



The University of Sheffield

Safety Services



Restriction of Exposure - Hazard Control

In order to minimise the exposure to ionising radiations, one needs to appreciate the properties of the ionising radiations and the two principal hazards that they can present.

We can be irradiated by a source of radiation that is outside the body - this presents us with an external hazard, or we can accidentally incorporate radioactive materials into the body - this presents us with an internal hazard. All hazards from ionising radiations can be minimised by using the lowest activity source or energy of X-rays consistent with experimental requirements.

6.1 External Hazard

External hazards can arise from any source of penetrating radiation, e.g. X-ray sets, gamma emitters, neutron sources and hard beta emitters. The more penetrating the radiation, generally the greater the hazard, although in some ways hard betas and soft X-rays, which are absorbed by the surface layers of tissue, can be more hazardous than more penetrating radiations which might go straight through the body (medical X-rays). Weakly penetrating particles do not pose an external hazard. There can only be a hazard from X-ray sets whilst the set is switched on. Sealed sources, used under normal conditions, should only present an external hazard, but this will always be present. Open sources can also present an external hazard, and as with other external radiation hazards, doses can be minimised by:-

- (a) use of effective **shielding**;
- (b) keeping one's **distance** and
- (c) exposing oneself for the minimum of **time**.

6.1.1. Estimating Dose Rates

The dose rate associated with any point source of gamma or X-radiation is inversely proportional to the square of the distance from the source - hence the term the **'inverse square law'**

$$D \text{ proportional to } 1/r^2$$

Therefore, doubling the distance from the source, reduces the dose rate by a factor of 4. Always remember **closeness endangers - distance protects**.

Use the following expression to calculate the approximate **dose rate from a gamma source**:-

$$D = ME / 6r^2$$

D is dose rate in μSvh^{-1}

M is activity in MBq

E is energy/disintegration in MeV

r is distance from source in metres

This of course assumes no shielding, and a monitor should always be used to establish the true dose rate (see [guidance](#) on dose-rate response of Mini E).

The table below gives some examples of dose rates at 1 m from 10 MBq sources, using information on the energy and intensity of their gamma emissions from ICRP publication 38.

Isotope	gamma dose rate at 1 metre in μSvh^{-1} for 10 MBq source
Na-22	3.65
Cr-51	0.05
Fe-59	1.98
Co-57	0.21
Co-60	4.17
I-125	0.07
I-131	0.63

A useful expression for estimating the **dose rate from a hard beta emitter** is given by the formula:-

$D=760A$ where D is the dose rate in $\mu\text{Sv/h}$ at 10cm from a point source of activity A in MBq.

6.1.2. Shielding

Beta particles are best shielded by materials of low atomic number to prevent the production of bremsstrahlung. Perspex makes good shields, because it is robust and easily worked. Glass is also very effective, and thick walled glass vessels are particularly useful. The table below shows the thickness required for complete shielding.

E max (MeV)	0.5	1.0	2.0	3.0
Glass	1mm	2mm	4mm	7mm
Perspex	2mm	4mm	7mm	12mm

Gamma rays and X-rays are far more penetrating than beta particles of the same energy and require dense shielding materials - lead is the material which is usually used. They are attenuated exponentially, and a knowledge of the half-value layer (HVL) or tenth-value layer (TVL) is useful in determining the amount of shielding required. 1 HVL is the thickness required to reduce the intensity to one half the incident value and 1 TVL is the thickness needed to reduce the intensity to one tenth the incident value. Some approximate values of HVL and TVL are given in the table below.

Gamma energy MeV	millimetres of lead shielding	
	HVL	TVL
0.5	4	12.5
1.0	11	35
1.5	15	50
2.0	19	60

The good working practices required for work with sealed sources are given: in the [Laboratory Rules](#) ; in the conditions of individual Work Certificates; and in some cases in additional detailed operating instructions. Detailed precautions for work with X-ray crystallographic equipment are given in the [x-ray guidance notes](#).

6.2 Internal Hazard

When working with open or unsealed sources of radioactive material, as well as having a possible external hazard to contend with, one is faced with the possibility that radioactive material might find its way into the body. One would then be faced with an internal radiation hazard, and shielding, distance and time would no longer afford protection. Only by a combination of physical half-life and biological half-life can the material be eliminated from the body - some may remain there forever. It can easily be appreciated that small amounts of radioactive material inside the body can be more harmful than much larger amounts outside the body.

Every effort must be made, therefore, to prevent radioactive material from entering the body. Routes of entry into the body are via the mouth by inhalation or ingestion and through the skin via cuts or absorption. Internal contamination can be avoided by adopting good working practices, and by following some basic precautions, such as:-

1. use of materials of minimum radiotoxicity;
2. presence in the laboratory of the minimum quantities;
- 3 work behind a screen;
4. containment, to prevent spread of contamination;
5. cleanliness and good housekeeping; and
6. use of appropriate protective equipment.

The good working practices required for work with unsealed sources are spelt out in the [Laboratory Rules](#).

A useful indication of the radiotoxicity of an isotope is its annual limit of intake (ALI). This is the amount which, if taken into the body in a year, will result in the individual receiving the full annual dose limit from this source of radiation alone. A list of the most restrictive ALI's for the common isotopes is given below:-

Isotope	ALI (Bq)
H-3(water)	1.1×10^9
H-3(OBT)	4.7×10^8
Cr-51	5.3×10^8
C-14	3.4×10^7
S-35	1.5×10^7
P-33	1.4×10^7
P-32	6.2×10^6
I-125	1.3×10^6

The importance of regular monitoring cannot be stressed enough as it is the only way of ensuring that the other precautions you have taken have been effective in minimising contamination.

6.2.1 Contamination Monitoring

There should always be a suitable contamination monitor available in areas where unsealed sources are used. It should have a check source with it, so that it can be tested before and during use, to make certain that the monitor is functioning correctly. Every time you handle radionuclides, you should use the appropriate contamination monitor to monitor yourself and your immediate work area - bench top, equipment, bench front and floor - at the end of each work session. Any contamination found should be removed immediately, or if this is not practicable, a suitable warning notice should be displayed. On no account should contamination be left unmarked which would pose a hazard to others.

At regular intervals, depending upon the grade of the laboratory, a full monitoring survey should be carried out to establish that:-

- (a) the area is correctly designated (on grounds of contamination); and
- (b) any contamination that has occurred has been dealt with efficiently and has not been spread to - fridge doors, cupboard doors, floors, door handles, etc.

These [monitoring surveys](#) have to be recorded.

If you are working with tritium, then conventional monitoring will not be any use, as the very weak beta emissions from tritium cannot be detected by the contamination monitors. You therefore have to perform [wipe tests](#) using moistened filter papers and sampling a known area.

6.3 Decontamination Procedures

All contamination should be removed as soon as possible after it has occurred, except in the following circumstances:-

- (a) the contaminated item is disposable and can legitimately be put in the solid radioactive waste drum; and
- (b) the isotope is of such short half-life (no more than a few hours) that, if the contamination was left, it would rapidly decay away.

In the case of (b) above, one is concerned not to unnecessarily expose personnel to hazardous radiations during the cleaning process. Any area left with a high level of contamination should be clearly and prominently marked, to keep people away from it until the isotope has safely decayed.

Any decontamination exercise should always start with the mildest cleaning agent, e.g. soap and water, before moving on to harsher treatments. The cleaning process should always commence from the outer extent of the contamination and proceed towards the centre, to avoid spreading the contamination.

If an individual is heavily contaminated the emergency procedures outlined on page 2 should be followed and the individual taken to the special decontamination facility that is available at the Northern General Hospital.

Further information on [decontamination](#) is available in the guidance notes.