Introduction:

Previous sections have focussed on mainly on doses resulting from internal exposure to radionuclides. In this section, we will examine some of the aspects of exposure to sources external to the body.

Types of External Exposure

The following are general categories of external exposure that must be considered by the Health Physicist.

Whole Body exposures from uniform fields of penetrating radiation (e.g. in an area or room)	• Exposures arising from photons and sometimes neutron radiation • Radiation fields in the area may be described as "ambient", "average" or "background" for example • Assumption that fields are fairly uniform over a wide area and that the measured dose rate reflects the whole body or effective dose rate while occupying the area.
Whole body exposure from radiation emitted from an item	• Exposure arises from photons and (less commonly) neutrons. • Similar to above – but the radiation field of concern is originating from an item such as a sample or a pipe full of radioactive material. • Often the dose rate at a fixed distance (such as 3 cm) is measured and used to assess the dose that will result while in proximity. • The assumption is generally made that the measured dose rate is a whole body or effective dose rate.
Partial body exposures	• Exposures to part of the body – e.g. from a beam of radiation leaking through a shielding crack. • Assessment is required to interpret the exposure in terms of effective and equivalent doses.
Skin Exposures	• Exposures arising from the penetrating and non-penetrating radiation. • Skin contamination is a special case. • For unshielded beta/gamma emitters the non-penetrating radiation will dominate within the range of the beta particles. • The equivalent dose rate to the skin is the penetrating plus non-penetrating dose rate.
Extremity	• A special case of partial body exposure frequently encountered. • The total (penetrating plus non-penetrating) radiation field is assessed in "near-contact" to items to be handled – this is taken as the equivalent dose rate to the extremity. • Care must be taken in estimating exposures due to geometry factors.

External Exposure from Photon Emitters

The absorbed dose rate at a point from photons is

$$\dot{D} = \phi E_\gamma \frac{\mu_{en}}{\rho}$$

ϕ = the photon fluence rate

E_γ = the photon energy

$\frac{\mu_{en}}{\rho}$ = the mass energy absorption coefficient (cm^2/g)

A table of mass energy absorption coefficients reproduced from Cember [1] is provided on a separate sheet.

For a point, isotropic source,

$$\phi = S\frac{1}{4\pi r^2}$$

S = the source strength (photons s^{-1}) = $A\, n_\gamma$ (activity in Bq times the yield)

r = distance from the source

Example – calculate the absorbed dose rate in tissue at 2 m from a 10 MBq ^{137}Cs point source.

The dose rate at a meter from a point source of activity has been tabulated in many units. It is known as the gamma specific dose constant and is a useful tool in estimating dose rates from point sources and other source geometries. This is probably familiar territory for anyone in this course.

External Exposure from Beta Emitters

The dose rate from a charged particle flux is given by

$$\dot{D} = \phi\left(\frac{S}{\rho}\right)_{col}$$

ϕ = the charged particle fluence rate $(cm^{-2}s^{-1})$

$\left(\frac{S}{\rho}\right)_{col}$ = the collision mass stopping power $(MeV\ cm^2/g)$

Because the collision mass stopping power is pretty constant for energies over about 200 keV, it is possible to approximate the dose rate from a point source.

$$\dot{H}(Sv/h) = 8E-12 \cdot n \cdot C \cdot d^{-2} \text{ Sv/h Bq}^{-1}\text{m}^2$$

or in "old" units

$$\dot{D}(rad/h) = \frac{300 \cdot C \cdot n}{d^2} \text{ rad/h Ci}^{-1} \cdot \text{ft}^2$$

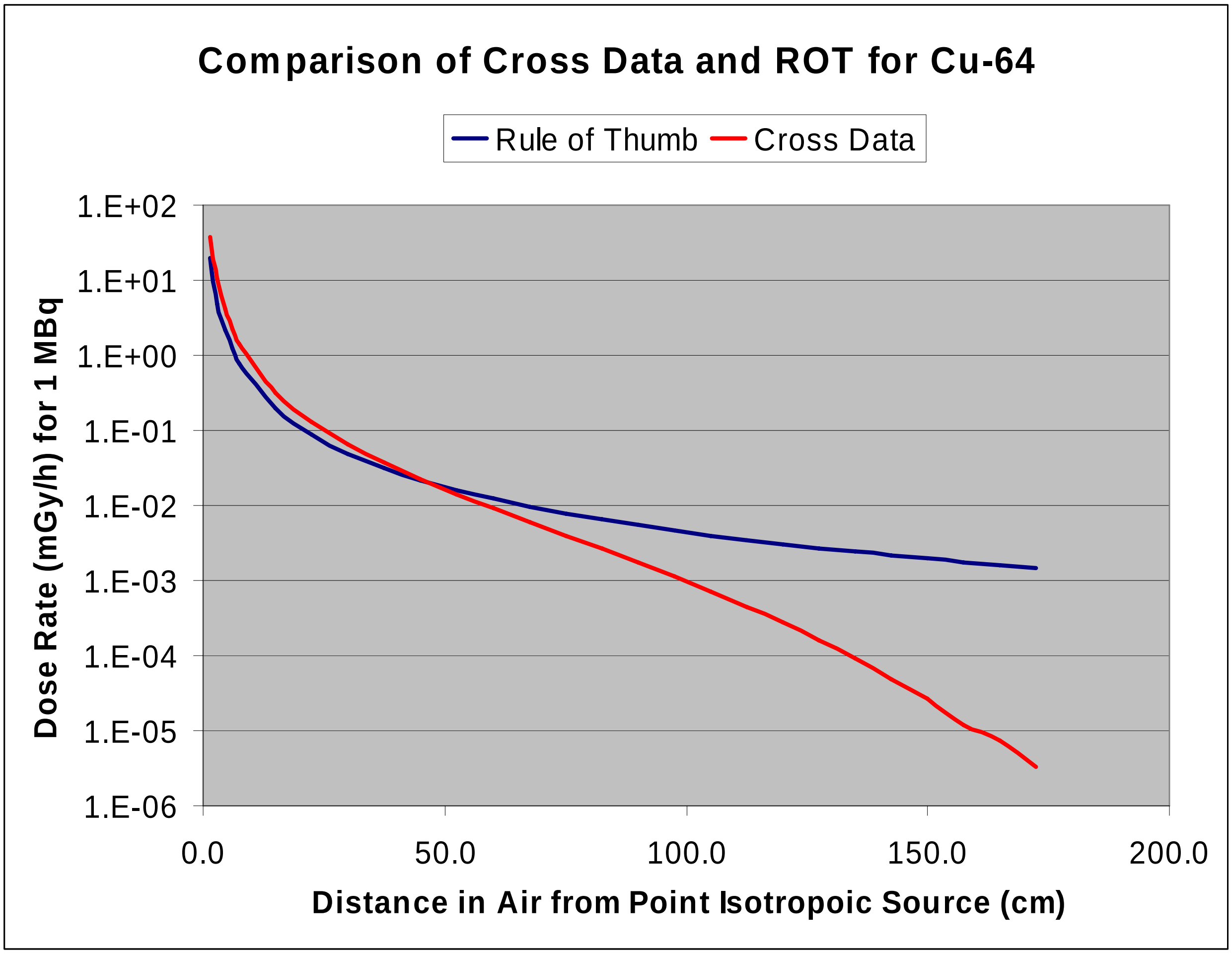
n = number of beta particles per decay

C = source activity in appropriate units

d = distance from the source in appropriate units

These are approximations that do not take account of air attenuation or self shielding and should be used with awareness. For example, the estimate will be out by 90% for C-14 at 30 cm (1 ft), and by 30% for Co-60 at the same distance due to air attenuation.

Cross has published data for point isotropic beat sources in air that are very useful. The data for Cu-64 is compared with the rule of thumb below:



Example – estimate the dose rate at 30 cm from a 1 GBq point source of P-32, neglecting self shielding.

External Exposure from Neutrons

Neutron dose conversion factors are published in ICRP 51. Neutron doses rates are estimated in a similar manner to that of photons.

$$\dot{H} = \phi \bullet DCF$$

$\phi =$ the neutron fluence rate ($\mathrm{cm}^{-2} s^{-1}$)

$DCF =$ the *d*ose conversiuon factor in appropriate units, for the neutron energy of concern

Specific values are provided in ICRP 51 or approximations (old units) are:

$$\mathrm{DCF}_{\mathrm{thermal}} = \frac{2.5 mrem/h}{670 cm^{-2} s^{-1}}$$

$$DCF_{fast} = \frac{2.5 mrem/h}{17 cm^{-2} s^{-1}}$$

References:

1. Cember, Introduction to Health Physics, Third Ed., 1996, McGraw Hill, New York.
2. Cross, Tables of Beta-Ray Dose Distributions in Water, AECL, 1992.
3. Schlein, Health Physics and Radiological Health Handbook, Scinta, 1992