal exposures, as many isotopes in body go to a particular organ, and so only expose the cells in that tissue. The risk depends on how sensitive the exposed cells are . . .

So we need to do something to correct for this effect also . . .

Effective dose

We obtain the effective dose received by an organ by multiplying the equivalent dose in that organ by the appropriate tissue weighting factor

The effective dose is the sum of the weighted equivalent doses in all the tissues and organs of the body. It is given by:

$$E = \sum w_T H_T$$

where H_T is the equivalent dose in tissue or organ T and w_T is the weighting factor for tissue T.

The SI unit : Sievert (Sv) ; 1 Sv = 1 joule/kilogram

Old unit : rem 1 Sv = 100 rem

Tissue Weighting Factor (W_T)

- W_T represents the contribution of tissue T to the total risk due to stochastic effects resulting from uniform irradiation of the whole body.

- W_T values are useful for converting equivalent dose received by one or more tissues (in partial body irradiation) to effective dose, which is whole body exposure equivalent.

Tissue weighting factors

From ICRP Publication 60 (1990)

The organs in the body which are most sensitive to radiation damage have the highest tissue weighting factors.

Tissue	Factor
Gonads	0.20
Bone marrow (red)	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Oesophagus	0.05
Thyroid	0.05
Skin	0.01
Bone surface	0.01
Remainder	0.05
Total	1.00

Note how the factors add up to 1.

Tissue Weighting Factor (W_T)

- Account for fact that the probability of stochastic effects depends on the organ or tissue irradiated
- Represent the relative contribution of irradiation of each organ or tissue to the total detriment due to the effects resulting from uniform irradiation of the whole body
- Desirable that a uniform equivalent dose over the whole body should give an effective dose numerically equal to that uniform equivalent dose
- Achieved by normalizing the sum of the tissue weighting factors to one

Effective dose

Effective dose accounts for the different radiosensitivity of the different cells in the body.

This gives us a system which we can use to compare the risks arising from internal and external exposures, whether these be uniform whole-body exposures or partial body exposures.

The effective dose is the best measure we have of the risk associated (true measure of risk) with all exposures to ionising radiations.

Concept of Effective Dose

- The relationship between the probability of stochastic effects (primarily cancer and genetic effects) and equivalent dose is found to depend on the organ or tissue irradiated.

- The effective dose combines the equivalent doses to the various body organs and tissues in a way which correlates well with the total of the stochastic effects

Dose rate

We measure the radiation dose a person receives in mSv or mrem

When considering external exposure we want to measure the dose rate at a position. To do this we use instruments which read in:

microSv/h or mrem/h

This tells us the rate at which a person will build up a radiation dose.

As we will see later, we can calculate the dose a person receives if we know how long they stay at that position:

Dose = Dose rate x time

Converting units

curie	becquerel
1 pCi	37 mBq
27 pCi	1 Bq
1 nCi	37 Bq
27 nCi	1 kBq
1 μCi	37 kBq
27 μCi	1 M Bq
1 mCi	37 MBq
27 mCi	1 GBq
1 Ci	37 GBq
27 Ci	1 TBq

1 Bq = 1 decay per second

1 Ci = 37 GBq

rem	Sievert
0.1 mrem	1μSv
0.25	2.5 μSv
0.5	5 μSv
0.75	7.5
1 mrem	10 μSv
2.5	25
10 mrem	100 μSv (0.1 mSv)
100 mrem	1 mSv
500 mrem	5 mSv
1 rem	10 mSv
1.5 rem	15 mSv
5	50
100 rem	1 Sv

1 Sv = 100 rem

Old & New Units

Quantity	Unit		Relationship
	Old	New	
Radioactivity	Ci	Bq	1 Bq = 0.27×10^{-10} Ci
Exposure	R	C / Kg	1 C Kg^{-1} = 3876 R
Air Kerma	-	Gy	1 Air Kerma = 114 R
Dose	Rad	Gy	1 Gy = 100 Rad
Equivalent Dose	Rem	Sv	1 Sv = 100 rems

Questions

Convert 500 mCi into MBq

- 1 mCi = 37 x 10^6 Bq

- A person gets an exposure X of 5.16 X 10^{-5} C/kg Convert this exposure in Roentgen

- 1 C/kg (X unit) = 3881 R

- 2.75 mGy = ---- Rad (1 Gy = 100 rads)
- 2 Rem = ----mSv (1 rem = 0.01 Sv)

- If 4 J of energy is deposited in 200 gm of a material, what is the amount of absorbed dose?

W_R depends on

a) Type of radiation

b) Energy range of the radiation

c) Activity of the source

d) Radiosensitivity of the tissue

- W_T depends on --------

- Calculate the equivalent dose for
  20 mGy of γ-radiation
  10 mGy of α- radiation

- Calculate the equivalent dose for 5 Gy of β-radiation

- A persons stomach and bladder receive a dose of 100 mGy each due to γ-radiation calculate the effective dose.

THANK YOU