RP CoP020: Working with Sealed Sources

Introduction and Scope

This Code of Practice (CoP) concerns University staff or students who work with sealed (or closed) sources of radioactive material and outlines the arrangements in place at the University, and the general precautions that persons must take, when working with sealed sources on University premises.

The term **'sealed sources'** is used throughout this document to mean sealed sources AND closed sources (as defined below) as they are treated similarly.

Work with unsealed sources of radioactive material is covered in RP CoP006 – *Work with unsealed radioactive material*.

The CoP aims to set out the University's arrangements for its work with sealed sources and provide practical guidance to University personnel on control measures and safe working with sealed radioactive sources. Sealed sources are constructed so that the radioactive material cannot be dispersed and therefore, where practicable to do so, sealed sources should be used in preference to open sources of radioactive material. Examples of sealed sources used at the University might be:

- Calibration/Test sources, such as Instrument test sources, Co-57 flood sources, Ge-68 PET calibration sources, etc.;
- Demonstration and Teaching sources;
- Rock/minerals containing naturally occurring radioactive material (NORM);
- Gamma irradiators;
- Electron capture detectors (ECDs) (containing Ni-63 sources) contained within some Gas Chromatographs;
- Neutron density gauges;
- Static eliminators (or alpha ionisation devices or alpha ionisers);
- (some) liquid scintillation counters / gamma counters with internal sealed source standards.

These three additional arrangements are discussed in more detail below.

The document navigation pane (CTRL+F) can be used as a Contents Page to locate a section/topic of interest.

Contents

Glossary of Terms

Term	**Definition / Description**
ALARP	As Low As Is Reasonably Practicable
Closed Source	A **closed source** was a term used by the Environment Agencies pre-2011 to describe sealed sources, homogeneous sources and laminated sources. The term is no longer used in environmental legislation but the University wishes to retain this term and it is taken to mean open sources of radioactive material which are not consumed. Open sources of radioactive material that are not being consumed are neither 'open sources' (as there is no contamination hazard present if they are not being consumed) or 'sealed sources' (as they strictly don't meet the definition of a sealed source as given in current legislation). If a closed screw-top vial of Cl-36 liquid is not being used (consumed) then it would be better treated as a closed (sealed) source than an open source. There is no need to define homogenous and laminated sources as they are not used in the rest of this document or in other UoE guidance.
D-Value	'D' values were originally derived in relation to emergency preparedness to establish a reference point/activity corresponding to a 'dangerous source' on a scale of the risks that could arise from these sources if they became 'uncontrolled' (e.g. in a fire).
EASR	The Environmental Authorisation (Scotland) Regulations
HASS	High Activity Sealed Source
IAEA	International Atomic Energy Agency
IRR17	The Ionising Radiations Regulations 2017
ISO	International Organziation for Standardization
NaCTSO	National Counter Terrorism Security Office
NORM	Naturally Occurring Radioactive Material
PPE	Personal Protective Equipment

Term	**Definition / Description**
REPPIR	The Radiation (Emergency Preparedness and Public Information) Regulations
RPA	Radiation Protection Adviser
RPU	Radiation Protection Unit
RRA	Radiation Risk Assessment
RWA	Radioactive Waste Adviser
Sealed Source	A **sealed source** means a radioactive source in which the radioactive substance is permanently sealed in a capsule or incorporated in a solid form with the objective of preventing, under normal conditions of use, any dispersion of radioactive substances.
SEPA	Scottish Environment Protection Agency
TLD	Thermoluminescent Dosemeter

Risk Assessment and Authorisation

Radiation Risk Assessments

Prior to any work taking place with radioactive sealed sources, a Radiation Risk Assessment (RRA) must be undertaken. The purpose of the RRA is to identify the hazards and evaluate the nature and magnitude of the risks to University staff and students from working with the sealed source(s).

To meet this requirement for a suitable & sufficient risk assessment under IRR17 Regulation 8, the University has adopted a two-tier approach to risk assessment comprising:

1. A project/task-based Radiation Risk Assessment (RRA); and,
2. A signed 'Radiation User Registration (RADUSER) form'.

To ensure these project/task-based risk assessments capture and address all the requirements for a suitable and sufficient risk assessment (as outlined in IRR17 Approved Code of Practice paragraphs 70 & 71) a single template is provided by the University RPU for recording Radiation Risk Assessments.

A guidance note to assist users with their sealed source radiation risk assessments (RRAG_02 "*Risk Assessment Guidance – Sealed Sources*"), together with the radiation risk assessment template, can be found on the University's Risk Assessment webpage.

The risk assessment guidance RRAG_02 also includes typical control measures that can be adopted when working with sealed sources to minimise the external and internal radiation hazard (See 5.1(a) in RRAG_02).

Example/model risk assessments for various Sealed Source uses can be found on the RP Unit SharePoint site.

Authorisation

Work with sealed sources, like any other work with ionising radiation, must be carried out in such a way as to minimise the risks to staff, students and any other person who might be affected by the work. In order to demonstrate this, the University needs to know who is doing the work, that they are adequately trained and instructed, and that they are being appropriately managed and supervised (e.g. they are authorised to carry out the work).

This authorisation is addressed through completion of the RADiation USEr Registration (RADUSER) form. A template can be found on the University's Risk Assessment webpage.

Further information on Authorisation to work with ionising radiation can be found in Radiation Protection Code of Practice RP CoP007 "*Authorisation to work with ionising or non-ionising radiation sources*".

Local Rules

In most cases, work with Sealed Sources should be accompanied by Local Rules to ensure procedures are followed to reduce the likelihood of significant exposures. The IRR17 specify what Local Rules must contain; for example:

- The Dose Investigation Level (DIL) set in 5.6 (f) of the risk assessment;
- A summary of the contingency arrangements set out in 5.8 (h) of the risk assessment;
- The name of the appointed Radiation Protection Supervisor;
- A description and identification of the area covered by the Local Rules;
- A summary of the key working instructions for restricting access to the area;
- The written arrangements for non-classified workers (i.e. the steps they need to follow to keep their radiation exposures as low as reasonably practicable when in the area).

In addition, the IRR17 also contain other matters which might be useful to include in the Local Rules. For sealed sources, it is suggested that the Local Rules also contain the following information:

- A summary of the arrangements for pregnant and breast-feeding staff;

- A link to the Risk Assessment carried out for the work;
- Arrangements for the information, instruction and training of staff and other persons who wish to work in the area or who are affected by the work in the area;
- Personal dosimetry arrangements (if applicable);
- Arrangements for any Personal Protective Equipment (PPE) required for the area (if applicable);
- Arrangements for radiation monitoring of the area to ensure that the area is designated correctly or to confirm it doesn't require designation;
- Arrangements for managing service engineers and others who may need to enter the area to carry out work;

The University RPU have created model local rules for sealed sources work to capture many of the routine procedural controls designed to reduce exposures to ionising radiation. These model local rules will need to be adapted to suit each individual area. More information can be found on the Local Rules area of the RPU website.

Training

All persons working unsupervised with sealed sources must be given appropriate information, instruction and training to ensure they can carry out their work safely. In terms of training, this normally involves:

- Attending the following parts of the University's Basic Course in Radiation Protection in Teaching and Research:
    - Introduction;
    - Regulation; and,
    - Module B – Sealed/Closed Sources; and
- Passing the competence assessments associated with the above modules; and,
- Receiving local instruction on the local arrangements for the sources; and,
- Refreshing that training at appropriate intervals not exceeding 5 years.

In some cases, postgraduate-taught and undergraduate-taught students may work with sealed sources but only under direct supervision by a trained person. The students under supervision do not need to attend the University's basic course in Radiation Protection as sufficient information and instruction can be given by the RPS (or deputy/equivalent/trained person) to allow them to carry out their work safely under supervision and ensure their radiation exposure is kept as low as is reasonably practicable.

If the person intending to work unsupervised with one or more sources of radiation has undergone training in radiation safety elsewhere, then providing that that training was equivalent to the University's course(s), they do not need to attend all

of the University's course. However, no other course can provide instruction on the University of Edinburgh's arrangements to comply with the law. They must therefore attend the "Regulation" lecture as soon as practicable. The University may ask for proof and the detail of training provided elsewhere.

Further information is given in Radiation Protection Code of Practice RP CoP008 "Information, Instruction and Training in Work with Radiation Sources".

Acquisition of Sealed Sources

A network of Radiation Protection Supervisors (RPSs) and Assistant RPSs (ARPSs) across the University assist the RPU in complying with the Ionising Radiations Regulations 2017 (IRR17) and the conditions within the General Binding Rules or Environmental Permits; including the control of acquisition of radioactive material.

Those wishing to purchase a new sealed source of radioactive material must notify the relevant RPS or deputy/assistant RPS for their area before purchasing such material. A list of RPSs and Deputy/Assistant RPSs can be found on the Radiation Protection Unit's website.

Sealed sources above IAEA Category 5 (see source categorisation) will require a Radioactive Permit for holding/management and therefore significant guidance from the RPA/RPU must be sought as early as possible in the acquisition process.

The Environmental Authorisation (Scotland) Regulations

The Environmental Authorisations (Scotland) Regulations 2018 ("EASR") adopt an 'Inclusion' approach to environmental regulation; for example the regulations only apply to 'regulated activities'.

In most cases, sealed sources fall under one of the two categories below and are therefore *regulated activities* under EASR.

- Artificial radionuclides (e.g. Americium-241 or Caesium-137) or;
- Radionuclides of natural terrestrial or cosmic origin which are used for their radioactive properties (e.g. a sealed source of Radium-226).

However, some radioactive substances that contain Naturally Occurring Radioactive Material (NORM) are only regulated under EASR if they:

- Arise from, or are used in, a NORM industrial activity; OR
- Are processed for their radioactive fissile or fertile properties.

The Scottish Government provide guidance on radioactive substances activities in Scotland that are out of scope of the Environmental Authorisations (Scotland) Regulations 2018 (EASR).

The collection, preparation & display/storage of geological specimens by the University is therefore NOT regulated under EASR because they are not used for their radioactive fissile or fertile properties nor is their keeping and use classed as a 'NORM industrial activity' (See EASR Schedule 8, Regulation 6).

Whilst not regulated under EASR, the University wishes to ensure control over its geological specimens and aims to follow similar rules on handling, disposal, use, storage, holding and transport as it does for its regulated sealed sources.

Any person or business carrying on, or intending to carry on, a regulated radioactive substances activity in Scotland is subject to the EASR. The Scottish Environment Protection Agency (SEPA) is responsible for regulating radioactive substance activities across Scotland and does so within an authorisation framework which is designed to ensure that suitable controls are in place that are appropriate to the nature of the activity and any associated risk to human health and the environment.

As the level of complexity and risk associated with an activity increases, the type of authorisation required under EASR changes to reflect that complexity or risk. There are 4 types of authorisation under EASR and, for sealed sources, all 4 could apply depending on the source strength and the work activity being carried out. These are summarised below (shown below in increasing order of complexity/risk):

Authorisation type	Sealed Source example
• General Binding Rules (GBR)	• Management of IAEA Category 5 Sealed Sources below 200kBq.
• Notification (followed by compliance with GBRs)	• Management of an IAEA Category 5 Sealed Source with an activity above 200kBq.
• Registration	• Management of Sealed Sources that are normally kept in the UK out with Scotland and are kept in Scotland for less than 4 months at any one time.
• Permit	• Sources above IAEA Category 5 (e.g. HASS and IAEA Category 4 Sealed Sources)

In general, the University's use of Sealed Sources does not require registration. The University has already notified the SEPA that it works with IAEA Category 5 Sealed

Sources above 200kBq and has applied for Permits for its current work with High Activity Sealed Sources (HASS) and IAEA Category 4 Sealed Sources.

Further information and guidance on EASR authorisations and how the University complies can be found in Radiation Protection Code of Practice RP CoP012 "*The University's Organisation and Arrangements for Compliance with its authorisations under the Environmental Authorisations (Scotland) Regulations 2018*".

IAEA Categorisation of Sealed Sources

For Sealed Sources held in Scotland, the SEPA have chosen to follow the IAEA's Safety Series Guide No. RS-G-1.9 "Categorization of Radioactive Sources". This places sealed sources into categories 1 – 5 based on their practice/use AND their activity; with Category 1 being the highest risk.

Gamma Irradiators, which typically contain high activities of Co-60 or Cs-137, are a 'listed practice' under Category 1 and so they are always assigned IAEA Category 1 under EASR regardless of their activity. These sources are also defined as HASS under EASR as they have an A/D value >1.

Most of the other practices listed in Table 1 of RS-G-1.9 are either not carried out by the University or they fall under IAEA Category 5; for example, Electron Capture Devices are IAEA Category 5 regardless of their activity.

Where a practice is not listed, the activity (A) of the source is used to determine its IAEA Source Category. Each radionuclide is assigned a 'D' value in RS-G-1.9 and if the A/D value is <0.01 then the source falls within IAEA Category 5. The table below lists some common radionuclides used as Sealed Sources at the University, their 'D' value and the activity when they cross from being a Category 5 source to a Category 4 source; as you can see the activities need to be quite high to cross into Category 4. The 'D' value is also used to determine if a source is defined as a HASS under EASR (A/D>1).

Radio-nuclide	'D' Value	IAEA Category 5 (upper limit of activity)		Radio-nuclide	'D' Value	IAEA Category 5 (upper limit of activity)
Am-241	60 GBq	0.6 GBq		Ir-192	80 GBq	0.8 GBq
Ba-133	200 GBq	2 GBq		Kr-85	3E4 GBq	300 GBq
Bi-210	8000 GBq	80 GBq		Na-22	30 GBq	0.3 GBq
C-14	5E4 GBq	500 GBq		Ni-63	6E4 GBq	600 GBq

Radio-nuclide	'D' Value	IAEA Category 5 (upper limit of activity)		Radio-nuclide	'D' Value	IAEA Category 5 (upper limit of activity)
Cf-252	20 GBq	0.2 GBq		Pb-210	300 GBq	3 GBq
Cl-36	2E4 GBq	200 GBq		Pm-147	4E4 GBq	400 GBq
Cm-242	40 GBq	0.4 GBq		Pu-238	60 GBq	0.6 GBq
Cm-244	50 GBq	0.5 GBq		Pu-239	60 GBq	0.6 GBq
Co-57	700 GBq	7 GBq		Ra-226	40 GBq	0.4 GBq
Co-60	30 GBq	0.3 GBq		Sr-90	1000 GBq	10 GBq
Cs-137	100 GBq	1 GBq		Tl-204	2E4 GBq	200 GBq
Eu-152	60 GBq	0.6 GBq		Th (nat)	Unlimited	N/A
Ge-68	70 GBq	0.7 GBq		U (nat)	Unlimited	N/A
I-129	Unlimited	N/A		U (dep)	Unlimited	N/A

Sealed Sources held under General Binding Rules

The majority of the sealed sources held by the University fall under IAEA Category 5 and are therefore managed, w.r.t. environmental legislation, under the General Binding Rules; specifically GBR1 "The management of a Category 5 Sealed Source".

These General Binding Rules are a set of mandatory rules that cover specific low risk activities and include the "Radioactive Substance common rules" which apply to all GBRs.

These Radioactive Substances common rules and General Binding Rules for Category 5 (i.e. low activity) Sealed Sources are shown below.

Radioactive Substances Common Rules

a) A radioactive substance must be managed in a manner which prevents the reckless or accidental dispersal of radionuclides and, in the case of a sealed source, which prevents any dispersal of radionuclides.
b) A radioactive substance must be managed safely and securely to minimise the risk of:
    i. Unauthorised or accidental use;
    ii. Loss; and,
    iii. Theft.
c) Records of a radioactive substances must be kept:

   i. From receipt of a radioactive substance until at least 2 years after the date of its transfer or disposal;
   ii. Which include, as a minimum, a description of each source, article or radioactive substance, the location of where it is normally kept or used, details of any transfer and details of any disposal;

d) Where practicable, a radioactive substance must be marked or labelled as radioactive but any labelling or marking must be removed before it is disposed of in normal refuse.
e) [abridged version of common rule] SEPA must be promptly notified of a loss or theft (or a suspected loss or theft) of a radioactive substance where the amount lost exceeds the value that is ten times the value in Column 3 of Table 2 (of Schedule 9 in the EA(S)R regulations).
f) A radioactive substance must not be transferred to a person who is not legally entitled to manage it.
g) A radioactive substance must be transferred or disposed of as soon as practicable after it becomes waste.

How the University complies with these common rules is addressed in RP CoP012 but is summarised for sealed sources below.

- Users behave responsibly when working with sealed sources (Local Rules and training);
- Up to date leak test records ensure dispersal is prevented (See Leak Testing of Sealed Sources);
- Sealed Sources are stored safely & are accounted for (Storage of Sealed Sources and Accounting for Sealed Sources);
- Contingency Plans are included in the Local Rules for reasonably foreseeable scenarios including loss/theft/etc. (Contingency Plans for Sealed Source use);
- Sealed Source records are kept by source owners or source keepers for all sources (Accounting for Sealed Sources);
- Disposal records for sealed sources are kept by the RPU for at least 2 years;
- Sealed sources and their immediate containers are marked with a radiation trefoil symbol to indicate the presence of radioactive material. This is checked as part of the leak test;
- Local Rules include contingency plans for loss/theft or suspected loss/theft. These require the RPU to be contacted. The University RPA/RWA decides, based on their knowledge of the incident, whether the loss/theft, or suspected loss/theft, of the radioactive substance is in excess of the values that require reporting to the SEPA under the Common Rule. The University RPA is responsible for notifying the SEPA in this regard;
- Any labelling is removed prior to disposal. Advice given by RPU;
- The University RPA is generally involved in all sealed source transfer and disposal discussions. They ensure that the waste is fully described in any pre-contract information supplied to the specialist waste contractor and that they are legally entitled to manage the sealed source waste;

- As part of the Leak Testing arrangements, the University RPU check that sources being held by the University are 'in use' and that any sealed sources which are no longer required (i.e. are waste) are considered for transfer / disposal.

GBR 1 – management of a category 5 sealed source

a) [comply with] The radioactive substances common rules;
b) A non-metallic Category 5 sealed source must only be disposed of in normal refuse;
c) The activity of an individual category 5 sealed source disposed of must not exceed 200 kBq;
d) More than one source must not be disposed of in any $0.1m^3$ of normal refuse;
e) The total activity of category 5 sealed sources disposed of in normal refuse from premises in a year must not exceed 10 MBq;
f) A metallic category 5 sealed source must only be disposed of by landfill.

The majority of 'how to comply' with the GBR requirements is covered above (under RS common rules) or in RP CoP012 "The University's Organisation and Arrangements for Compliance with its authorisations under the Environmental Authorisations (Scotland) Regulations 2018" and RP CoP009 "Waste Disposal".

There are some important points to note for Category 5 Sealed Sources and these are shown below:

- The introduction of EASR slightly changed the 'disposal' terminology. Sealed Sources may be 'transferred' to a specialist waste contractor; it would be the specialist waste contractor who would then 'dispose' of the sources either in accordance with their Permit or the GBR (if in Scotland) or arrangements under the Environmental Permitting Regulations (if in England or Wales).
- Non-metallic sealed sources up to 200 kBq may be disposed of (not transferred) by the University in normal refuse (e.g. black bag waste) provided all labelling identifying the source as radioactive have been removed and no other hazards or regulations apply (e.g. special waste regulations) to the source.
- Category 5 sealed sources marked for disposal are generally transferred to a specialist waste contractor for subsequent disposal;
- Metallic category 5 sealed sources (e.g. internal standards being removed from redundant LS counters) can be disposed of directly to landfill. This can be arranged through the RPU.

Sealed Sources held under an Environmental Permit

The University's HASS and IAEA Category 4 Sealed Sources are held under environmental Permits issued by the SEPA and are subject to the SEPA's Standard Conditions. Sections D & E in the Permits cover the additional conditions for sealed

sources and HASS respectively. Some of these additional conditions are outlined below in this section.

Holdings of sealed sources

The EASR Standard Conditions state that the aggregate activity of all sealed sources held on the premises (excluding HASS) must not exceed IAEA Category 3 (unless you have specific authorisation to exceed this value).

To exceed IAEA Category 3, the aggregate activity of the sealed sources would need to be ten times the 'D' value shown earlier in this document. In practice these are huge activities and it is highly unlikely the University would exceed these values for its sealed source holdings.

The University RPU requests copies of individual schools and colleges sealed source inventories on a regular basis and checks aggregate A/D values being held are typically less than 1 (i.e. all sources are IAEA Category 4 or 5 unless HASS).

Security requirements for IAEA Category 1 – 4 sealed sources (including HASS)

The vast majority of the University's sealed sources are IAEA Category 5 Sealed Sources and simple security arrangements can be put in place to keep these sources secure both in use and in storage (See Security of Sealed Sources).

The University's IAEA Category 4 sealed sources and HASS are subject to higher security measures and the EASR Standard Conditions specify that the security measures outlined in the NaCTSO "*Security Requirements for Radioactive Sources*"[1] must be complied with.

The security measures in the NaCTSO document require sealed source holders to:

- Ensure adequate security management of the sources;
- Have in place arrangements for detecting unauthorised removal of the source;
- Physical security measures to delay the unauthorised removal of the source; and,
- Arrangements for police response to an unauthorised removal.

As these security arrangements can be complex, those wishing to purchase sources above IAEA Category 5 must contact the RPU for advice.

The NaCTSO document also requires those persons accessing or using HASS or IAEA Category 4 sources to be subject to personnel background checks such as:

- Confirmation of identity of personnel from reliable documentation (e.g. passport, drivers licence, birth certificate, etc.)

[1] At the time of writing, this document is dated 2011 and is under review. Whilst a new version may be published soon, it is a restricted document and a link cannot be provided.

- Cross-checking of information on the application form;
- Taking up references in writing and confirming identity of referees.

The University's standard HR processes are sufficient to meet this requirement.

In addition, the EASR specifies that a Security Plan is implemented, maintained and reviewed for HASS and IAEA Category 4 sealed sources. These security plans contain most of the detail for security of the sources. The plans are prepared, managed and reviewed by the University's Security Operations Manager in conjunction with the University RPA/RWA.

Financial Provision

The SEPA are required to ensure that those holding HASS have in place adequate, valid and useable financial provision for the management of each HASS including when that source becomes waste. This financial provision must remain in place throughout the life of the source and the SEPA recommend it is reviewed regularly to ensure it remains adequate in a changing disposal landscape.

The University RPU has arranged a 'letter of guarantee' in conjunction with the SEPA and University legal teams to provide a financial guarantee that the University will fulfil its financial provision obligations under EASR in the event of a 'doomsday' scenario where the University is at risk of going out of business.

It is vitally important that Schools, Colleges and professional/support services etc. understand the liability they take on when purchasing a HASS. Whilst the University RPU has arranged for financial provision arrangements in a 'doomsday' scenario, the Schools, Colleges and professional/support services etc. are responsible for the operational management of that source; including the cost of disposal whilst the University is still in business which can be substantial sum of money (~£400k @ Jan 2022).

Note, no specific financial provision is required for the management of the University's IAEA Category 4 sealed sources. However, schools and colleges should understand the disposal costs associated with any source that they intend to purchase (which can be several thousands of pounds each).

HASS information and marking requirements

The University RPU keeps and maintains a central file of HASS records on behalf of the University's HASS holders.

This file contains all the necessary information to enable positive identification of the HASS including photographs of the source(s) from the manufacturer, special form certificates and serial numbers of the sources. Other information, such as identifying details of the equipment the source(s) are in, is also kept in the central file.

An electronic file, which includes the information kept as hard copies, is kept securely held on the University's shared drive which is regularly backed up.

Provision of information and data returns

For sealed sources, the EASR Standard Conditions require Permit holders to:

- Submit an annual inventory of the sealed sources you hold (excluding any HASS or IAEA Category 5 sources); and,
- Submit information on the radioactive waste you have transferred to another person during the calendar year (for subsequent disposal); and,
- Submit a HASS record form if you transfer a HASS to another person or it ceases to be a HASS (through decay).

The inventory of sealed sources sent to the SEPA excludes HASS and IAEA Category 5 sources. In practice, this inventory applies only to a handful of sources used by the University; i.e. the majority of sealed source users do not need to worry about this.

The vast majority of waste sealed sources are transferred to another person (e.g. specialist waste contractor) before being disposed (disposal by the contractor, not the University). Occasionally, some low activity sealed sources (<200kBq) may be disposed of to normal refuse/landfill but this would be under the General Binding Rules and not under the Permit (i.e. no data submission required).

The University RPU provides these data returns to the SEPA on behalf of the University's sealed source users (usually by the 28th February of each year). In order to do this, RPSs for sealed sources are asked at the start of each calendar year for an inventory of their IAEA Category 2, 3 or 4 sources as well as a summary of any sealed sources transferred to another person for the previous calendar year.

Accounting for Sealed Sources

It is important for sealed sources to be adequately accounted for to reduce the risk of sources becoming lost or stolen. RP CoP005 – *"Accounting for Radioactive Sources"* outlines the University's arrangements for its accounting procedures for sealed radioactive sources. It also gives advice on the frequency of checks which depends on the likely movement of the source, its potential for being displaced and its susceptibility to damage.

RP CoP005 includes the requirements to:

- Keep a sealed (closed) source record of every source, regardless of activity; and
- To keep a record of the whereabouts of any radioactive sources on the premises.

Where possible, taking into account the activity and dose rate of the source, sealed sources should be physically observed as part of the check. There have been

occasions noted where a check of the source container has missed the fact that the actual source has not been present in the container and therefore should not have been marked as present.

It is also advised that, for sources used away from their main storage location, a logbook is kept at the main storage location upon where persons log the following information when they take a sealed source away to another location for use:

- The date & time removed from the store;
- The ID number of the source removed;
- Name of the person removing the source;
- The location where the source is being taken to; and,
- The time the source was returned to its main storage location.

Storage of Sealed Sources

Sealed sources must be kept, when not in use, in suitable receptacles within suitable stores, or used in situ in secure equipment. Where practicable, sealed sources should not be stored loose, e.g. there should be some form of immediate container or housing around each sealed source which is marked to indicate the ID number, the radionuclide(s) and quantities of the sealed source within the container/housing. The general characteristics of a suitable receptacle and a suitable store are:

Suitable receptacle	Suitable store
• Marked to identify the ID number, radionuclide and activity – with the activity accompanied by a reference date; • Radiation shielding such that the dose rate from the source is As Low As is Reasonably Practicable (ALARP); • Should withstand damage from normal use and foreseeable misuse (e.g. dropping during movement); • Some resistance to fire; • Designed to prevent unauthorised exposure or dispersal;	• Protection from the effects of the weather; • Resistance to fire; • Warning notice to indicate presence of radioactive material within (see below); • Shielding such that the dose rate on the outside of the store is ALARP but not more than 3µSv/h; • Ventilation to prevent significant accumulations of gases or vapours or of any accidentally dispersed substance;

Suitable receptacle	Suitable store
	• Proper physical security such that access is only normally possible to persons authorised to enter; • Where possible, reserved for the storage of radioactive sources only.

The ionising radiation symbol and at least the word “Radioactive” must be displayed in the immediate location, e.g. the door of the store/cabinet or on the equipment, where radioactive substances are stored. An example of a typical sign that might be used on a source store is shown in Appendix 1. These can be purchased online from suppliers specialising in hazard and safety signage such as www.signs2safety.co.uk. The RPU may also have some available free of charge; contact the RPU if required.

Items of equipment containing sealed radioactive sources must also be labelled to warn persons that a radioactive source is present. If there is no indication already on the FRONT of the instrument or item of equipment that there is a radioactive source inside then this University specific label, shown in Appendix 1, must be applied in a prominent position on the FRONT of the instrument / equipment. This label can be supplied by the RPU free of charge.

The type of shielding required for sealed sources depends on the radiation being emitted from the source; note that many sources will emit more than one type of radiation. An example of the different types of radiation being emitted and notes on the choice of shielding materials is shown in Appendix 2.

Designated Areas

Under IRR17, areas must be designated as Controlled Areas where:

- Persons are likely to exceed 6 mSv whole body dose (or an equivalent dose greater than 15 mSv to the lens of the eye or 150 mSv to the skin or extremities); or,
- Where it is necessary for persons working in the area to follow special procedures designed to restrict significant exposure to ionising radiation.

And designated as Supervised areas where:

- Persons are likely to exceed 1 mSv whole body dose (or an equivalent dose greater than 5 mSv to the lens of the eye or 50 mSv to the skin or extremities); or,

- Where it is necessary to keep the conditions of the area under review (to determine whether the area needs to be designated as a Controlled Area).

In practice, University staff and students are not likely to exceed 1mSv whole body dose (or an equivalent dose of 5mSv to the lens or 50 mSv to the extremities/skin) when working with sealed sources.

The IRR17 ACoP paragraph 297 advises on situations where a controlled area must be designated based on special procedures; for example where the external dose rate in the area exceeds 7.5 µSv/h (when averaged over the working day) or where the hands of an employee can enter an area and the 8-hr time average dose rate exceeds 75 µSv/h.

IRR17 paragraph 307 also gives guidance to employers on situations where designated is unlikely to be needed and includes routine work in the vicinity of a fixed radiation gauge (e.g. routine work in the vicinity of a sealed source). In addition, places which cannot physically be entered do not need to be designated.

The need for a designated area is discussed and written down in the Radiation Risk Assessment covering the work. Examples of where Controlled and Supervised areas might need to be designated for sealed sources work are given below:

Controlled Areas:

- Radiation stores/rooms used for the storage of sealed sources where the dose rate exceeds 7.5 µSv/h (if a person can enter the store) or 75 µSv/h (if only the hands can enter the store).

Supervised Areas:

- A teaching laboratory where sealed sources are temporarily removed from storage for use in an experiment or experiments during which they are subject to constant supervision;
- Radiation stores/rooms used for the storage of sealed sources where the dose rate exceeds 2.5 µSv/h inside the store;

No area designation required:

- Rooms housing gamma irradiators do not need to be designated as Controlled or Supervised areas for radiation protection purposes (but access does need to be ‘controlled’ for security purposes).
- Areas where work with low activity sealed sources is carried out and dose rates greater than 7.5 µSv/h are not accessible (e.g. even in situations where sources could be directly handled).

Further information on Controlled and Supervised areas can be found in RP CoP011 “Controlled and Supervised Areas”.

Security of Sealed Sources

IAEA Category 4 sealed sources and HASS are subject to higher security measures than for low activity sources (e.g. IAEA Category 5). Additional specific security arrangements for Category 4 and HASS sources is given earlier in this document.

The vast majority of the University's sealed sources are IAEA Category 5 Sealed Sources and simple security arrangements can be put in place to keep these sources secure both in use and in storage.

Simple measures can be adopted to keep IAEA Category 5 sealed sources secure and these are outlined below. Arrangements for the security of sealed sources must be included in Local Rules:

- When not in use, sealed sources must be kept in suitable receptacles in accordance with the requirements set out in IRR17 Regulation 30(1);
- When not in use, sealed sources must be kept in separate stores that provide physical security and meet the requirements of a suitable store as defined in IRR17 Regulation 30(1);
- Storage areas containing radioactive substances must be marked to indicate the presence of radioactive material (e.g. radiation trefoil symbol – see Appendix 1);
- There must be physical security of rooms or labs where radioactive substance stores are kept. This can be done through a combination of key locks, digi-locks and swipe-card access which should only be made available to authorised persons;
- Regular checks on the whereabouts of sealed sources are carried out minimises the risk sources being lost or stolen; sources used more frequently are subject to more regular checks.

Leak Testing of Sealed Sources

The structure of a sealed source is such that it prevents, under normal conditions of use, any dispersion of radioactive material to the environment. It follows then that there must be some check to ensure that this structure is continuing to function as intended; this check is called a Leak Test.

Note, a leak test is not required for some closed sources; e.g. radioactive rocks or minerals. If in doubt about whether a leak test is required, contact the RPU.

The IRR17 deem that any leak test of a sealed source must be 'suitable' and must also be carried out at 'suitable' intervals to detect any leakage of radioactive substances. A leak test is a statutory requirement.

The University RPU carry out the majority of the statutory leak testing of the University's sealed sources in line with ISO9978. In certain cases, the leakage test is undertaken by a maintenance contractor as part of a maintenance contract. RPSs must keep a copy of these test records by third party contractors. The primary test method chosen is a direct wipe test of the source capsule using a filter paper moistened with water. The filter paper is then presented to a suitable contamination monitor capable of detecting the radionuclide being tested and the test is passed if the activity on the wipe is less than 200Bq. If a direct wipe of the source capsule is not possible, an indirect wipe is taken of the source at a part where it could be reasonably expected to be contaminated in the event of leakage.

Where sources are generally in good condition, and within their recommended working life, a leak test is carried out by the RPU every two years.

Typically, new sealed sources will be leak tested as part of the QA before their consignment and therefore no leak test is required on a new source. However departments may want to check that any new sources are not leaking or damaged on arrival (note the difference being no official 'leak test' record needs to be kept for arrival tests.

Where sources are retained beyond their recommended working life, or their use is such that the risk of damage is greater, it is recommended that a periodic review of the source condition is carried out as part of the leak test. An annual leak test is often recommended.

The recommended working life of a sealed source is usually provided by the manufacturer or supplier at the point of purchase. If a recommended working life is not specified by the manufacturer or supplier then a review of the condition of the source, incorporated into the leak test, is recommended to be carried out 5 years post-purchase.

The RPU record the following information as part of the Leak Test record:

- The name and address of the source user;
- The ID/reference number of the source or article being tested;
- A description of the source;
- The initial activity and reference date;
- The current activity (decay corrected);
- The date of the test;
- The reason for the test (e.g. routine, after incident, pre-use, manufacturer's test);
- The method of test and whether an indirect or direct test was carried out. This includes a statement on what part of the source was tested and whether it is likely to detect any leaking material;
- A statement of the pass/fail criteria;
- The result of the test (pass or fail);

- The numerical result of the test (e.g. the minimum detectable activity on the wipe based on 10% pick up factor and the capability of the monitoring instrument(s));
- Make, model and serial number of the instruments used to count the wipe;
- Any action taken if the source failed the test;
- Whether the source is within its recommended working life or not;
- A statement on the condition of the source, its suitability for continued use and the when the next review of its conditions should be carried out;
- The name and signature of the person carry out the test.

Monitoring radiation levels from sealed sources

When working with sealed sources it is vitally important that you know and understand the radiation risk presented by them. The radiation being emitted from a sealed source could be of any type (e.g. alpha, beta, gamma/x-ray, neutron (fission) or a combination of all) and of variable energy and dose rate. There are many different types of radiation detectors and it is important that the appropriate detection method is used for the type of radiation being measured.

If an instrument is incorrectly selected then it may not detect the radiation being emitted from the sealed source thus giving a false impression that no radiation hazard exists.

Users of sealed sources should have knowledge about the radionuclides and energies of the source as well as the expected activity.

When monitoring radiation levels from sealed sources the preferred method is to use a dose rate monitoring instrument scaled in µSv/h or mSv/h. Typically instruments used for dose rate measurement are compensated; i.e. they exhibit an approximately flat response (e.g. +/-30%) over a typical energy range (e.g. 50 keV to 2 MeV) and have a calibration factor close to 1 with the indicated reading approximately equal to the H*(10) ambient dose equivalent rate[2]. Schools and departments who use sealed sources should have access to a radiation monitoring instrument scaled in µSv/h or mSv/h (or equivalent).

In the vast majority of cases, sealed sources used at the University will emit gamma radiation of sufficient energy such that they can be easily measured using a suitable gamma dose rate instrument.

[2] Ambient dose equivalent H*(d) is the normal monitoring quantity for X, gamma and neutron radiation where d is the depth in tissue at which the dose rate applies. It is designed to give an upper estimate of effective dose for external irradiation of the whole body. The international convention is that a depth of 10mm, i.e. H*(10), is suitable for use as determining the radiation dose received by the body (if dose is related to a person then $H_p(10)$ is used).

In some cases, sealed sources emitting beta radiation are used; measurement and interpretation of beta dose rates can be complicated (i.e. often an under-read due to energy) and the RPU should be contacted for advice where required.

Examples of the types of radiation (and energy) that may be encountered, recommended detector and instrument types are shown below. Note, alpha radiation isn't mentioned as there is not a need to measure the dose rate for radiation protection purposes due to significant attenuation of the alpha particle.

Radiation type	Energy range	Detector type	Example of a suitable hand-held instrument
Low energy X & gamma	From approx. 10-20keV to 2MeV	Ionisation chamber	ThermoFisher Scientific Mini SmartION (shutter closed)
		Thin end window GM tube, *energy* compensated	Southern Scientific Radhound SS330/335
		Thin end window GM tube *partially* compensated	ThermoFisher Mini 900 Type D
Medium energy X and gamma	From approx. 50-60 keV to 2MeV	Compensated GM tube	Any of the above plus Southern Scientific Radhound X/I or Tracerco T402
β Dose rate	> 225 keV (β_{max})	Ionisation chamber	ThermoFisher Scientific Mini SmartION (shutter open)
	> 150 keV (β_{max})	Thin end window GM tube *partially compensated*	The SmartION or ThermoFisher Mini 900 Type D
Neutron dose rate	0.025 keV to 17 MeV	Helium tri filled counter with a polyethylene and boron plastic moderator	Neutron Monitor 2222A "DigiPig"

Further information on monitoring can be found in Radiation Protection Code of Practice RP CoP003 "Contamination monitoring procedures in research laboratories".

Personal Dose Monitoring

As sealed sources, under normal conditions of use, only present an external radiation hazard, personal dose monitoring could be achieved (if required) using whole-body Thermoluminescent Dosemeters (TLDs) or equivalent passive dosimetry.

The exact requirements for personal dose monitoring depend on a number of individual factors such as source activity, radionuclide, type(s) of radiation being emitted from the source, proximity to the source, time in contact with the source (e.g. frequency of use), local shielding, etc. It is therefore important that the need for personal dose monitoring is assessed on an individual task-specific basis and this is determined following review of the Radiation Risk Assessment and RADUSER form.

Where work with sealed sources is such that there is no significant whole-body doses expected, and guidelines on handling of sources is followed, then personal dose monitoring is not normally necessary. The radiation risk assessment makes an estimate of personal doses based on the frequency of use and sources used. In the majority of cases, no personal dose monitoring is required for those working with sealed sources at the University (although persons may be wearing personal dosemeters for other purposes; e.g. X-ray work).

Further guidance on the arrangements for personal dosimetry, including internal dosimetry, can be found in Radiation Protection Code of Practice RP CoP018.

Disposal and Transfer of Sealed Sources

In practice, the majority of sealed sources are transferred to a specialist waste contractor for disposal. Only in a limited number of cases, i.e. when the sealed source activity is less than 200kBq, can it be disposed of by the University. The arrangements for disposal and transfer of sealed sources are summarised below.

Further information on the transfer and disposal of radioactive substances can be found in Radiation Protection Code of Practice RP CoP009 "The management and Disposal of Radioactive Waste".

Disposal of non-metallic IAEA Category 5 sealed sources <200kBq

Sealed Sources which have decayed down to less than 200kBq can be disposed of provided that:

- The source is disposed of in normal refuse (i.e. it is mixed with substantial quantities of non-radioactive waste). The University black bag route meets the definition of 'normal refuse' under EASR; and
- All markings on the waste identifying it/them as radioactive are removed; and
- The source is not metallic; and
- A record of the disposal is kept (usually by the RPS) for at least 2 years from the date of disposal (NB: the sealed/closed source record sheet records all the necessary details).

Users disposing of sealed sources to the normal refuse may wish to contact the University RPU prior to disposal to check that they have addressed all the arrangements in the EASR General Binding Rules.

Disposal of metallic IAEA Category 5 sealed sources <200kBq

The SEPA acknowledge that the normal refuse (e.g. dustbin) route could include a sorting/segregating or recycling step. In the case of metallic sealed sources, the SEPA want to ensure that they do not come back into the recycled metal route and therefore metallic and non-metallic sources are treated slightly differently.

Unfortunately the SEPA do not have a 'de-minims' value/mass for metallic sources and a small 5 gram metallic pellet source (which is unlikely to be segregated by a metal recycling station due to its small size and mass) is treated the same as a 1kg metallic source for example.

Metallic Sealed Sources which have decayed down to less than 200kBq can be disposed of provided that:

- The sealed source(s) goes straight to landfill; and,
- All markings on the waste identifying it/them as radioactive are removed; and,
- A record is kept (usually by the RPS) for at least 2 years from the date of disposal (the sealed/closed source record sheet records all the necessary details).

As the conditions on disposal require the source to go directly to a landfill, users disposing of metallic sealed sources will need to contact the University RPU prior to disposal to discuss the direct-to-landfill options (and any associated cost).

Transfer of sealed sources for disposal with an activity >200kBq

Sealed Sources with an activity greater than 200kBq are generally transferred to a specialist radioactive waste contractor for subsequent disposal. The onus is placed on the University to ensure that any person (i.e. company) it transfers radioactive substances to is legally entitled to manage them.

Disposal of sealed sources to a waste contractor are covered in more detail in RPCoP009 "The management and Disposal of Radioactive Waste".

Any transfers of a HASS to another person requires the HASS record form (held by the RPU) to be updated and sent to the SEPA.

Disposal of rocks/minerals containing NORM

As mentioned earlier, the collection, preparation and display/storage of the University's geological specimens is not regulated under EASR. As these geological specimens fall outside the scope of EASR, there is no specific guidance regarding their disposal.

The University recognises that whilst the disposal of these naturally occurring materials is low risk, a pragmatic approach to disposal is advised.

Therefore rocks/minerals containing naturally occurring radioactive material can be disposed of through the University's normal refuse waste (e.g. black bag route). However, it is advised that no more than 5 specimens are disposed of IN ANY ONE WEEK. This is to ensure that the disposal of the specimens follow 'dilute and disperse' principles as they enter the disposal chain (which is in line with the principles of 'dustbin' disposal).

Note, the above DOES NOT apply to compounds of Uranium or Thorium as these ARE regulated under EASR.

Contingency Plans for sealed source use

Where a Radiation Risk Assessment (RRA) shows that a radiation accident is reasonably foreseeable, it is a legal requirement (Regulation 13 of IRR17) to prepare a contingency plan designed to restrict exposure to ionising radiation to persons who may be affected by the accident. The IRR17 guidance (paragraph 240) also points to examples of events that could be reasonably foreseeable and could cause significant exposure (e.g. a contingency plan is recommended). For sealed sources, Contingency Plans for the following events should be in place:

- Fire (leading to a possible dispersal of radioactive material or melting of lead shielding leading to substantial increase in dose rates);
- Loss or theft of radioactive material;
- Leaking source leading to personal contamination;

IRR17 paragraph 244 outlines what a Contingency Plan should identify. These need to be included in the Local Rules in their entirety, as a summary or a reference provided.

To ensure the University's Contingency Plans identify all the necessary points in ACoP 244, model versions have been written which can be modified to suit each

individual site/area. These can be found on the Contingency Plans area of the RPU website.

Radiation (Emergency Preparedness and Public Information) Regulations 2019

The Radiation (Emergency Preparedness and Public Information) Regulations 2019 (REPPIR) establish a framework of preparedness measures to ensure that arrangements are in place to effectively respond to significant radiation accidents; both on the site of the emergency situation and off-site where members of the public might be affected.

Holders (e.g. employers) of sealed sources are required to check if the activities of the sources they hold are above the Schedule 1 values in REPPIR. If they are, they must carry out a 'hazard evaluation' of their sealed sources to determine if REPPIR applies (and record the evaluation). In general, if it can be demonstrated that a member of the public would not receive an effective dose of greater than 1mSv following a radiation emergency, then REPPIR does not apply.

The University has carried out a hazard evaluation of all the radioactive substances it holds, including HASS, and concluded that a person off-site would not receive a dose greater than 1mSv in a radiation emergency situation from the radioactive substances it holds (including sealed sources). This hazard evaluation is regularly reviewed to ensure REPPIR continues to not apply for the sources held by the University.

Document version

Version number	Summary of change	Date and by whom
1.0	First version of the document.	10/04/2023 Mark Green

If you require this document in an alternative format please contact The Health and Safety Department on health.safety@ed.ac.uk or call (0131) 651 4255.

Appendix 1: Warning Signs

Suitable warning sign for a radioactive substance store containing sealed sources:

Suitable warning label for equipment containing a sealed source inside:

Appendix 2: Shielding of Sealed Sources

Note, many sealed sources will emit more than one type of radiation so ensure you know what radiations are being emitted from your source.

<table>
<tr><th>Radiation type</th><th>Shielding material</th><th>Notes/comments/discussion</th></tr>
<tr><td>Alpha</td><td>Paper / source capsule</td><td>As alpha particles are very easily shielded, in general, the source capsule prevents the alpha particles from penetrating beyond the boundaries of the source. For homogenous (closed) sources like rocks containing naturally occurring radioactive material, depleted Uranium etc., it is unlikely that a sufficient number of alpha particles will escape the surface of the source to cause any significant external radiation protection problem.</td></tr>
<tr><td>Beta</td><td>PMMA / Aluminium</td><td>Beta particles are more penetrating than alpha particles and can travel up to several metres in air. Light materials such as PMMA (e.g. Perspex) or Aluminium should be used closest to the source instead of dense materials like lead or steel as heavier materials produce more Bremsstrahlung radiation.

Total absorption of the beta particles depends on the maximum energy of the beta and also the thickness of the absorber material (in mg cm^{-2}). Some example radionuclides often used in sealed sources and their maximum range (i.e. total absorption) in common absorbers are shown below [Ref: Delacroix et. al. radionuclide and radiation Protection Handbook 2002 (plastic) and approx. rule-of-thumb of 3.7m per MeV (beta in air)]:
<table>
<tr><th>Radionuclide</th><th>B_{MAX}</th><th>Air</th><th>Plastic</th><th>Radionuclide</th><th>B_{MAX}</th><th>Air</th><th>Plastic</th></tr>
<tr><td>Nickel-63</td><td>66 keV</td><td>24 cm</td><td>0.1 mm</td><td>Thallium-204</td><td>763 keV</td><td>2.8 m</td><td>2.2 mm</td></tr>
<tr><td>Carbon-14</td><td>156 keV</td><td>57 cm</td><td>0.3 mm</td><td>Bismuth-210</td><td>1.1 MeV</td><td>4.3 m</td><td>3.8 mm</td></tr>
<tr><td>Promethium-147</td><td>225 keV</td><td>83 cm</td><td>0.5 mm</td><td>Sr-90 / Y-90</td><td>2.2 MeV</td><td>8.1 m</td><td>9.2 mm</td></tr>
<tr><td>Chlorine-36</td><td>710 keV</td><td>2.6 m</td><td>2.0 mm</td><td></td><td></td><td></td><td></td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>Radiation type</th><th>Shielding material</th><th>Notes/comments/discussion</th></tr>
<tr><td>Gamma</td><td>Lead/Steel /concrete</td><td>
Gamma radiation, including x-radiation, is the most penetrating form of electromagnetic radiation. Shielding materials for X- and Gamma rays normally consist of heavy materials like lead, steel or concrete.

Shielding thicknesses for gamma and x- rays are normally expressed in ‘half-value layer’ (HVL) or ‘tenth-value layer’ (TVL) where the thickness of the shielding material will reduce the radiation intensity to one-half or one-tenth respectively. Some examples [Ref: Delacroix Handbook 2002] for commonly held sealed sources are:

<table>
<tr><th rowspan="2">Radionuclide</th><th rowspan="2">Main gamma emission</th><th colspan="2">Lead (mm)</th><th colspan="2">Steel (mm)</th></tr>
<tr><th>HVL</th><th>TVL</th><th>HVL</th><th>TVL</th></tr>
<tr><td>Am-241</td><td>59 keV</td><td>< 1</td><td>< 1</td><td>1</td><td>3</td></tr>
<tr><td>Co-57</td><td>122 keV</td><td><1</td><td>1</td><td>6</td><td>18</td></tr>
<tr><td>Ba-133</td><td>356 keV</td><td>1</td><td>7</td><td>10</td><td>44</td></tr>
<tr><td>Cs-137</td><td>662 keV</td><td>8</td><td>24</td><td>29</td><td>72</td></tr>
<tr><td>Na-22</td><td>511 & 1275 keV</td><td>10</td><td>37</td><td>31</td><td>80</td></tr>
<tr><td>Co-60</td><td>1173 & 1332 keV</td><td>16</td><td>46</td><td>36</td><td>93</td></tr>
</table>
</td></tr>
</table>

Radiation type	Shielding material	Notes/comments/discussion
Neutron	Water / Boron / Paraffin wax	Neutrons have no net electric charge and therefore cannot be stopped by electric forces. Heavy materials such as lead are ineffective at shielding neutron radiation as it simply passes through the material. The principle of neutron shielding is to first try and slow down the neutrons and then absorb them. Materials with a high hydrogen content are useful at slowing down neutrons and materials with a high neutron capture cross section, like Boron, are useful for capturing the neutrons. Water can be used for both (if a sufficient thickness is used to capture the neutrons). The act of slowing down the neutrons and capturing them results in additional gamma radiation being emitted; this then requires shielding too. Incorrect placement of the 'gamma' shielding can result in insufficient dose reduction. As the selection of the right shielding material for neutrons can be complex, advice should always be sought from the RPU regarding neutron shielding of sealed sources.
Fission	Lead/Steel /concrete	Sources which have been activated and are undergoing fission will emit several types of radiation (e.g. neutron, alpha, gamma). In most cases, this radiation will be short-lived and shielding may only temporarily be required. It is advised that shielding for gamma radiation is followed as this is the most penetrating radiation.