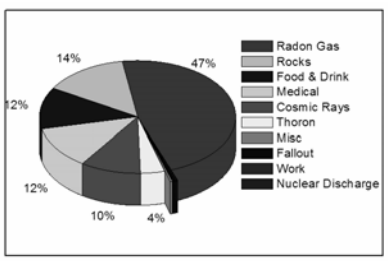
PAM2001 Dosimetry

In this lecture

- ★ Ionizing radiation doses in the UK
- ★ Effects of Ionizing Radiation
- ★ Exposure
- ★ Exposure in Air
- ★ KERMA
- ★ Absorbed Dose
- ★ Exposures in Different Media
- ★ Dose Equivalent
- ★ Effective Dose

UK Average Dose

- We live in an environment where we are continuously bombarded by ionizing radiation
- UK average
  - 90% Natural
  - 10% Artificial
- All ionizing radiation is considered a hazard



Ionizing Radiation

- X-rays passing through air cause;
- Excitation, Ionization & Heating

<u>Photoelectric Effect</u>

- Electron produced can have sufficient energy to ionize other atoms
- Produces more electrons – Delta rays
- Delta-rays are responsible for great deal of ionization --Secondary Ionizations

Net Effects

1. Formation of electrical charge in air
2. Air absorbs energy as electric charges are slowed down by collisions with air molecules. Causes more ionizations
3. Heating via transfer of energy to air molecules

Traditional measure of exposure concerned only with 1.

Measure of amount of ionization in air

Exposure

<u>Definition</u>

"Exposure at a particular point in a beam is the ratio Q/M. Where Q is the total electric charge (of one sign) produced in a small volume of air of mass M"

•Units: C . Kg^{-1}

Exposure Rate

- Measure of the intensity of a beam of given quality
- Greater number of photons passing through unit area the greater the amount of ionization of air per unit time
- Units: $C \cdot Kg^{-1} \cdot s^{-1}$

Exposure in Air

- Average atomic number of Air ~ 7.65
- Average atomic number of Muscle ~ 7.42
- Therefore have similar mass attenuation coefficients

$$I = I_o \exp[-(\mu/\rho)x]$$

Mass attenuation coefficient μ/ρ

Exposure in Air

- Energy absorbed from X-ray beam by given mass of air is similar to energy absorbed in the same mass of muscle
- Energy absorbed in air & muscle is therefore proportional to exposure measured in air

Air as a Medium in Dosimetry

- Allows dose in tissue to be calculated from knowledge of air exposure

Exposure & Air Kerma

- Exposure has been replaced by absorbed dose in air or air kerma

Kinetic Energy Released per unit Mass of Absorber

- Main Reason:
  - Much easier to calculate the absorbed dose in a structure from the air kerma

Absorbed Dose & Air Kerma

- Quantity of *charge* produced in air is NOT the same as the *energy* actually absorbed
- The two quantities are proportional to each other

Absorbed Dose

Definition

"Absorbed dose in a medium is the ratio E/M. Where E is the energy absorbed in a medium due to a beam of ionizing radiation directed at a small mass M."

Units: Gray
1 Gray = 1 Joule per Kilogram

Exposure & Absorbed Dose

Note:

- Exposure is defined in terms of X- or *γ-rays*
- Absorbed dose is defined in terms of any form of ionizing radiation

Effects of Different Media

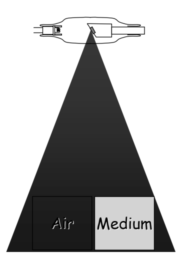
- Dosemeters & Dose Rate Meters
- Calibrated to read absorbed dose in air
- I.e. Reading of 0.5 mGy in air at a particular point in a X- or γ-ray beam
  - Not true that this is the dose absorbed in any other medium

Effects of Different Media

- For two media to received the same dose, they must absorbed the same energy per unit mass
- This is the same as saying the mass absorption coefficient (μ_a/ρ) of the two media must be equal

Effects of Different Media

- Air and a medium with a different absorption coefficient are irradiated with identical X-ray beams
- D_{air} is the absorbed dose in air
- D_m is the absorbed dose in another medium.
- We can calculate the relative doses…

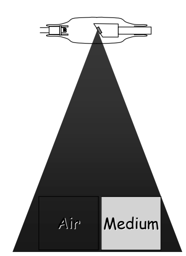


Effects of Different Media

$$\frac{D_m}{D_{air}} = \frac{(\mu/\rho)_m}{(\mu/\rho)_{air}}$$

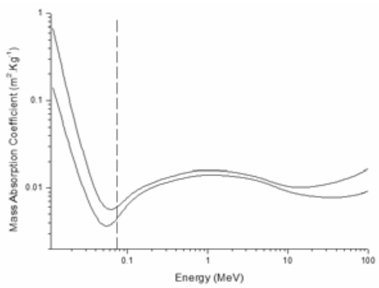
$$D_m = D_{air} \times \frac{(\mu/\rho)_m}{(\mu/\rho)_{air}}$$

- If mass absorption coefficient of air & medium are know for particular photon energy
- We can calculate the absorbed dose in the medium



Effects of Different Media

- Mass absorption coefficients of air & bone vary with photon energy



Quality Factor & Dose Equivalent

- Biological effects do not depend solely on absorbed dose
- Type of radiation & absorbed dose rate
- For instance:
  - α-particles are known to cause 20 times more damage than the same dose of X-rays
  - Also a dose received in one go will cause more damage than the same dose received in several smaller doses

Quality Factor & Dose Equivalent

- Differences are due to different densities of ionizations they produce in the same sample
- Therefore absorbed dose is NOT an accurate measure of the *biological effects* of different types of radiation.

Quality Factor & Dose Equivalent

- Units used to measure overall biological effectiveness of different types of radiation
- Dose Equivalent
- Unit: sieverts (Sv)

Quality Factor & Dose Equivalent

- Absorbed dose and dose equivalent are related

$$\text{dose equivalent (Sv)} = Q \times \text{absorbed dose (Gy)} \times N$$

- Q – quality factor
  (related to № of ion-pairs produced per unit length)
- N – other factors effecting biological effectiveness (dose rate)

Quality Factor & Dose Equivalent

- Absorbed dose and dose equivalent are related

$$\text{dose equivalent (Sv)} = Q \times \text{absorbed dose (Gy)} \times N$$

Radiation	Quality Factor
X- & γ-rays	1
Electrons or β-particles	1
Thermal Neutrons	2.3
Fast Neutrons	10
Protons	10
α-particles	20
Recoil Nuclei	20
Fission Fragments	20

Quality Factor & Dose Equivalent

- Dose equivalent is too crude for use in radiobiology
  - Considers only the average effects on a group of cells
- For Radiobiology we may wish to look more precisely at the effects on individual cells
- As with Q, this is compared usually compared with the same dose of X- or γ-rays
- Use Relative Biological Effectiveness (RBE)
  - Compares the absorbed dose of different types of radiation required to produce the same biological effects

Effective Dose

- Different tissues show different sensitivities to radiation
- Tissue Weighting factor (W_t)

"Risk of stochastic event being induced in a particular tissue when singularly radiated, compared to the risk of inducing effect if the same dose is received by whole body"

$$Effective\ Dose = Dose\ Equivalent \times W_t$$

- Units: sieverts (Sv)

Tissue Weighting Factor

- The sum of the tissue weighting factors is unity

Tissue weighting factors	
Testes & Ovaries	0.20
Red Bone Marrow	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Breasts	0.05
Bladder	0.05
Oesophagus	0.05
Thyroid	0.05
Liver	0.05
Bone Surfaces	0.02
Skin	0.01
Remaining Tissues	0.04

Example

- A radiograph is produced with the following dose equivalents:
  - breasts 0.2 mSv,
  - lung 0.4 mSv,
  - thyroid 0.06 mSv,
  - Bone surface 0.02 mSv,
  - stomach 0.08 mSv,
  - oesophagus 0.01 mSv,
  - skin 0.2 mSv.
- Calculate the effective dose received by the patient.

Tissue weighting factors	
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Red Bone Marrow	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Breasts	0.05
Bladder	0.05
Oesophagus	0.05
Thyroid	0.05
Liver	0.05
Bone Surfaces	0.02
Skin	0.01
Remaining Tissues	0.04

Summary

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- ★ Effects of Ionizing Radiation
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