RADIATION PROTECTION NOTE 6: THE EXTERNAL HAZARD

The external radiation hazard arises from sources of radiation outside the body. When radioactive material actually gets inside the body it gives rise to an internal radiation hazard. The internal radiation hazard is discussed in Radiation Protection Note No: 7.

Alpha radiation is not normally regarded as an external radiation hazard as it cannot penetrate the outer layers of the skin. The hazard may be due to beta, X-ray, gamma or neutron radiation and is controlled by applying the ALARP principals of using least activity, time, distance and shielding.

USE LEAST ACTIVITY

All experiments involving radioactive materials should be designed and planned so that successful results may be obtained by using the minimum amount of radioactivity. Taking the random nature of radioactive decay into account, it is possible to calculate the statistical error $n^{½}$ associated with the count "n" obtained at the end of the experiment. This error should be arranged to be considerably less than other experimental errors and one can then work back through other procedures involved to calculate the activity of radioisotope required in the initial stages of the experiment. It should be noted that using twice as much stock solution will double the final count but, at best, will only improve the statistical error by a factor of $\sqrt{2}$.

USE LEAST TIME

The radiation dose received by a person working in an area having a particular dose rate is directly proportional to the amount of time spent in the area. Therefore, dose can be controlled by limiting the time spent in the area.

Dose = Dose rate x time

Experiments should be carefully planned beforehand and all apparatus should be present and be in a serviceable condition. It is good practice to carry out a dummy run using non-radioactive compounds to highlight weaknesses in technique before radioactivity is used.

USE DISTANCE PROTECTION

It has been shown previously that radiation dose is proportional to the number of ionisation events per unit mass. This in turn is proportional to the flux of radiation incident on the tissue in question. For a point source of radiation the flux is inversely proportional to the square of the distance. This is the Inverse Square Law ie, doubling the distance from a point source reduces the dose received by a factor of four and trebling the distance reduces the dose rate to one ninth and so on.

The extra distance provided by the use of tweezers or tongs produces a tremendous lowering in exposure compared to holding a source in the hands. Distance also exerts some protective effect through the interposition of air between the source and worker, but except for the low energy beta emitters, this effect is generally small at normal working distances eg:

(i) 400 μSv/hr at 5cm

(ii) 100 μSv/hr at 10cm

(iii) 1 μSv/hr at 1m

Remember the rule of thumb - **double the distance, quarter the dose**

SHIELDING

It is generally found that radioactive sources have to be shielded to allow personnel to work in their close vicinity. Alpha particles are easily absorbed. A thin sheet of paper is usually sufficient to stop alpha particles so alpha particles never present a shielding problem. Beta radiation is more penetrating than alpha radiation. In the energy range which is normally encountered (1–10 MeV) beta radiation requires shielding of up to 1cm of perspex for complete absorption.

The ease with which beta sources may be shielded sometimes leads to the erroneous impression that they are not as dangerous as gamma or neutron sources and large open beta sources are often handled directly. This is an extremely dangerous practice ie, the absorbed dose rate at a distance of 3mm from a typical beta source of 37 MBq is about 30 Sv/hr.

One important problem encountered when shielding against beta radiation concerns the emission of secondary X-rays that result from the rapid slowing down of the beta particles. This radiation is known as bremsstrahlung. The fraction of beta energy converted to bremsstrahlung is approximately ZE/1000 where Z is the atomic number of the absorber and E is the beta energy in MeV. This is why beta shields are normally constructed of materials of low atomic mass number (perpex).

When dealing with the ranges of charged particles in matter, it is convenient to express the “thickness" of material in terms of mass per unit area because the physical or chemical form of the stopping material does not affect the numerical value of the range expressed in this “thickness” unit. If we know the density of the material to be used as shielding then,

Mass/Unit Area (gm/cm^2) = Thickness (cm) x Density (gm/cm^3)

For beta particles of energy E_β (MeV) the range R_β is given to a close approximation by:

$$R_\beta = \frac{E_\beta}{2} \text{ gm/cm}^2$$

Example using ^{32}P - E = 1.7 MeV The density of perspex = 1.2 gm/cm^3

$$\text{The range R} = \frac{1.7}{2} = 0.85 \text{ gm/cm}^2$$

$$= \frac{0.85}{1.2} = 0.7 \text{ cm}$$

Attenuation of X and gamma radiation is exponential in character and a given thickness of a shielding material reduces the incident radiation flux by a factor depending on its absorption and scattering properties. For X-radiation and gamma photons of energy less than 100 kEv, lead sheeting of thickness approximately 1mm provides adequate shielding. For more energetic gamma radiation, several cm of lead are required to produce appreciable attenuation. Remember it is always better and cheaper to shield radioactivity at the source rather than at a distance.

<u>The Adequate Shielding Level</u>

The Ionising Radiations Regulations 2017 set an annual dose limit of 20 mSv/year for radiation workers and have retained the adequate shielding level at 7.5 μSv/hour.

ESTIMATION OF DOSE RATE BY CALCULATION

Since the radiation dose received depends on the incident flux of particles or photons, the dose rate at a given distance from a point source of known activity can be calculated. The dose rate is the radiation dose received in a given time and is usually measured in microsievert/hour (μSv/hr) or millisievert/hour (mSv/hr).

Beta Radiation

The radiation dose received from beta radiation does not depend on the energy of the beta particle. This may seem surprising, but it is because the higher energy beta particles deposit their energy in a greater depth of tissue and radiation dose is defined in terms of energy dissipated per unit mass.

Thus "soft" beta radiation such as ^{14}C and ^{35}S is just as damaging to the basal layers of the skin as the "hard" betas from ^{32}P. However, whereas ^{14}C and ^{35}S irradiate to a depth of < 1mm, ^{32}P radiation penetrates to a depth of 8mm. It should be noted that ordinary laboratory disposable gloves are of sufficient thickness to stop ^{14}C and ^{35}S, but not ^{32}P.

Quantifying the dose rate produced by beta radiation we find:

1 beta particle per cm^2 s^{-1} => 1 microsievert h^{-1}

The dose rate D_β, in μSv/hour produced by a point source of beta radiation of Activity M Megabecquerels at a distance of 0.1 m (hand distance) from the source is given by:

D_β = 1000 M μSv/hr at a distance of 0.1 m

example:- Suppose you are dispensing from 4 MBq ^{32}P for five minutes. Find the dose to the hands at a distance of 0.1m.

$D_\beta = 10^3 \times 4 = 4000$ μSv per h^{-1} at 0.1 m = 4 mSv per h^{-1}

5 mins = 1/12 hr therefore dose = 4/12 mSv = 0.33 mSv

Annual dose limit to the hands is 500 mSv = 10 mSv per week

Therefore you received 1/30 of a week's dose to the hands

Gamma Radiation

For gamma radiation with a photon energy > 100 keV, the dose rate is proportional to photon energy. Taking the total energy emitted as gamma radiation in one nuclear disintegration as E (MeV), the gamma dose rate at a distance of 1m from a source of activity M Megabequerel is given by:

Dose rate D_γ = ME/7 μSv/hr at 1m

example:- Find the gamma dose rate at a distance of 0.5m from a ^{60}Co source of activity 50 MBq. (*Note:* ^{60}Co emits two gamma ray photons per disintegration of energy 1.17 and 1.33 MeV respectively.)

Therefore E	= 1.17 + 1.33 = 2.5 MeV
Dose rate at 1m	= 50 x 2.5/7 = 17.9 μSv/hr
Dose rate at 0.5m	= 17.9 x 4 = 71 μSv/hr

ESTIMATION OF DOSE RATE BY MONITORING

It has been shown that the Ion Chamber is the recommended instrument for measuring dose rate or dose but, as this instrument is very expensive, it is not cost effective to have one in every laboratory. We may obtain an approximate estimate of dose by calibrating a minimonitor against the reading given by an ion chamber at a set distance.

<u>Beta Radiation</u>

The response of end window GM Minimonitors such as Type E, EB, EL,EP15 and all 900 series depends upon the window area and the type of grille fitted.
The RPS carries out annual calibration of all monitors within the University and part of the calibration tests each monitor's response to a dose rate of 10 μSv/hr. For all monitors this response lies between 20–40 counts per second (cps). The actual response is typed onto a label that is affixed to the side of each instrument.

<u>Gamma Radiation</u>

The response of a typical GM to gamma radiation is shown below. It can be seen that for a given dose rate the tube is most sensitive at photon energies below 100 KeV, peaking at about 50-60 KeV and above 150 Kev the response is relatively flat.

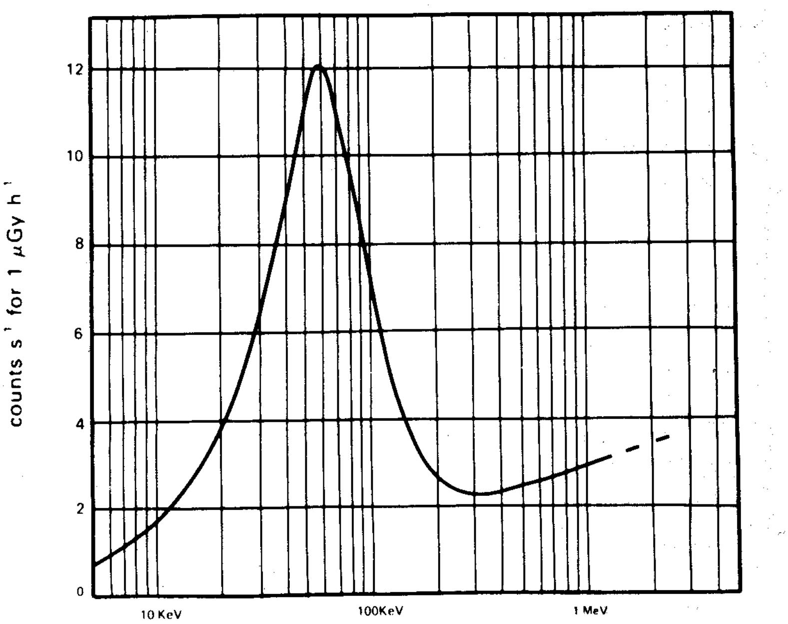

Fig. 4 Energy response of ZP1490 (Model E)

Using the plateau region it can be seen that about 30 cps corresponds to a dose rate of 10 μSv/hr