Radiation Safety Management

Information Sheet: General Radiation Information

Purpose

The purpose of this information sheet is to provide technical information on radiation and support the information provided in the Radiation Safety Management HSW Handbook chapter.

Q1 What is a radiation dose?

- Radiation dose is the term given to the energy absorbed from ionising radiation.
- It is measured as the energy absorbed from the radiation field per unit mass of the absorbing material.
- The absorbed dose rate is the absorbed dose per unit time.
- The word dose is normally used instead of the more correct absorbed dose.

Q2 What are the biological effects of ionising radiation?

Ionising radiation is harmful to life because it acts on cells and their constituents at the molecular level. Absorption of energy from ionising radiation may result in changes to the molecules, destruction of cellular elements and altered function or death of the cell. At low doses ionising radiation may cause cancers and induce genetic defects. At high doses it can kill cells, damage organs and cause rapid death.

Somatic effects (appearing in the individual)

These are the result of direct cell damage and can be:

- acute if they appear within a short time of the exposure (hours or days); or
- delayed if they appear after months or years.

The damage done by high doses normally becomes evident within hours or days, but cancers may take many years to emerge.

Genetic effects (appearing in the offspring)

These are the result of damage to the DNA of germ cells and may occur at low doses. The effects are only apparent in offspring and are so small they are difficult to observe even in large populations.

Hereditary malformations and diseases caused by genetic damage may take generations to show in the descendants of those irradiated.

Q3 What are the medical effects of ionising radiation?

Medical effects can be divided into:

Deterministic effects

The severity of the effect increases with the dose and there is a threshold dose below which no detrimental effects are seen. These are produced by relatively high doses. The effects vary considerably from one organ to another and the more radiation sensitive tissues or organs are the ovaries, testes, bone marrow and the lens of the eye.

Stochastic effects

These are statistical or random in nature and occur with a probability that depends on the radiation dose. In general only the probability of an effect can be established. The probability of the effect occurring is very low or zero at low doses. For radiation protection purposes the probability is assumed to be proportional to the dose. There are two types of stochastic effects. The first may result in the induction of cancer in the exposed person (somatic). The second may result in genetic (hereditary) disorders.

Q4 What are the sources of radiation exposure?

Everyone is exposed to natural radiation from cosmic rays and radioactive elements in the earth, the atmosphere and our own bodies. The dose from natural radiation background radiation in South Australia is about 2 mSv per year.

People are also exposed to radiation sources at work/study, most commonly in medical, dental and veterinary procedures.

Q5 What are the terms and units associated with radiation protection?

Absorbed Dose: is the amount of energy absorbed by any medium from any type of ionising radiation.
It is often just called the dose.
The unit is the Gray (Gy)
1 Gray = 1 Joule per kg

Dose Rate: is the rate at which a dose is delivered, as in µGray per hour (background, most radiation work), milliGray per minute (diagnostic X-ray).

Radiation Weighting Factor wR depends on the type of radiation, and is 1 for β and γ radiation and X-rays, and larger (10) for neutrons.

Equivalent Dose is the calculation to estimate the biological hazard of different types of radiation.

Equivalent Dose (in Sievert (Sv) = Absorbed Dose in Gray x Radiation Weighting Factor.

Effective Dose is used as an indicator of the effects of radiation on the body as tissues and organs in the body differ in their sensitivity to radiation (i.e. the skin and liver are much less sensitive than the reproductive organs [testes and ovaries] or bone marrow). Tissue weighting factors, wT are used to indicate the relative sensitivity. In general, measurement of a radiation field in Sieverts by distance of a meter away will be a close approximation to the whole body effective dose.

Activity is a measure of the quantity of radioactive material. For general purposes the rate at which a radioactive material is disintegrating (decaying) is the most useful quantity. It is important in designing experiments and in estimating the hazard from the radiation produced by the decay.

Because the decay rate is directly proportional to the number of atoms of the radionuclide, the activity is a measure of the quantity of radioactive material.

The unit is the Becquerel (Bq).

1 Becquerel = 1 disintegration per second.

As this is a very small quantity, we usually deal with kiloBecquerel (kBq), MegaBecquerel (MBq) or GigaBecquerel (GBq). Some sealed sources may be in the TeraBecquerel (TBq) range.

Old Units are used in the USA but are not referenced in regulations or codes of practice in Australia.

Absorbed dose:	rad	1 rad = 10 mGray
Equivalent and effective dose:	rem	1 rem = 10 mSv
Activity:	Curie, Ci	1 Curie = 3.7 x 10^{10} Becquerel
	1 mCi = 37 MBq	1 µCi = 37 kBq
	1 GBq = 27 mCi	1MBq = 27 µCi
	1kBq = 27 nCi	

Q5 What are the terms and units associate with radiation protection? Continued

Dose Limits are limits to the effective dose (over and above normal background approximately 2 mSv a year) equivalent for radiation workers and the general population and are based on the best current data, which is that the probability of developing a fatal cancer is about 0.05 (about 20,000 to 1) per Sievert.

The current South Australian legislated dose limits are:

- Radiation Workers 20 mSv per year averaged over 5 years and no more than 50mSv in a year
- Pregnant Workers 0.75 mSv during pregnancy
- General Public 1 mSv per year

Dose Constraint is an exposure level that is not expected to be exceeded. It is not a legal dose limit. It is used by the University as a guide to identify unusual changes in a worker's dose and as a basis for investigation. The current dose constraint set by the University for radiation workers is 1 mSv per year. (Please note that an investigation will occur to prevent any worker reaching 1mSv per year should an anomaly be identified in the quarterly dose report received by the HSW Team).

The **Annual Limit of Intake** (ALI), is the amount of a radionuclide that if ingested, inhalation or absorption will lead to a committed dose equal to the annual dose limit of 20 mSv. Data for the ALI of common radionuclides are included in Properties of Some Commonly Used Nuclides.

Derived Air Concentration (DAC) is the maximum concentration of a radionuclide, which if present in air, breathed at a standard rate of 20 litres per minute for 2000 hours per year, would be equivalent to the ALI.

Derived Limit for Surface Contamination is contamination on surfaces which can cause external irradiation of the skin, and indirectly, ingestion of the radionuclide. The surface concentration of a radionuclide (in Bq per cm^2) which in a working year would deliver the maximum annual skin dose (500 mSv) is the Derived Limit for Surface Contamination. It is the contamination in Becquerel per square centimetre that will deliver 250 μSv per hour to the skin. It is normally used as an indication of whether a surface needs decontamination. Data for surface contamination limits common radionuclides are included in Properties of Some Commonly Used Nuclides.

Q6 What is the classification for radionuclides and laboratories?

Radionuclides

For simplicity the radionuclides are classified into four classes according to their hazard. The radionuclides in Class 1 are the most hazardous (e.g. alpha emitters) while those in Class 4 (e.g. tritium) are the least. The classes for the common radionuclides are included in Properties of Some Commonly Used Nuclides.

Laboratories

Laboratories in which radionuclides are used are placed in three classes: A, B and C. The classification is based on the activity level of radionuclides that can be safely used in each type of laboratory. Type C is the common type and is the one where the least quantities of radionuclides are used. Type B is designed for medium level and Type A is for the highest level of activity.

The classification depends on:

- the class to which the radionuclides belong;
- the maximum activities used; and
- the type of operations performed.

Laboratories will have the classification signage displayed.

Q7 What is the range of isotope activities allowed in laboratories

Radionuclide Class	Laboratory Type		
	C	B	A
1	< 400 kBq	400 kBq - 40 MBq	> 40 MBq
2	< 40 MBq	40 MBq - 4 GBq	> 4 GBq
3	< 4 GBq	4 GBq - 400 GBq	> 400 GBq
4	< 400 GBq	400 GBq - 40 TBq	> 40 TBq

- In general, University laboratories are Type C and are used for the less hazardous operations.
- The quantity of a radionuclide that will be used in a laboratory must be multiplied by the factors in the following table and the results applied to the table above to determine the laboratory class that is required. The types of radionuclides and the maximum quantities that may be used are included in the Registration Certificate for each registered area.
- The HSW Team (Human Resources) is responsible for the classification of registered premises
- The maximum amount of a radionuclide that can be used in a laboratory depends on the hazard from the type of work being done.
- Working with dry, powdered material is more hazardous than pipetting of liquids.
- The modifying factors indicate the level of precaution needed in handling the radionuclide. The modifying factor is **one** for normal chemical operations but up to one hundred times the normal quantity may be stored in the same type of laboratory.

Modifying Factors

Type of Operation	Modifying Factors
Simple storage	0.01
Simple wet operations such as preparation of aliquot of stock solutions	0.1
Normal operations involving few transfers	1
Complex operations involving many transfers or complex apparatus	10
Simple dry operations (e.g. manipulation of powders)	10
Work with volatile radioactive compounds	10
Dry, dust producing operations such as grinding	100

Q8 What are properties of some commonly used nuclides?

Nuclide	Class	Half-life	Biological $t_{1/2}$ days	Effective $t_{1/2}$ days	Main radiation	Energy MeV (Max for beta)	Gamma dose rate from 1MBq at 10cm, μGy/hr	Ingestion ALI MBq	Suggested Shielding for a Factor of 0.1	Surface Contamination Limit Bq/sq cm
H3	4	12.3 yr	12	12		0.018		1000		1000
C14	3	5730 yr	10	10		0.156		40		1000
Na22	2	2.6 yr				1.275	32	10	37mm Pb	100
P32	3	14.3 dy	241	13.5		1.7		8	10mm Perspex	100
P33	3	25.4 dy	241	25		0.248		80	10mm Perspex	100
S35	3	87.4 dy	70	44		0.17		70	10mm Perspex	1000
Cl36	2	$3x10^5$ yr				0.71		20	10mm Perspex	1000
Ca45	2	163 dy				0.26		10	10mm Perspex	1000
Cr51	3	27.7 dy	670	26	EC	0.32	0.6	400	7mm Pb	1000
Mn54	2	312 dy			EC	0.84		25	25mm Pb	1000
Fe55	3	2.7 yr			EC	0.006		100	1mm Pb	1000
Fe59	3	45 dy				1.1	17	10	44mm Pb	1000
Co57	3	270.9 dy	9	9	EC	0.122	2.5	60	2mm Pb	1000
Co60	3	5.26 yr				0.31	35.7	3	40mm Pb	
Ni63	3	100 yr				0.067		100	Not required	100
Cu64	3	12.8 hr				0.64	3.1	150	12.5mm Pb	100
Zn65	3	244 dy				0.33	8.9	5	5mm Pb	1
Se75	3	120 dy				0.265	5.4	50	5mm Pb	100
Rb86	3	18.7 dy				1.78			30mm Pb	
Sr90	2	29 yr				0.66		6	10mm Perspex	10
Mo99	3	2.8 dy				1.21	3.1	20	20mm Pb	1000

Q8 What are properties of some commonly used nuclides? (Continued)

Nuclide	Class	Half-life	Biological $t_{1/2}$ days	Effective $t_{1/2}$ days	Main radiation	Energy MeV (Max for beta)	Gamma dose rate from 1MBq at 10cm, μGy/hr	Ingestion ALI MBq	Suggested Shielding for a Factor of 0.1	Surface Contamination Limit Bq/sq cm
Tc99m	3	6 hr				0.14	1.9	1000	1mm Pb	1000
Cd109	3	1.27 yr			EC	0.062		10	1mm Pb	100
I125	2	60.0 dy	138	42		0.035	ca. 0.2	1	0.2mm Pb	100
I131	2	8.04 dy	138	7.6		0.61	7.7	1	11mm Pb	100
Cs137	2	30 yr				0.66	21	1	20mm Pb	100
Ir192	2	74 dy				0.67	16	10	25mm Pb	1000
Hg203	3	46.6 dy				0.28	3.6	10	10mm Pb	
Am241	1	432 yr				0.06	8.5	0.1	10mm Pb	0.1
Th-nat*	4	1.4×10^{10} yr				2.61	34	0.2	75mm Pb	
U-nat*	4	4.5×10^{9} yr				2.29	15	0.3	60mm Pb	

Q9 What specific information is there on Low Energy Emitters: Tritium, Carbon 14 and Sulfur 35?

The energies of the beta particles from these radionuclides are so low that the **external** radiation hazard is negligible.

External contamination is not a hazard in itself but must be kept to a minimum as it can lead to ingestion and internal contamination and can also interfere with experimental results.

All three nuclides have the potential for incorporation into biologically important molecules, such as DNA and proteins. Care should be exercised when using these radionuclides to prevent ingestion despite their apparent low radiation risk.

S35 labelled compounds (especially methionine) may be easily volatilised at moderate temperatures. Heating S35 materials is to be conducted in a fume cupboard.

Q10 What specific information is there on Phosphorus 32?

Phosphorus 32 is the highest energy emitter radionuclide commonly encountered and requires special care. The maximum range of P32 particles in air and soft tissue is about 7 mm.

General rules (as per the Radiation Protection and Control Ionising Radiation Regulations 2015), for shielding P32 beta particles 10 mm of Perspex is sufficient. The Perspex container or shielding should be surrounded by about 3 mm of lead to absorb the more penetrating bremsstrahlung.

Work with P32 behind a small Perspex shield - this not only acts as a beta shield but also reduces the chance of splashing causing contamination

Handle Eppendorf tubes behind Perspex shields and use forceps. The dose rate will fall by a factor of ten thousand by moving your fingers from a distance of 1mm to 10 cm with forceps.

Eye protection is to be worn at all times when handling radioactive materials and especially P32 solutions. A splash could lead to serious damage in a short time.

Q11 What specific information is there on Iodine 131?

The energy of I131 gammas is 0.38 MeV and the betas 0.18 Mev and direct shielding may be needed for quantities of more than a few MBq.

A main hazard with iodine radionuclides is ingestion; the hazard is increased because it is selectively taken up by the thyroid gland.

Iodine compounds can easily generate volatile elemental iodine, which may then be inhaled. Great care must be taken to reduce the risk of inhalation of elemental iodine.

Radioactive iodine bound to the carriers used in radioimmunoassays (RIA) is less hazardous than iodine or iodide ions.

Except in the small quantities used in some RIA kits (<400 kBq), radioactive iodine **should** (< 40 MBq) and **must** (>40MBq), only be used in a Type B premise.

Low gamma energy of I131 may make contamination surveys difficult.

General rules

- All operations with radioactive iodine are to be performed in a properly operating fume cupboard. The ventilation fan should be left running continuously;
- Containers should be opened for as short a time as possible;
- It is advisable to wear two pairs or use a pair of polythene gloves over the latex gloves as some iodine compounds can penetrate surgical latex gloves;
- To reduce the formation of volatile elemental iodine, solutions containing iodide ions must not become acidic. Compounds of radioactive iodine may generate free iodine by radiolytic decomposition;
- Materials which may contain radioactive iodine must **NEVER** be treated with oxidisers such as bleach as it releases free iodine;
- A solution of sodium thiosulfate is to be available when handling radioactive iodine compounds. Poured on a spill this ensures the iodine is in the reduced form for clean-up; and
- Contaminated wastes are to be sealed before being sent for storage or disposal.

Q12 What if you require further information on Radiation?

If you require further information, please contact your local HSW contact.