WHS UNIT

RADIATION SAFETY GUIDELINES

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1. **Introduction**

These guidelines detail the responsibilities and administrative procedures as well as general information on how to reduce the risks associated with work involving the use of radioactive substances or sources.

2. **Acknowledgments**

These guidelines were developed with the assistance of Mr William C.F. Bartolo (Bartolo Safety Management Service).

3. **Guiding Principles**

The University of Wollongong (UOW) will ensure that all work and learning involving the acquisition, storage and use of radioactive substances or the operation of irradiating apparatus is carried out in a manner which is safe and does not breach the legal requirements of the New South Wales Radiation Control Act 1990 and Radiation Control Regulations 2013 (and all subsequent amendments).

Facilities and procedures will be assessed against the Legislation, Australian Standards and Codes of Practice requirements, with the assessment being documented, to ensure exposure doses are maintained ALARA (as low as reasonably achievable) for the acquisition, storage and use of radioactive substances or the operation of irradiating apparatus.

The University will ensure that the risk of injury to people and/or the environment from the use of radioactive substances or irradiating apparatus is minimised by the implementation and regular review of safety requirements, this guideline and emergency procedures.

4. **Definitions**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>ALARA</td>
<td>As low as reasonably achievable</td>
</tr>
<tr>
<td>ARPANSA</td>
<td>Australian Radiation Protection and Nuclear Science Agency</td>
</tr>
<tr>
<td>Cpm</td>
<td>Counts per minute</td>
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<tr>
<td>Cps</td>
<td>Counts per second</td>
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<tr>
<td>DECC</td>
<td>Department of Environment and Climate Change</td>
</tr>
<tr>
<td>Dpm</td>
<td>Disintegrations per minute</td>
</tr>
<tr>
<td>Dps</td>
<td>Disintegrations per second</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency – renamed to DECC</td>
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<tr>
<td>IAEA</td>
<td>International atomic energy agency</td>
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<tr>
<td>ICRP</td>
<td>International commission on radiation protection</td>
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<tr>
<td>IRPA</td>
<td>International radiation protection association</td>
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<tr>
<td>LRSO</td>
<td>Local radiation safety officer</td>
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<tr>
<td>LRPA</td>
<td>Local Radiation Protection Advisor in the Faculty, Division or Unit</td>
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<tr>
<td>NSWRAC</td>
<td>New South Wales Radiation Advisory council</td>
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<tr>
<td>OSD</td>
<td>Optically stimulated dosimeter</td>
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<tr>
<td>PPE</td>
<td>Personal protective equipment</td>
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<tr>
<td>TLD</td>
<td>Thermoluminescence dosimeter</td>
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<tr>
<td>URPA</td>
<td>University radiation protection advisor</td>
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5. Responsibilities

WHS responsibilities are detailed in the WHS Policy and Roles and Responsibilities for WHS document. Specific radiation safety responsibilities are outlined in the following sub-sections.

5.1. Deans and Directors
- allocating adequate resources to units to ensure compliance with these guidelines

5.2. Heads of Units
- radiation activities comply with relevant radiation safety legislation, codes of practice and UOW guidelines
- occupationally exposed persons are provided with the necessary instruction, information, training and supervision to enable work to be carried out safely
- ensure that appropriate health surveillance is in place
- appointing a competent Local Radiation Safety Coordinator.

5.3. Radiation User Licence Holder
- complying with radiation safety legislation, standards, codes of practices and UOW guidelines
- complying with ARPANSA Security code
- complying with the conditions of their licence
- ensuring their licence conditions are suitable for the tasks and responsibilities they have, for example, authorisation to approve licence exemptions for students, authorisation to supervise students.
- where applicable, submitting personal radiation monitors at appropriate intervals to the WHS Unit
- ensure proper management of radiation facilities including ensuring the monitoring of radiation areas are performed as per requirements, and that signage is posted as per requirements.

5.4. Students
- complying with radiation safety legislation, standards, codes of practices and UOW radiation safety guidelines including applying for a licence exemption and complying with the conditions.
- following directions from the licence holder supervising their work
- if required, submitting personal radiation monitors at appropriate intervals to the WHS Unit.

5.5. Local Radiation Safety Coordinator (LRSC)
- consulting with the WHS Unit on radiation issues
- providing advice on the content of these guidelines to workers and students working with radiation in their local area
- maintaining local radiation safety records and documentation
- monitoring radioactive waste disposal prior to transfer to low level radiation waste store.

5.6. Workplace Health and Safety Manager
- development and monitoring of UOW radiation safety policies, procedures and its radiation protection program through consultation with all relevant parties
- coordination of personal radiation monitoring
- maintenance of personal dosimetry records for employee health surveillance
- monitoring the implementation of safety requirements contained in these in areas where radiation is in use
- maintain records of radiation safety training, licences, exemptions, equipment and other relevant issues.

To fulfil the needs of the “Radiation Safety Officer” (URSC) as prescribed by legislation the WHS Manager will engage and coordinate a suitable external consultant to deliver the following:
- assessment of radioactive waste for disposal
- training and advice.

6. Consultation

UOW will consult with stakeholders so that they may contribute to decisions about the implementation of radiation safety practices and systems designed to ensure the health, safety and welfare of employees and students. Employee involvement at all levels is critical for ensuring a safe workplace. Further information on the University’s consultative arrangements can be found in the UOW Consultation Statement.
7. PART 1 - Administrative Procedures

Under current Radiation and WHS legislation it is the responsibility of UOW to ensure radiation safety training and documentation relating to radiation safety compliance is provided. As such the UOW has adopted the following procedures to ensure the safety of all who may be required to visit, work, or learn in an environment where radioactive sources are present.

Additionally UOW will fulfil the requirement that all relevant documentation, records of isotopes, sealed radiation sources, premises, licensees, exemptions, users, personal monitoring, area monitoring, disposal, and inspections are maintained, and relevant information is attached to the employee/student records.

To this end, the following procedures are to be adopted by all UOW employees, students and visitors.

8. Permission to use Radiation

The use of ionising radiation is governed by the Radiation Control Act (NSW) 1990 and the Radiation Control Regulation 2013. It is important to ensure that correct planning is undertaken before work with radiation occurs so that all risks can be eliminated or minimised. The acquisition of radioactive material or irradiating apparatus must also be approved by the Head of Unit before the material or apparatus is brought into UOW and used by University employees and/or students.

Any proposed work involving radiation requires completion of the Radiation Approval Form.

It is important that the academic supervisor completes the relevant sections of the form in sufficient detail to allow assessment and to prevent undue delays. This form must be signed by the academic supervisor and the LRPA before submission to the Dean and WHS Unit.

The WHS Unit will engage a consultant RPA (URSC) to review the approval form regarding the proposed material/apparatus, the physical facilities to be used and the details of the collaborators for the project team. The CRPA/URSC will then make an assessment of the proposal with regard to the proposed level of radiation safety, and the adequacy of the experience of the members of the team for carrying out the proposed work.

Any recommendations from the CRPA/URSC must be in-place prior to the undertaking of work associated with radiation. Where the work is carried out in more than one organisation, the LRSC and/or URSC for all organisations must be informed.

Radiation work must not commence without the specific approval of the Dean, Head of School or equivalent authority in writing.

Work involving regulated material must only be conducted in areas that have been listed in the University’s Radiation Management Licence. The academic supervisor must ensure that any recommendations of the CRPA/URSC are complied with during the course of the work. Changes to submitted projects must also be submitted to the Dean and WHS Unit for review.

When exposure rates are less than those that require approval or a licence, normal lab safety procedures should be implemented in order to manage the risk associated with working with the substance.

9. Radiation Licences

The Radiation Control Act 1990 (NSW) requires that any person responsible for regulated material must hold a radiation management licence in respect of the regulated material and must comply with any conditions to which the licence is subject.

Any person who uses regulated material must hold a radiation user licence and must comply with any conditions to which the licence is subject.

Licences are granted by DECC. Students are able to apply for a licence exemption as detailed in Section 12 for radiation use.
9.1. Radiation Management Licence
The University is required to hold a licence, as per EPA requirements, in respect of the regulated material and must comply with the conditions the licence is subject to.

9.2. Radiation User Licence
The following outlines information obtaining, renewing and making variation to user licences:

9.2.1. Obtaining a User Licence
Any person who uses regulated material must hold a radiation user licence and must comply with any conditions to which the licence is subject. Certain persons will be able to apply for a radiation licence exemption (see section 10). Any person required to apply for a radiation user licence will need to complete following form:

- APPLICATION FOR USER LICENCE to use regulated material in NSW

A copy of the licence must be forward to the WHS Unit to update the radiation register.

9.2.2. Renewing Your User Licence
Any person with a radiation user licence should receive the form below prior to the licence expiration.

- RENEWAL OF LICENCE AND CHANGE OF LICENCSEE DETAILS

On receiving the notice of licence renewal from the DECCW, forward a copy to the WHS Unit. The WHS Unit register will insert the updated details on the radiation register upon receiving a copy of the renewed licence.

9.2.3. Making a Variation to Your User Licence/s
A licence can be varied so that it relates to regulated material to which it did not relate to before the variation. The following form will be required to be completed:

- APPLICATION TO VARY A USER LICENCE to use regulated material in NSW

Reasons for completing a variation application might include:
- Using a different substance
- Using a different radiation apparatus
- If you require to grant exemptions.

9.3. Licence Exemption Procedures
Licence exemptions are granted to students as specified in the NSW Radiation Control Regulation 2013. For an exemption to be granted the following requirements must be met:

- Students may only be granted an exemption by an appropriate licensee as deemed under Part 2, Clause 8 of the Radiation Regulation;
- Students must have successfully attended a DECC approved radiation safety course and obtained a certificate in the safe use of ionising radiation apparatus and/or radioactive substances depending on the work to be performed – contact the WHS Unit for course information;
- The exemption must be in writing using the Licence Exemption Notification;
- Only licensees with an authority to grant an exemption included on the licence are able to grant exemptions;
- The licensee granting the exemption must ensure that a copy of the exemption is:
  - given to each person to whom it relates,
  - conspicuously displayed at each place in which the radioactive substances and/or radiation apparatus to which the exemption relates are proposed to be used, and
  - kept for the local records( Unit level),
  - sent to the WHS Unit to record exemption details in the Licence Exemption register;
- Exemptions must be renewed annually.

9.4. Training
To gain a licence in NSW (under NSW Legislation) or on Commonwealth Land (under Federal Legislation), it is a requirement that individuals are trained by an approved or accredited radiation safety trainer. In addition, to obtain a licence exemption, students must have successfully attended a EPA approved radiation safety course and obtained a certificate in the safe use of ionising radiation apparatus and/or radioactive substances depending on the work to be performed. See the UOW WHS Training Guidelines for more information.
9.5. Supervision for Students Working Under a Licence Exemption
Any undergraduate or postgraduate student who has obtained a licence exemption must be subject to general supervision at all times whilst they are working with regulated material. General supervision is defined under the NSW Radiation Control Regulation as supervision by a qualified person who oversees the person being supervised and ensures that the person follows safe radiation work practices in relation to the use of the apparatus in respect of which the supervision is required.

10. Personal Radiation Monitoring and Health Monitoring

Personal monitoring may be required for individuals who may be exposed to radiation during the course of their work or learning at the UOW, as prescribed by the Radiation Control legislation.

Personal monitoring is coordinated by the WHS Unit and includes the periodic issue of personal radiation monitors. The WHS Unit will maintain central records of all personal monitoring at UOW. A report detailing an individual's personal monitoring history may be obtained upon request. To obtain a monitor contact the WHS Unit on extension 3931 or email whs-admin@uow.edu.au.

Refer to UOW Air and Health Monitoring Guidelines for information on ongoing health monitoring requirements.

11. Procedures for Inspection of Radiation Usage/Storage Sites

The inspection of areas that use or store radioactive substances or irradiating apparatus should be inspected in line with the UOW Workplace Safety Inspection Guidelines using the UOW Laboratory Inspection Checklist.

12. Radioactive Waste

Radioactive waste is to be disposed in accordance with the UOW Radioactive Waste Disposal Guidelines.

13. Emergency Response Procedures

Refer to the relevant UOW Campus Emergency Response Procedures and UOW Incident Management Procedures.

13.1. Basic First Aid

In the case of an accident involving radioactive material, the following simple first aid instructions may be found useful whilst waiting for appropriate medical attention:

**Radioactive material in the eyes or nose (solid or liquid):**

- Irrigate with saline (0.9 per cent common salt solution). If this solution is not available, use tap water;
- Care must be taken to avoid swallowing contaminated material.

**Radioactive material on skin:**

- Brush lightly with soap and cold water (to prevent opening of pores of skin to contaminant);
- If this fails, a paste of fuller’s earth, bentonite, or Kaolin may be applied and subsequently washed off with soap and water;
- If this fails, try EDTA solution (a chelating agent) with gentle sponging or rubbing to ensure that the skin is not broken.
- As a last resort, immerse the hands or swab affected skin in saturated potassium permanganate solution, rinse in water and remove stain with 5 per cent solution of sodium bisulphate.

**Radioactive material on mouth:**

- Wash out with hydrogen peroxide solution (1 tablespoon full of 10 volume hydrogen peroxide to a tumbler of water) several times.
Contamination of a wound:

- Wash under a tap with copious quantities of water and encourage bleeding.
- If the wound is on the face take care not to contaminate the eyes, mouth, or nostrils.
- Next, wash the wound with soap and water and apply disinfectant and first aid dressing.
- Maximum permissible level of skin contamination is listed in the previous contamination table.

Note: All materials listed above should be stocked in the area’s first aid kit.

All accidents involving contamination of personnel must be reported immediately to the WHS Unit via telephone and recorded via the SafetyNet online reporting system.

All material used in decontamination or treatment of an injury must be collected and bagged and labelled for disposal once treatment has been completed.

14. Training

Training in this instance is not only the technical or academic training in scientific methods to do research with radioactive materials. It also includes the training of individuals to understand the properties of radioactive materials and equipment. Part of this is radiation safety, which is given some priority due to the difficulty to determine physiological damage immediately after exposure to most laboratory radiation levels.

Often the damage or the symptoms of this exposure may take several years to be observed, for example cataract formation and cancer. Hence, emphasis on radiation safety and safety training is strongly promoted. The worker and/or researcher must take primary responsibility for prevention.

Legally, to gain a licence in NSW (under NSW Legislation) or on Commonwealth Land (under Federal Legislation), it is a requirement that individuals are trained by an approved or accredited radiation safety trainer. A training register is required to maintain records of training.

UOW requires that all individuals are given radiation safety training before commencing work with radiation (documentation of prior radiation safety training before joining UOW may be accepted).

Refresher training can be undertaken at the individuals request or may be required as a corrective action following an incident.

Training is required to cover:

- An outline of radiation physics basics
- Radiation Interaction (including with biological tissue)
- Detection and measurement
- Legal/ICRP dose limits
- Radiation SI Units
- Unsealed sources (if appropriate)
- Laboratory safety
- Sealed sources and XRD/F safety (if appropriate)
- Current legal requirements.

UOW is required to maintain records of all radiation safety training for its employees and students. Most approved trainers issue a unique certificate indicating the name of the individual, type of training, date and level of achievement of the individual. A copy of this should be kept in the individual’s record (employee or student file) as well as a register of the training with a reference to the certificate which is maintained by the WHS Unit.

Note: If applying for a licence from the NSW Authority, do not send the original certificate (send a certified photocopy) as no material included in the application is returned to the applicant.

Contact the WHS Unit for more information on radiation safety training.
15. PART 2 - Radiation Information and Guidance

Part 2 of the Radiation Safety Manual provides general information on a range of topics concerning the management and day to day use of radiation. The material provides supplementary guidance on the administrative procedures contained in Part 1.

16. Risk Management

The implementation of the Radiation Safety Manual utilises the risk management principle as outlined in the UOW Risk Management Guidelines.

16.1. Hazard Identification

Hazards from exposure to ionising radiation fall into two main categories:

- External exposure from sealed sources, unsealed sources and radiation apparatus,
- Internal exposure resulting from ingestion, absorption or inhalation of unsealed sources.

These hazard identification factors may include:

- The nature of the potential radiation exposure based on the type and energy of the radiation source(s),
- The possibility of contamination,
- The type of work – including storage and waste management,
- The facilities and personnel involved,
- Pregnancy and radiation exposure,
- Research involving planned irradiation of humans,
- Research involving the administration of radiation to live animals,
- Credible incident scenarios,
- Any non-radiological hazards associated with the proposed work.

16.2. Risk Assessment

An increase in exposure to ionising radiation is linked to a corresponding increase in the risk of adverse health effects. Factors that could potentially influence the assessment of risk include:

- The nature of potential external radiation exposure based on the type of the radiation source (alpha, beta, gamma, X-ray, neutron),
- The nature of potential radiation dose based on the energy of the radiation source,
- Potential radiation dose based on the duration and frequency of exposure,
- Any potential internal dose as a result of possible contamination,
- Maximum potential radiation doses from normal operations and credible accidents,
- Non-radiological hazards associated with the proposed work.

16.3. Risk Controls

The main principles of risk control commonly accepted are:

- **Justification** - any practice involving potential exposure to radiation should be undertaken only if the net benefit can be justified.
- **Optimisation** - All radiation exposures should be kept as low as reasonable achievable, economic and social factors being taken into account
- **Limitation** – In no case should the relevant dose limits be exceeded. These dose limits are detailed in the Radiation Regulations

Where a risk assessment identifies a risk it shall be eliminated or minimised in the planning phase. This can be done by applying the Hierarchy of Controls.
17. Radiation Fundamentals

17.1. Introduction

For the purposes of this manual, we can use a simplistic model of an atom. The atom can be thought of as a system containing a positively charged nucleus and negatively charged electrons in orbit around the nucleus.

All matter is composed of elements and all elements are composed of atoms. While it may appear that the atom is the basic building block of nature, the simplified, classical (Bohr’s concept) model of the atom itself is composed of three smaller, more fundamental particles called protons, neutrons and electrons.

Each atom has the same number of protons as it has electrons. This means that the total positive charge in the nucleus is equal to the total negative charge of the electrons resulting in an electrically neutral atom. Each element has a unique number of protons and electrons. For each element, every individual arrangement of protons and neutrons is called a nuclide. All the atoms of a particular element contain the same number of protons. However, the number of neutrons may vary for the same element.

The nucleus is the central core of the atom and is composed of two types of particles, protons, which are positively charged, and neutrons, which have a neutral charge. Each of these particles has a mass of approximately one atomic mass unit (amu). (1amu = 1.66E-24 g)

Electrons surround the nucleus in orbitals of various energies. (In simple terms, the farther an electron is from the nucleus, the less energy is required to free it from the atom.) Electrons are very light compared to protons and neutrons. Each electron has a mass of approximately 5.5E-4amu.

A nuclide is an atom described by its atomic number (Z) and its mass number (A). The Z number is equal to the charge (number of protons) in the nucleus, which is a characteristic of the element. The A number is equal to the total number of protons and neutrons in the nucleus.

These different nuclear forms of an element are called isotopes, that is, an atom with the same number of protons but different numbers of neutrons. For example, phosphorous has seven different isotopes. Each of the isotopes has 15 protons, while the number of neutrons varies from 28 to 34.

Many nuclides are unstable because the ratio of neutrons to protons produces a nuclear imbalance (that is, too many protons or too many neutrons in the nucleus). These unstable isotopes attempt to become stable by rearranging the number of protons and neutrons in the nucleus to achieve a more stable ratio. The excess energy is ejected from the nucleus as radiation.

In this rearrangement process, the isotope often changes atomic number (for instance, a neutron changes into a proton and an electron, or a proton captures an electron and becomes a neutron) and sheds any excess energy by emitting secondary particles and/or electromagnetic rays (or photons). This change in the nucleus is called nuclear disintegration. The process of unstable isotopes disintegrating and emitting energy is called radioactive decay. An isotope undergoing radioactive decay is said to be radioactive.

This process of nuclear disintegration can be one of four different types:

- Alpha radiation
- Beta Radiation
- Gamma Radiation (including X-rays)
- Neutrons (both fast and thermal).

These forms of radiation have sufficient energy to cause atomic changes (i.e. ionization) on interaction. An ion is an electrically charged atom, group or molecule formed by the loss or gain of one or more electrons. Ionisation is the process of separation or change into ions.

17.2. Types of Radiation

Following is a short description of the four types:

- **Alpha radiation** is particulate radiation with a very large mass (atomic mass of 4) but it does not penetrate material (including air) very deeply. The mass means that this radiation can impart a large energy to material. Generally a sheet of ordinary paper is sufficient to act as a shield from external radiation.

- **Beta radiation** is equivalent to an electron. It has the mass of an electron (which is negligible) and can exhibit the characteristics of both particles and electromagnetic waves. Beta particles travel at greater speeds than Alpha particles and can penetrate to reasonable distances (e.g. 32P can travel approximately 6 meters in air, but only about 1mm in mammalian tissue). Beta radiation has another problem during the interaction with high Z (atomic number) materials such
as lead or steel. During this interaction the beta particle is dramatically slowed and the energy is lost as X-rays (gamma rays) and is termed bremsstrahlung, with energies ranging up to the peak energy of the interacting beta. This is why Perspex (of appropriate thickness) is used for shielding.

- **Gamma rays (and X-rays)** are electromagnetic waves from nuclear reactions. These waves travel at the speed of light and may penetrate to infinity (depending on a number of factors). High Z materials of appropriate thickness are the recommended shielding. As they are unlike alpha and beta radiations, i.e. they are not particulate, these waves can pass through the interstitial spaces of mammalian tissue without causing disruption. However having said that, in passing through sufficient thickness of living tissue the possibility of interaction and thus ionization greatly increases.

- **Neutrons**, these are one of the sub-atomic particles and are usually found only from nuclear reactions and a few specialist items of equipment such as bore hole loggers. Because they have mass and also a great velocity this radiation can impart great energy when they interact with matter and very easily cause ionisation. Care and good shielding are required for these radiations.

### 17.3. Radioactive Decay – Half-life

The decay of a radioactive sample is statistical in nature and it is impossible to predict when any particular atom will disintegrate. The result of this random behaviour of any particular atom is that the radioactive decay law is exponential in nature, and is expressed mathematically as:

\[ N = N_0 e^{-\lambda t} \]

Where \( N_0 \) is the number of nuclei present initially, \( N \) is the number of nuclei present at time \( t \) and \( \lambda \) is the radioactive decay constant.

The **half-life** \( (T_{1/2}) \) of a radioactive species is the time required for one half of the nuclei in a sample to decay. It is obtained by putting \( N = N_0/2 \) in the above equation:

\[ N_0/2 = N_0 e^{-\lambda T_{1/2}} \]

Dividing across by \( N_0 \) and taking logs

\[ \log_e(1/2) = -\lambda T_{1/2} \]

Now

\[ \log_e(1/2) = - \log_e(2) \]

and so

\[ T_{1/2} = (\log_e(2))/\lambda = 0.693/\lambda \]

Since the disintegration rate, or **activity** of the sample is proportional to the number of unstable nuclei, this also varies exponentially with time, namely:

\[ A = A_0 e^{-\lambda t} \]

This relationship is illustrated in Fig. 1 (real isotope example in figure 2) which shows the variation of sample activity with time. In one half-life the activity decays to \( 1/2 \) \( A_0 \), in two half-lives to \( 1/4 \) \( A_0 \), and so on. The half-life of a particular radioactive isotope is constant and its measurement assists in the identification of radioactive samples of unknown composition. This method can only be applied to isotopes whose disintegration rates change appreciably over reasonable counting periods. At the other end of the scale, the isotope must have a long enough half-life to allow some measurements to be made before it all disintegrates.
17.4. Hazards/Dangers/Effects

The hazard from radiation exposure can occur via two different routes, internal or external exposure. Internal exposure is where the radioactive material is contaminating the internal structure and systems of the human body (hence it has been absorbed into the body) and external exposure is where the radioactive material is outside the body (such as isotope sources or radioactive contamination of the structures). Of these two forms of exposure the internal form is the more insidious and the most potentially damaging (see Figure 17.2 for a comparison and grading of the radiation types for internal and external radiation).

Exposure, regardless of whether it is internal or external, leads to biological effects which may later show up as clinical symptoms. These clinical symptoms may appear within a short interval or over a much larger time scale, and the severity of the symptoms will depend on whether the radiation is alpha, beta, gamma or neutrons, and the dose received or accumulated. This damage can be divided into two classes: somatic effects in which the damage appears in the irradiated person, and hereditary effects that arise only in the offspring of the irradiated person as a result of radiation damage to germ cells in the reproductive organs. In the human body, these changes may manifest themselves as symptoms such as radiation sickness, cataracts or, in the longer term, cancer.

![Figure 17.1 Variation of Activity with Time: $^{131}$I decay example](image)
Figure 17.2 A diagram illustrating the relative risks from the types of radiation. The degree of risk depends on whether the exposure is internal or external.

Cancer from chronic exposure may be a risk for the worker but is difficult to define due to the fact that the estimation of the increased risk of cancer is complicated by the long and variable latent period, from about 5 to 30 years or more, between exposure and the appearance of the cancer, and by the fact that radiation-induced cancers are not normally distinguishable from those that arise spontaneously or from other routes of causation.

Thus it is generally agreed that the only practicable basis for radiological protection is to assume that any dose, no matter how small, carries some risk.

Radiation can induce gene mutations that are indistinguishable from naturally-occurring mutations. Because ionising radiation can cause an increase in the mutation rate, its use may possibly increase the number of genetically abnormal people present in future generations. Clearly, the consequences of excessive genetic damage would be very serious indeed and strict control must be exercised over the radiation exposure of the occupationally exposed worker and the general population.

In the short term, the symptom that occurs from acute severe exposure is erythema, reddening of the skin similar to sunburn. In the long term the symptoms would be those associated with diseases such as cancer, but as stated above these may not be related to the radiation exposure; these diseases such as cancer may be from other routes of causation. This also applies to the problem of cataract development of the eyes through exposure to beta radiation. Again this occurs over a long period and may not be discernible from "natural" cataract development related to age.

17.5 Radiation Units

The radiation units that are legally required to be used in Australia are the SI system which includes:
- Activity is the Becquerel
- Exposure is the Coulomb/Kg
- Absorbed dose is the Gray
- Dose Equivalent is the Sievert
- Effective dose is the Sievert

The Becquerel is defined as a disintegration per second.

The fundamental quantity in radiation protection is the absorbed dose. Absorbed dose is a measurement of energy deposition in any medium by any type of ionising radiation. The SI unit of absorbed dose is the Gray (Gy). It is defined as an energy deposition of one joule per kilogram. When quoting an absorbed dose, it is important to note the absorbing medium.

The same value of absorbed dose for different types of radiation does not necessarily result in the same degree of biological damage, and this is the concept of Equivalent Dose. For example, 0.05Gy of fast neutrons can do as much biological damage as 1Gy of gamma radiation.

This difference in biological effectiveness needs to be taken into account when doses of different radiations are added to obtain the total biologically effective dose. This is done by multiplying the absorbed dose of
each type of radiation by a **Radiation Weighting Factor**, $w_R$. The radiation weighting factor is selected for the type and energy of the radiation incident to the body, or in the case of sources within the body, emitted by the source. This weighted dose is the **Equivalent Dose**, $H_T$.

$$H_T = w_R D_T$$

where $D_T$ is the mean absorbed dose in a particular tissue or organ. The **SI unit of equivalent dose is the Sievert**.

**Dose Equivalent** remains, by definition, the absorbed dose multiplied by the quality factor, $Q$.

The value of the radiation weighting factor depends on the density of ionization caused by the type of radiation. For example, an alpha particle produces approximately one million ion pairs per millimetre of track in tissue, compared to beta particles, which produce approximately ten thousand ion pairs per millimetre of track in tissue.

$w_R$ is assigned as unity for gamma, X-rays and beta rays, and the values for other types of radiation are related to this.

<table>
<thead>
<tr>
<th>Radiation Type</th>
<th>Radiation Weighting Factor ($W_R$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photons</td>
<td>1</td>
</tr>
<tr>
<td>Electrons and Muons</td>
<td>1</td>
</tr>
<tr>
<td>Protons and charged pions</td>
<td>2</td>
</tr>
<tr>
<td>Alpha particles, fission fragments, heavy ions</td>
<td>20</td>
</tr>
<tr>
<td>Neutrons</td>
<td>A continuous function of neutron energy (see figure below)</td>
</tr>
</tbody>
</table>

**Table 2 Radiation Weighting Factors**

![Graph of radiation weighting factor vs neutron energy](image)

**Fig. 1.** Radiation weighting factor, $w_R$, for neutrons versus neutron energy.

For non-uniform irradiation to the human body, an annual effective dose equivalent limit of 50mSv is used. The **effective dose** is defined to take into account the radiological sensitivities of different tissues and organs. The effective dose is the sum of the weighted equivalent doses in all tissues and organs. (Note: The term "effective dose" replaces the quantity "effective dose equivalent" which was previously used.)
If the whole body were uniformly irradiated, the fractional contribution of each organ or tissue, $T$, to the total detriment resulting from exposure to the radiation is represented by a tissue weighting factor, $w_T$.

**Table 3. Recommended tissue weighting factors**

<table>
<thead>
<tr>
<th>Tissue</th>
<th>$WT$</th>
<th>$\Sigma WT$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone marrow (red), colon, lung, stomach, breast, remainder tissues*</td>
<td>0.12</td>
<td>0.72</td>
</tr>
<tr>
<td>Gonads</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>Bladder, oesophagus, liver, thyroid</td>
<td>0.04</td>
<td>0.16</td>
</tr>
<tr>
<td>Bone surface, brain, salivary glands, skin</td>
<td>0.01</td>
<td>0.04</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1.00</strong></td>
<td></td>
</tr>
</tbody>
</table>

* Remainder Tissues: Adrenals, Extrathoracic (ET) region, gall bladder, heart, kidneys, lymphatic nodes, muscle, oral mucosa, pancreas, prostate, small intestine, spleen, thymus, uterus/cervix

For example, a dose equivalent to the lung of 50mSv is the same as an effective dose equivalent of $50 \times 0.12 = 6$mSv to the whole body. A 50mSv effective dose would be the same as $50 / 0.12 = 417$mSv lung dose.

The following table summarises the relationship between the S.I. units that are now used in Australia and the previously used Empirical Units. Units of radiation are still expressed in Empirical Units in the United States and are still present in many reference books.

<table>
<thead>
<tr>
<th>Type</th>
<th>S.I. Unit</th>
<th>Symbol</th>
<th>Old Unit</th>
<th>Symbol</th>
<th>Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity</td>
<td>Becquerel</td>
<td>Bq</td>
<td>Curie</td>
<td>Ci</td>
<td>$1\text{Ci} = 3.7 \times 10^{10} \text{Bq}$</td>
</tr>
<tr>
<td>Exposure</td>
<td>Coulomb/Kg</td>
<td>$C\text{Kg}^{-1}$</td>
<td>Roentgen</td>
<td>$R$</td>
<td>$1 \text{C Kg}^{-1} = 3876 \text{R}$</td>
</tr>
<tr>
<td>Absorbed Dose</td>
<td>Gray</td>
<td>Gy</td>
<td>Rad</td>
<td>rad</td>
<td>$1\text{Gy} = 100\text{rad}$</td>
</tr>
<tr>
<td>Dose equivalent</td>
<td>Sievert</td>
<td>Sv</td>
<td>Rem</td>
<td>rem</td>
<td>$1\text{Sv} = 100\text{rem}$</td>
</tr>
<tr>
<td>Effective Dose</td>
<td>Sievert</td>
<td>Sv</td>
<td>Rem</td>
<td>rem</td>
<td>$1\text{Sv} = 100\text{rem}$</td>
</tr>
</tbody>
</table>

**Table 4 Comparison of radiation units**

17.6. **Occupational and Public Effective Dose Equivalent Limits**

Exposure to radiation is controlled by State or Territory regulatory practices, which are based on the ARPANSA RPS 1 “Recommendations for Limiting Exposure to Ionising Radiation (Printed 1995 - Republished 2002) and National Standard for Limiting Occupational Exposure to Ionising Radiation (Printed 1995 - Republished 2002)”. The ARPANSA recommendations are based on ICRP Publication 60, 1991, which contains information and recommendations for occupational and public exposure to radiation.

An **occupationally exposed person** or radiation worker refers to workers who, as a result of their employment, may be exposed to ionising radiation.

**Members of the public** refers to all other persons not considered to be radiation workers.

The ICRP (in Publication 60) recommends an occupational effective dose limit of 20mSv per year averaged over a five year period, with no more than 50mSv in any single year. These recommendations have been adopted by the ARPANSA and have subsequently been translated into regulatory requirements for Australian States and Territories.
### Applications

<table>
<thead>
<tr>
<th>Dose Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Occupational</strong></td>
</tr>
<tr>
<td>20 mSv(^{-1}) averaged over 5 years (i.e. 100 mSv averaged over 5 years with a max of 50 mSv in any one year)</td>
</tr>
<tr>
<td><strong>Public</strong></td>
</tr>
<tr>
<td>1 mSv(^{-1})</td>
</tr>
</tbody>
</table>

#### Effective dose

<table>
<thead>
<tr>
<th>Annual equivalent dose to:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Occupational</strong></td>
</tr>
<tr>
<td><strong>Public</strong></td>
</tr>
<tr>
<td>150 mSv</td>
</tr>
<tr>
<td>15 mSv</td>
</tr>
<tr>
<td>500 mSv</td>
</tr>
<tr>
<td>50 mSv</td>
</tr>
</tbody>
</table>

In a laboratory situation, it is very rare for workers who are practicing good personal hygiene and adopting safe work practices to exceed the 20 mSv per year limit.

Separate effective dose limits are not considered necessary for female radiation workers with reproductive capacity. Where a pregnancy is confirmed, it is recommended that arrangements be made to ensure that the woman works in conditions where it is unlikely that her external skin exposure, during the remainder of her pregnancy will exceed 1 mSv. It is very unlikely that any worker in a laboratory would reach this dose limit under good safe work practices.

Different radioactive materials tend to concentrate in certain tissues more than other tissues. ICRP Publication 68 contains reference to effective dose coefficients for a wide range of radionuclides. From this data, annual limits on intake (ALIs) and derived air concentrations (DACs) have been calculated so that the primary dose limits will not be exceeded.

AS 2243.4 lists some of the more commonly used radionuclides and their ALI and DAC values. The data are given for guidance only, and are based on the most restrictive assumption, which may lead to an overestimate of the actual dose received. If it is necessary to calculate the best estimate of dose received, for example, in an accidental exposure situation or when occupational exposure is close to the limit, data from ICRP Publications 66 and 68 (available at most University libraries) should be used.

### 17.7. The Tenets of Radiation Protection

#### 17.7.1. Inhalation Hazards

The potential hazard posed by inhalation of radioactive material depends on several factors, such as particle size, radiotoxicity, solubility of the contaminant and the physiology of the person.

The size of the inhaled particles determines where within the respiratory system the material will be deposited. Particles of approximately 10 - 100 µm are deposited in the nose and throat whilst smaller particles are deposited into the trachea, bronchi and the smaller airways. Depending on where the material lodges, particle size and chemical form, some of the material will pass into the bloodstream and may then concentrate in organs that have a particular affinity for the material, some material may pass into the intestinal tract and some will be exhaled.

#### 17.7.2. Ingestion Hazards

Soluble radioactive material that has been ingested will be distributed in a similar manner to inhaled material. Insoluble material will predominantly pass through the gut and be excreted.

#### 17.7.3. Absorption through the skin

Small amounts of radioactive contamination on the skin can cause a high local dose because of the closeness of the radioactivity to tissues. Any contamination should be removed as soon as possible by washing the area.

Practical control measures that can be implemented at the workplace to control internal hazards include:

- containment of the material - limit the area that could possibly become contaminated by the use of fume cupboards, glove boxes, spill trays and safe work techniques;
- good personal hygiene and housekeeping in the work area;
- use of the least radiotoxic and smallest activity radioactive material that is suitable for the project being undertaken.
17.7.4. Control of External Radiation Hazards

External hazards refer to the hazards which arise from sources of ionising radiation that are outside the body. External hazards have the potential to irradiate all or part of the body with sufficient energy to affect the skin or underlying tissues.

Practical control measures that can be implemented at the workplace to control external hazards include:

**Time**
- The dose accumulated by a person is directly proportional to the amount of time they spend in the radiation area. **Dose = Dose Rate x Time**
- The less time spent in a radiation environment the smaller is the radiation dose.
- Plan the work to avoid unnecessary exposure. If necessary, a dose rate measurement or estimate can be made and a time limitation set for the work undertaken.

**Distance**
- The greater the distance from a source of radiation the smaller is the radiation dose. For distance, the inverse square law applies, i.e. for an isotropic point source of radiation the dose rate at a given distance from the source is inversely proportional to the square of the distance. Thus if you double the distance from a source, the dose rate decreases by a factor of four as outlined in the following equation:
  \[ D_1 r_1^{-2} = D_2 r_2^{-2} \]

where \( D_1 \) is the dose rate at a distance \( r_1 \) from the radiation source, and \( D_2 \) is the dose rate at distance \( r_2 \) from the same source.

**Shielding**
- Shielding is the practice of placing an attenuating medium between the source of ionising radiation and the worker. The attenuating medium, or shield, then minimises the radiation that would ordinarily reach the worker. The type and amount of shielding required depends on the type and energy of radiation emitted and its intensity.
- If shielding is to work effectively it must be properly designed and made from materials of the appropriate density. Dense (high atomic number) materials (e.g. lead and depleted uranium) make the most effective shields for highly penetrating radiation such as gamma radiation. For lesser penetrating radiation such as beta particles low atomic number materials can be used (e.g. perspex or aluminium).
- The most efficient shield is one that has been properly designed for the job, for example:
  i. the shield may also serve as structural support.
  ii. heavy lead shielding itself may need to be structurally supported, for example, by a heavy steel frame.
  iii. lead glass windows may be required for transparency.
  iv. ideally, shielding should contain no gaps, hence it should be made of one-piece construction or from interlocking blocks.
  v. the intensity and type of radiation determines what material is required and its thickness.
  vi. shield design must take into account secondary radiation problems (bremsstrahlung) from high energy beta radiation.
  vii. neutrons are effectively shielded by materials containing large quantities of hydrogen, such as polyethylene.
- The reduction of exposure by shielding not only requires good design but good management techniques as well. Effective shielding management includes the following items:
  i. before carrying out an operation involving the use of radioisotopes calculate the shielding requirements using half-value layers or gamma ray constants.
  ii. the quality of the shield should be examined from all directions, including the top and bottom.
  iii. store radioactive materials in appropriately shielded containers with secure lids.
  iv. handle glass vials and test tubes in shielded containers.
  v. use custom design syringe barrel shields when handling large quantities or activities of an injectable radioisotope.
  vi. to view operations behind a non-transparent shield use a periscope or a leaded glass port - do not directly view the operation.
- the half value layer of a shielding material refers to the thickness of that material, which reduces the intensity of the radiation by 50%.
18. Radiation Monitoring

18.1. Monitoring Equipment

The determination of the appropriate monitoring equipment is very important for radiation safety. The type of radiation and activity levels, or the energy levels of the radiation, is vital for the selection of equipment to be used. It is important to know the isotopes as it is from this information that the selection of monitoring equipment is made. Advice should be sought from the WHS Unit.

18.2. Notes on the Selection and Use of Instruments

There are two broad types of radiological exposure hazard, namely external and internal radiation. Measuring the extent of each one requires different instrument types and sampling devices to perform a variety of investigative functions.

For example, the monitoring of external radiation hazards may require fixed (installed) external radiation monitors that indicate levels and, in some versions, alarm at a pre-set level. Alternatively, you may use portable instruments for conducting external radiation surveys and issue personal dosimetry devices such as TLDs or film badges.

For internal radiation hazards or contamination monitoring you may require air sampling apparatus for particulates (or gases) and material for taking surface smears. In addition, you will need instruments for measuring these sampled radioactive particulates, gases and smears. (e.g. beta counting castles, or gamma spectrometers). You may also use portable instruments for conducting surface contamination surveys.

Once it is established that a monitoring unit is required the next step is to select the most appropriate monitoring instruments available to detect the types and levels of radiation present in the area to be surveyed. Selecting the right instrument requires careful thought as there are a number of vital points to consider.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Types of radiation</td>
<td>Alpha, beta, gamma, x-ray or neutron</td>
</tr>
<tr>
<td>Energy levels</td>
<td>keV or MeV</td>
</tr>
<tr>
<td>Units required</td>
<td>Counts, exposure, absorbed dose, dose equivalent</td>
</tr>
<tr>
<td>Intensity</td>
<td>$\mu$Sv h$^{-1}$, mSv h$^{-1}$ or Svh$^{-1}$</td>
</tr>
<tr>
<td>Survey type</td>
<td>Radiation monitoring or contamination</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>Minimum detectability required</td>
</tr>
<tr>
<td>Power source</td>
<td>Mains power or replaceable batteries</td>
</tr>
<tr>
<td>Other</td>
<td>Ruggedness and portability</td>
</tr>
</tbody>
</table>

Table 5 - Primary selection criteria for survey instruments

18.2.1. Special Instrument Problems - Low Energy Beta Emitters

Radionuclides that emit beta particles of energy less than 0.25MeV pose special detection problems when they are present as surface contamination. The ‘window’ of the contamination meter's detector tube is usually too thick to allow the low energy beta particles to penetrate into the sensitive inner volume of the detector tube.

Four low energy beta emitters fall into this category; they are $^3$H, $^{14}$C, $^{35}$S and $^{45}$Ca: their maximum energy, range and half-thickness are shown in Table. These radionuclides are often used as tracers by biologists and biochemists.
Most probe windows are far too thick to allow the effective detection of low energy beta emitters, especially $^3$H. However, there are commercial beta probes that have a sufficiently thin window to allow the detector to respond to $^{14}$C, $^{35}$S and $^{45}$Ca beta emissions when at sufficiently high concentrations. It is not practical to monitor low energy beta surface contamination using portable beta detectors. Instead, wipe samples or air samples have to be taken and assessed by liquid scintillation techniques or by using gas-flow proportional counters.

### 18.2.2. Noteworthy Instrument Problems - Electronic

There are several important instrumental characteristics or effects that can mislead by giving false readings. For example:

- **Fold Back** - Some radiation detectors, especially GM tubes, become paralysed in very high radiation fields and can give low or zero readings. This, in turn, gives the surveyor the impression that there is minimal radiation hazard when in fact the opposite is true and it is quite hazardous.
- **Light Sensitivity** - Some radiation detectors (GM tubes and scintillation detectors) respond to light. If their opaque covering is damaged, even a pinhole, and light enters the detector false (high) readings will be obtained.
- **Magnetic Fields** - High magnetic fields will affect the photomultiplier tubes found in scintillation detectors by deflecting the electron beam and giving a false reading.
- **RF Fields** - Some instruments may pick up signals from radio frequency fields and give spurious (usually high) readings.
- **Pulsed Radiation Fields** - Portable dose rate instruments are not suitable for measurements in pulsed radiation fields and will give false low readings.

A few instruments use multiple detectors in order to extend their range. Failure of one detector can leave the instrument functioning normally for part of its range but without response over the rest.

Given the information above, it is important that the probe of the instrument does not get damaged or contaminated during the contamination survey. It is also important to keep thin film windows away from any pointed objects as well as corrosive materials.

### 18.2.3. Legal Requirements and a Common Error

With monitoring equipment, the legal requirements and some faults are:

- The instrument requires annual calibration to the Australian Standard.
- Records or the documentation of these calibrations are to be kept.
- All maintenance records for the instrument are to be kept.
- Covering the probe and/or end window with “Parafilm” or “Glad Wrap” to prevent contamination will reduce the instrument’s efficiency to zero for Betas and Alphas in most instances. Covering the probe is not a recommended practice.
- All probes and end windows should never come into contact with contaminated surfaces. The minimum practical distance between the probe and the surface is to be at least one centimetre.
- Fingers, sharp instruments and pointy objects are not to come near or touch the end window.
- If the instrument reads in CPM or CPS, unless you know the efficiency of the instrument and do the calculations, then the reading is not a direct reading of the Activity (as in Becquerels) and may indicate a larger quantity than in reality. E.g. a unit reads 5000cpm from a spot of $^{32}$P, the instrument has 5% efficiency, and thus this is really about 1.66kBq of activity.
18.3. Personal Monitoring
Radiation workers who are expected to receive greater than the public dose limit of 1mSv per annum should be subject to continuous individual personal monitoring in addition to that prescribed in the Radiation Control Legislation.

The three main systems of personal monitoring that are routinely used throughout Australia are the photographic film badge, the thermo-luminescence detector (TLD) and the electronic Personal Monitor. TLDs have now replaced Film Badges as the legally acceptable method.

The personal monitors are usually worn at the chest or belt level. Wearing personal monitors at belt level effectively measures the radiation dose received by the trunk of the body, but care must be taken to ensure that the personal monitor is not shielded by a bench or table when working with radiation.

18.3.1. Photographic Film Badge
This operates on the principle that ionising radiation causes a latent image to be formed in the film emulsion.

18.3.2. The Thermo-Luminescence Detector (TLD)
TLDs utilize the ability of some materials to trap the electrons produced by exposure to ionising radiation. After irradiation this material is heated allowing the release of the trapped electrons and in the process the release of a photon of light. The release of light photons is proportional to the radiation dose the detector has received.

The thermoluminescent material is usually impregnated into a small card of Teflon material and this card is housed in a holder similar to a film badge holder. The holder has several filters that help in determining the type and energy of radiation. The badge will detect gamma and x-rays, high energy beta particles, and in certain special cases, neutrons. It does not register radiation from low energy beta emitters such as $^3$H, $^{14}$C, and $^{35}$S, because their betas will not penetrate the plastic covering on the TLD holder.

Compared to film badges, TLDs are more sensitive to low levels of radiation. Typically, most films are inaccurate below $100\mu$Sv, whilst the TLD is accurate down to approximately $10\mu$Sv.

18.3.3. TLD Ring
The TLD ring is used to measure dose to the hand. They are issued to individuals who may use gamma or high energy beta emitters, such as $^{125}$I. The crystal is mounted in a ring which should be worn on the hand that is expected to receive the larger dose. The ring is worn inside the disposable gloves with the label facing towards the palm.

18.3.4. Electronic Personal Monitors
These are useful instruments for the short term monitoring of an individual. These work in the same way as many of the portable monitors discussed at the beginning of this chapter. These are becoming quite small and accurate and can have the advantage over a TLD in that many of these instruments have a visual readout of the accumulated dose as well as an audible alarm if the dose rate is too high or the cumulated dose is too great. However, these units are expensive and easily lost and damaged.

18.3.5. Practical measures to consider and Legal Considerations
The radiation doses recorded by your dosimeters become part of your occupational radiation dose record. Film and TLD badges must be kept in good condition. These ‘badges’ are usually processed every 3 months or more often if necessary. The results should be made available to the worker and are required to be kept by the institution for a period of at least fifty years after the last entry. The RSO or equivalent, usually maintains a cumulative dose record for all registered users.

To ensure that the cumulative dose is valid and accurate the following precautions and legal requirements are to be observed (if you are issued with a personal dosimeter these are a legal MUST):

- A personal monitor is to be worn when using radioactive materials or irradiating apparatus (basically at all times whilst in the laboratory).
- Dosimeters are to be kept away from radiation sources when not in use - they should not deliberately be exposed to radiation or worn when receiving medical or dental x-rays. They are also to be securely stored away from radiation sources at the place of employment (i.e. not taken home, etc.)
- Personal monitoring badge (the actual TLD film) is not to be tampered with or removed from the holder.
- Personal monitoring badges should not be exposed to high temperatures or to water.
- Personal monitors are not transferable and should never be exchanged between individuals.
- A ring badge should be worn when handling gamma or high energy beta
- The TLD is to be returned to the WHS Unit for assessment at the appropriate time
- The WHS Unit is to be notified if personal monitoring badges or rings have been damaged or lost, or if there is reason to believe that the personal dosimeter has received an accidental high dose.

18.4. Workplace Monitoring

18.4.1. The Monitoring Program

Monitoring for both internal and external radiation hazards is a very effective strategy to assess the effectiveness of the radiation protection program.

A monitoring program should include measurements of:

- Doses received by radiation workers
- External dose rates in the work area
- Contamination of work services and on clothing
- Contamination of the air and waste water

Various codes of practice and guidelines have a quality assurance routine for radiation premises that includes the following:

- Physical inspection at least every twelve months to insure minimum standards (design) and radiation safety
- Measurement of external dose rates at least once per month of radiation stores
- Surface contamination monitoring at least once a week with decontamination if necessary
- Calibration of radiation monitoring equipment annually as a minimum
- Documentation of the above.

The above quality assurance routine is strongly recommended to be adopted by all facilities and users of radiation, especially those who work with unsealed sources.

18.5. Workplace Surveys

18.5.1. Types of Surveys

There are four types of surveys that may be performed depending on the types and quantities of radioactive materials being used. These surveys should be documented and are in addition to the routine checks that workers should perform at the end of the work or each week.

- General Use Survey - This survey is a visual check of the lab areas to ensure appropriate warning signs, labels, alarms, notices and procedures are being used.
- Instrument Survey - This survey uses a survey instrument to locate fixed and removable contamination on surfaces, equipment, personnel and clothing.
- Wipe Survey - This survey uses a filter paper wipe to locate and quantify (e.g., in dpm) removable contamination on surfaces, equipment, personnel and clothing. Imprecise Only for low energy isotopes such as $^3$H.
- Exposure Rate Survey - This survey uses an appropriately calibrated meter to determine exposure rates (e.g. in $\mu$Svh$^{-1}$) for compliance with regulatory limits. For example, all radiation storage areas are to be monitored for dose rate each month.

18.5.2. General Use Survey

When working in a radioactive material laboratory, the following items should be assessed and maintained by the laboratory supervisor using the Radiation Inspection form. The WHS Unit inspects these items during audits and reports any deficiencies to the authorised user for correction:

- The use of appropriate signage and placards (see Section 24)
- The use of appropriate radioactive waste containers. Containers shall be labelled with the appropriate signs
- Ensure that radioactive waste is not being deposited in the normal trash
- Ensure that food and drink is not prepared, consumed or stored in the laboratory or designated radiation areas
- Ensure that appropriate ALARA principles are being applied (ALARA = As Low As Readily Achievable)
- Ensure that the monitoring program is applied.

The laboratory supervisor is responsible for correcting identified deficiencies.
18.5.3. Survey Procedures using Portable Instruments

Instrument surveys should be performed while working with unsealed radioactive materials and immediately after completion of the work. This survey is used for an immediate indication of a problem or to detect contamination prior to the wipe survey if necessary. (Note, for tritium and other low energy beta use, proceed directly to the wipe survey because the low-energy tritium beta will not be detected by portable survey instruments.) Surveys shall be performed and documented at intervals as specified in Table 7 of this section.

The following procedures shall apply:

- Select an instrument appropriate for the nuclide being detected. Check the battery condition and function check the instrument using a suitable check source.
- Slowly scan items and areas with the probe or detector approximately 1cm away from items or surfaces. If radiation levels are greater than two times normal background levels (usually no more than 50 cps), a more accurate assessment is required. Increased radiation levels in the general area may mask lower levels of contamination from instrument detection. Refer to table in section on Contamination and Decontamination.
- If contamination is found, decontaminate the area following procedures recommended in section on Contamination and Decontamination.
- After cleaning, a second survey shall be performed to ensure that contamination has been removed.

18.5.4. Wipe Survey Procedures

It is recommended that an instrument survey be performed prior to a wipe survey to minimise the chance of inadvertently spreading the contamination and to identify the areas requiring greater attention in wipe sampling. Surveys shall be performed and documented at intervals as specified in Table 7 of this section and as follows:

- Wear gloves.
- While applying light pressure, run a dry 5cm filter paper or equivalent over the surface being surveyed. A standardized area approximating 100cm² should be covered with each wipe to allow comparisons of results.
- Analyse the sample by using a liquid scintillation counter (LSC) or gamma counter. The instrument shall be sufficiently sensitive to detect the allowable contamination levels defined in the Section 25.4 - Contamination and Decontamination.
- If contamination above the allowable contamination level is found, decontaminate the area.
- After cleaning, a second survey shall be performed to assure that contamination has been removed.
- ACTION LEVELS: Contamination above the allowable contamination levels defined in the Section 25.4 Contamination and Decontamination.

To document wipe surveys, the results of the wipe survey should be recorded in Bq/cm² and indicate the location of each of the wipes.

<table>
<thead>
<tr>
<th>Radio-toxicity Group (and examples)</th>
<th>Instrument and/or Wipe Surveys (based on scheduled levels)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily or after use</td>
<td>Weekly</td>
</tr>
<tr>
<td>1</td>
<td>40kBq</td>
</tr>
<tr>
<td>2</td>
<td>400kBq</td>
</tr>
<tr>
<td>3</td>
<td>4MBq</td>
</tr>
</tbody>
</table>
19. Biological Monitoring

This is a short overview of Biological monitoring for human radiation contamination.

With some of the isotopes used in laboratories, it is very difficult to determine internal contamination by nuclides. This is especially so for the low energy nuclides such as $^{14}$C, $^3$H, $^{35}$S, etc. Portable monitors are ineffective for this purpose.

With body contamination by these nuclides it is important to know the properties of the labelled chemical and the associated isotope so as to be able to determine the route of transport in the body, the major site of deposition and the main site of damage. From this it then can be determined how to achieve a reasonable determination of the amount of isotope incorporated.

For example if the liver is determined as the major site of deposition then a liver biopsy may need to be conducted – a not very pleasant procedure where a large bore needle is bored into the liver to take a sample of the tissue so as to be able to do a count of radioactivity. Of course not all biopsies are so traumatic, for example contamination by *tritiated thymidine* only requires sequential samples of urine to determine the level of contamination.

Biological monitoring needs to be conducted by a medical specialist, or by a specialist supervised by a health physicist, who is familiar with the procedures. These people are not always available in your locality.

**If there is any suspicion of internal contamination then the WHS Manager must be contacted as soon as possible.**

Intervention (and the method of intervention) can only occur when the isotope, its level and its site of contamination has been determined.

It is important to remember that prevention of contamination is the only way to ensure that biological monitoring is not required.
20. Personal Protective Equipment

For radiation safety, all forms of PPE must be used as is appropriate. The minimum that is required in a radiation laboratory is:

- Fully enclosed shoes
- Long pants
- Lab coat
- Double gloves (when working with radioisotopes)
- Eye protection

The workplace and the workers must be supplied with all the relevant PPE in regards to the hazards and for emergencies. PPE is to be considered the last resort in protecting the workers from exposure to hazards. Engineering controls should be used first, but in a radiation laboratory the range of hazards may be great and the ability to control all hazards by engineering methods may be impossible. This will certainly be the case for radioisotopes, leaks, spills and emergencies.

20.1. Selecting Personal Protective Equipment

When selecting appropriate personal protective equipment, the nature of the hazard, the required degree of protection and the ease with which the equipment may be used should be considered. It should be properly selected for the task, readily available, clean and well maintained.

PPE has limitations which may include:

- it is personal and is not to be shared,
- there are limitations to its effectiveness in regards to airborne or exposure concentrations, its working life and its need for maintenance and cleaning,
- it requires training in its effective use, and
- may not be appropriate for some individuals, viz. beards and breathing apparatus.

20.2. Eye Protection

The lens of the eye is susceptible to damage by radiation. Energetic $\beta$ emitters (e.g. $^{32}$P) are a particular danger in this regard. The temptation to look into the open neck of a vessel containing a radioactive substance must be resisted. If it is essential to see into the vessel, a mirror should be used and, if necessary, the illumination increased.

In work with $\beta$ sources, a tall shield of transparent plastic (Perspex) is recommended. The design should be such as to give shielding protection to the eyes, face and body (as well as clear vision in every direction). For $\beta$ sources, the shield is made of 10 mm thick perspex or acrylic which totally stops betas.

For very low energy $\gamma$ sources (e.g. $^{125}$I), similar transparent screens are available in Pb-impregnated acrylic. The acrylic is 12mm thick and has a lead equivalency of 0.5mm. For $^{125}$I such a screen provides $10^3$ x attenuation of the 0.035MeV gammas. Note that the attenuation of such screens is poor for higher energy gammas.

It is difficult in a workplace situation to eliminate or totally control eye hazards. Damage to eyes can result from irradiations, flying particles, dusts, gases, aerosols, or splashing of chemicals.

The risks associated with a particular task should be evaluated and appropriate eye protection such as safety spectacles, goggles or face-shields selected. The minimum eye wear for a laboratory is safety glasses.

Approved eye protection should comply with AS 1337 and should be selected and used in accordance with AS 1336.

20.2.1. Safety Glasses

Protective glasses are useful for general purpose protection for the eye from radiation exposure, impact, some dust and some chemical hazards. They will protect from some chemical splash hazards if they have an eyebrow ridge and are close fitting. They will not protect against mists, vapours, aerosols, severe dusts and splash hazards, and they do not protect the face.
20.2.2. Goggles
Goggles are very good protection from radiation contamination, impact, dusts, mists, vapours, aerosols and all splash hazards. Again they do not protect the face nor are they protection against breathing hazards. They may be worn with some breathing apparatus but in general tend to interfere with the close fit of both apparatus. In addition they can become uncomfortable when worn for extended periods.

20.2.3. Face Shield
A face shield is very good protection for the face and eyes from radiation contamination, splash and impact hazards, and is very useful when dealing with spills and handling of materials such as solvents and cryogenics. They do not protect from dusts, mists, vapours and aerosols.

Face shields should be worn at all times when using transilluminators, etc. handling any cryogenics or decanting any liquids, solvents and some corrosives from “bulk” containers.

20.3. Respiratory Protection
There may be circumstances when fume cupboard facilities do not adequately control the hazard and the risk of inhalation may pose a potential health problem. Normally this is the case during emergency rescue or clean-up operations.

Hazards that may be encountered should be assessed, especially in an emergency situation, and suitable respiratory protection, such as dust masks and canister, cartridge or particulate filter respirators or combinations of these should be available. If appropriate, self-contained breathing apparatus should be available for emergency situations and located in an easily accessible area within the building.

When selecting respiratory equipment, it is important to ensure that the filters, cartridges or other screening devices will effectively block the particular hazard to be controlled. If in doubt, contact the manufacturer or supplier to verify the suitability and effectiveness of the proposed equipment for the intended purpose.

Once the correct equipment has been selected, it is vital that it is cleaned, maintained and stored correctly to ensure it affords full protection. Remember to check the “use by” dates on cartridges and filters and to discard old ones.

Persons should be suitably trained in the use and limitations of respiratory protection. Specialised instruction from an accredited trainer is required for the use of self-contained breathing apparatus. It should be noted that the effectiveness of the seal may be compromised by facial features such as beards, moustaches, long side-levers and by wearing glasses.

All approved respiratory protective equipment should comply with AS 1716 and be selected, used and maintained in accordance with AS 1715.

20.3.1. Half face masks
These are useful for a range of short term operations such as clean-up of spills, inspection and assessment of suspect packages.

A close fit and good seal is a must with beards, etc. compromising this seal, and as such totally negating the effectiveness of the breathing apparatus.

It is IMPORTANT to note that these types of breathing apparatus are meant for airborne concentrations below 2% level and not for use in atmospheres where the oxygen level is below that of normal air.

A selection chart needs to be consulted for selection of the correct canister(s) for the operation to be undertaken. Some suppliers of these types of equipment may have up to and over 100 types of canisters and the correct selection is vital to the protection of the wearer. ALSO it must be noted that these canisters have a working life of approximately 30 minutes duration and a shelf life of only about 7 days after being removed from the sealed plastic packaging in which they are supplied.

It is also vital that when the canister(s) are removed from this packaging that the date be written on the canister(s) to ensure that they will be disposed after 7 days of first use. As an addendum these types of masks do not protect from eye hazards and often impede the effectiveness of goggles, etc.
20.3.2. Full face masks
These types of BA protect both from breathing hazards as well as giving eye protection. Again beards etc., compromise their effectiveness.

These have a range of canisters available for different types of hazards as well as different size canisters up to a one (1) litre size that affords protection up to 1 hour duration. However they have the same limitations that were detailed for half face masks.

It is very important to maintain the cleanliness of these as dirt, grime, etc., will negate their effectiveness as well as their visual capabilities. Also when used with the larger canisters can reduce head movement and visibility as well as increase the fatigue of the head and neck muscles.

20.3.3. SCBA (Self Contained Breathing Apparatus)
This equipment provides complete protection to all breathing hazards including low oxygen levels. However to use this equipment, the user must be trained and certified in its use.

The advantages of SCBA gear are:
- the one set protects against all inhalation hazards
- they provide air and so can be used with high concentrations of contaminants and low oxygen situations
- the life of the cylinder is controlled by how hard and fast you breathe - not by the concentration of the contaminant
- there is usually a warning that they are about to run out of air.

The disadvantage of the SCBA sets is that they are bulky and heavy and so working in them can be more difficult. These units also take some time to fit in an emergency.

SCBA comes in two main types: demand and full flow.

The demand set relies on a seal between the face and the mask in a similar manner to a canister mask. With a demand SCBA, the user breathing in creates a vacuum that opens the regulator to provide air.

The full flow SCBA provides a positive pressure of air to the mask. This has a number of advantages:
- breathing is more normal
- it is not relying on a close seal between the face and the mask for safety
- if there are any leaks, the air leaks out - the contaminant doesn't leak in.

Fitting the SCBA mask is similar to fitting a canister mask. You need to don the tank set before fitting the mask.

20.4. Hand Protection
The primary purpose of gloves is to prevent contamination of the skin and not to provide shielding, so thin disposable rubber gloves which allow greater dexterity are always preferable to thicker gloves, and **double-gloving is highly recommended**.

If the dose of radiation to the hands is an important factor, remote handling methods must be employed.

Of equal or even greater importance to the wearing of gloves is their removal after the task is completed and the proper disposal of the gloves to prevent further contamination. The recommended technique for glove removal is as follows:

This procedure is such that the inside of the glove is not touched by the outside, nor is any part of the outside allowed to come in contact with the bare skin:
- The gloves should be lubricated internally with talcum powder.
- The cuff of each glove should be folded over, outwards, for 4 cm.
- Put one glove on by grasping only the internal folded-back part with the other hand.
- Put the second glove on by holding it with the fingers of the gloved hand tucked in the fold and only touching the outside of the glove.
- Unfold the gloves by manipulating the fingers inside the fold.
- Gloves should be thoroughly washed before they are removed.
- Gloves should be removed so that they are inside-out after removal, and without touching the outside surface to either hand, or internal surface of the other glove.

It is also important to consider the potential for employees developing latex allergy, a serious and debilitating health problem. Evidence suggests that frequent contact with latex products such as protective gloves may cause latex sensitisation. The current recommendation for managing this issue is to try to source protective gloves made from purer forms of latex - ask your supplier or manufacturer for advice. Testing of employees for latex allergy may also be considered. Workers using latex gloves are advised to wash their hands thoroughly before and after contact and to use moisturisers. All protective gloves, where applicable, should comply with AS 2161.

21. Laboratory Classification, Requirements and Registration

21.1. Laboratory Classification
The Australian Standard AS2243.4 uses the following system of classification (based on international standards), and this system is used in most legislation throughout Australia. Because there is a requirement for the registration of laboratories (premises) that use or store unsealed and sealed radioisotopes, UOW expects that facilities that are using radiation comply with these requirements.

21.2. Radioisotope Laboratory Grading
The radiotoxicity groups can be incorporated in a grading system that relates the standards of finish and facilities in a laboratory to the amounts of unsealed radioactive substances that can be used safely in it. Table 8 shows laboratory gradings for normal, wet chemical operations.

<table>
<thead>
<tr>
<th>Radiotoxicity group</th>
<th>Grade of laboratory for specified levels of activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low level laboratory</td>
</tr>
<tr>
<td>1</td>
<td>&lt;0.2MBq</td>
</tr>
<tr>
<td>2</td>
<td>&lt;20MBq</td>
</tr>
<tr>
<td>3a/3b</td>
<td>&lt;2GBq</td>
</tr>
<tr>
<td>4</td>
<td>&lt;0.2TBq</td>
</tr>
</tbody>
</table>

*Table 8 Grading of Radioisotope Laboratories*

As there is a difference between laboratories in their procedures and materials, modifying factors need to be incorporated into the above figures to ensure that the facilities do contain the minimum design features to maximise safety. Because the potential for radioactive contamination is largely determined by the nature of the work (for example, storage presents a reduced risk, whereas dusty operations increase the inhalation hazard), the factors shown in Table 8 can be applied to modify the grading according to the operations performed in the laboratory.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple storage</td>
<td>x 100</td>
</tr>
<tr>
<td>Very simple wet operations (for example using aliquots of stock solutions)</td>
<td>x10</td>
</tr>
<tr>
<td>Normal chemical operations (for example analysis of simple chemical preparations)</td>
<td>x1</td>
</tr>
<tr>
<td>Complex wet operations (for example multiple operations, or operations with complex glass apparatus)</td>
<td>x0.1</td>
</tr>
<tr>
<td>With Biological/organic materials</td>
<td>x0.01</td>
</tr>
<tr>
<td>Simple dry operations (for example manipulations of powders) and work with volatile radioactive compounds</td>
<td>x0.01</td>
</tr>
</tbody>
</table>
A complicating factor is that labelled organic material of special biological importance (meaning any biochemical or material that may be absorbed into biological systems and be metabolised) may be metabolized differently from the elemental form, and hence may present a greater hazard. For example, $^3$H-labelled and $^{14}$C-labelled thymidine are incorporated differently from the elemental forms, and consequently for these biologically important materials an additional modifying factor of 0.1 should be applied.

For example, a laboratory purchases, stores and uses 25MBq of $^{32}$P labelled Glucose. The grading of the laboratory would be calculated thus:

- Radiotoxicity group = 3a
- Activity = 25MBq

Initial classification would then be Low Level (<2Gbq). However the modifying factors of Complex wet and biological needs to incorporated, thus giving: <2GBq x 0.1 x 0.1 = 20MBq

And as 25MBq are purchased and handled then the classification would be shifted to Medium level.

### 21.3 Facility Requirements

AS2243.4 briefly summarises the facility requirements in the following table. These requirements are more fully covered and explained in AS2982.1, and an abbreviated version of this section of that Standard is given in table 10. Any additional features that improve the safety of the facility should be considered. Reference should also be made to AS2982.1 Laboratory Design and Construction Standard as well as the Ventilation Standard.

#### 21.3.1. AS2982.1 “Laboratory Design and Construction: Part 1” Requirements

**Low level laboratories:** In low-level laboratories, fittings and finish shall be chosen so that they may be readily cleaned and shall incorporate features as follows:

- Joints shall be sealed and made waterproof and be located away from sources of contamination.
- Seamless PVC flooring is recommended. Painted or carpeted surfaces are not acceptable.
- Walls should be smooth and reasonably free of exposed pipes and conduits. These surfaces should be finished with a washable high gloss or semi-gloss paint.
- Bench-tops shall have a smooth waterproof, chemically resistant covering which is easy to clean. Melamine, seamless vinyl, cast epoxy resin and stainless steel are recommended. Painted surfaces are not acceptable.
- Drainage shall be arranged so that other building areas cannot become contaminated if the drainage system becomes blocked (only if the building was built after this publication).
- Secure storage facilities shall be provided for stocks of radionuclides. Shielding shall be provided if recommended by the RPA. Refrigerator storage or freezer storage, or both, may be required in medical and biological radionuclide laboratories.
- The advice of the RPA shall be sought to determine if a fume cupboard is necessary for handling small quantities of non-volatile radionuclides that are of low radiotoxicity class.
- A recirculating fume cabinet which complies with AS 2243.9 may have limited applications when small quantities of radionuclides of low radiotoxicity class are being handled.
- Stainless steel sinks are recommended.
- A hand washbasin with automated action, or knee- or foot-operated taps should be provided, preferably immediately adjacent to the entrance doorway. A hand-held shower on a flexible hose and an eye wash facility should be provided at each hand wash basin to assist decontamination of personnel.

**Medium level laboratories:** A high degree of cleanliness is essential in medium-level laboratories, and finishes and fittings shall be chosen to assist its achievement. In addition to meeting the requirements of low-level laboratories, the laboratory shall comply with the following:

- The floor shall be strong enough to support the weight of any shielding while maintaining its smooth decontaminable continuous surface.
- Where welded PVC floor covering is used, a polyvinyl chloride content in excess of 76% by weight is recommended for ease of decontamination. The acid resistance and solvent resistance of welded PVC flooring can be slightly improved by polishing with a plastics emulsion polish.
- The floor covering shall be coved up to and be sealed to walls and vertical surfaces to aid cleaning.
- Benches shall be strong enough to support the weight of any shielding likely to be used. The front and side edges of the bench top should be slightly raised and the back coved up to the wall or reagent shelf, so that the bench top acts as a shallow tray to help contain spills.
- Joins between bench surfaces shall be designed and constructed so that they do not leak or trap contamination.
- A hand washbasin shall be provided and the taps shall be operated automatically, or be operated by knee or foot.
- All drainage systems shall be continuous and be appropriately labelled at accessible locations. Polyethylene and PVC pipes and fittings are resistant to most chemicals and are less likely than metal pipes to become internally contaminated.
- If glove boxes are to be used, each shall have its own exhaust air filter. Discharge of the exhaust air shall comply with the requirements of AS 2243.8.
- Laboratory ventilation requires careful design with outdoor fresh air quantities increasing as the quantity of radioactivity proposed for use increases. Table 11 provides a practical guide to the supply of outdoor air requirements for laboratories assuming a floor area of 10m²/person and a ceiling height of 2.4m. Radioisotope laboratories shall be maintained at a negative pressure with respect to adjacent spaces. An alarm system which is automatically activated in the event of failure of the ventilation system shall be installed.

<table>
<thead>
<tr>
<th>Type of Laboratory</th>
<th>Minimum outdoor fresh air flow per unit of total floor area L/s.m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological and chemical</td>
<td>3 to 6</td>
</tr>
<tr>
<td>Animal rooms</td>
<td>10</td>
</tr>
<tr>
<td>Radionuclide counting rooms</td>
<td>3</td>
</tr>
<tr>
<td>Low-level radioisotope laboratories</td>
<td>3 to 6</td>
</tr>
<tr>
<td>Medium-level radioisotope laboratories</td>
<td>6 to 9</td>
</tr>
<tr>
<td>High-level radioisotope laboratories</td>
<td>&gt;9</td>
</tr>
</tbody>
</table>

Table 11 Minimum Outdoor Air Flow For Radioisotope Laboratories

NOTE: Heat loads will in many cases increase the total supply air requirements well above these figures.
- The RPA/RSO shall determine whether overshoes and barriers are required.
- Laboratories of a medical or biological nature, where sterility of products also has to be maintained, will present special design difficulties. In such cases the RPA will need to resolve the different requirements of the radioisotope codes and standards, the sterility standards for cleanrooms and the Australian Code of Good Manufacturing Practice for Therapeutic Goods (Ref. 4). In addition, for product and operator protection, laminar flow biological safety cabinets complying with AS 2252.2 may be required.
- Ceilings should be smooth and decontaminable as for walls. Flush light fittings should be used in preference to suspended fittings which will trap dust.
- Laboratories, in the upper part of the medium-level classification or above, should have ceilings coved to the walls to aid cleaning.

At least one fume cupboard in accordance with AS 2243.8 should be provided. Appropriate exhaust air filters are desirable and provision should be made to fit them at a later date even if they are not required in the first instance. Provision should be made for exhaust air sampling. The base of the fume cupboard should be capable of carrying 0.5 kg/cm² (0.5MPa) averaged over the whole area of the base.

**High level laboratories:** High-level laboratories need special detailed design and planning before construction. An existing laboratory can rarely be modified for use as a high-level laboratory. The RPA and the relevant regulatory authority shall always be consulted at an early planning stage. Such laboratories shall contain the features listed in both the low level and medium level requirements, and shall also provide the following:
A ventilating system capable of supplying at least 9 L/s.m² of floor area of fresh filtered air. Atmospheric discharge of airborne radioactive waste should be minimized at source where possible, by filtration of aerosols or airborne particulates or other appropriate collection or treatment methods.

Arrangements shall be made to demonstrate compliance with relevant legislation, by appropriate monitoring or other means acceptable to the regulatory authority.

Trapped contaminants arising from the treatment of laboratory or fume cupboard exhaust air shall be disposed of safely in a manner approved by the RPA and the regulatory authority.

A negative pressure shall be maintained at all times in any glove boxes and hot cells. A 'scram' alarm system shall be automatically activated when the ventilation system fails. Windows in the laboratory shall be of fixed glass and non-openable.

Extensive shielding and remote handling equipment for large quantities of gamma emitters. Consideration shall be given to permissible floor loadings and the provision of cranes.

Facilities for the decontamination of apparatus.

Warning signs, lights and interlocks, as necessary, in accordance with AS 1216 and AS 1319.

A change room located at the entrance to the laboratory. The layout shall be such that the correct route through it is obvious and difficult to bypass. Depending upon the type of laboratory served, the change room shall provide-

i) a clear barrier or demarcation between the 'radioactive' 'non-radioactive' areas, with adequate space on each side;

ii) storage for clothing on each side of the barrier and containers for used clothing beside the barrier on the active side;

iii) washing facilities on each side of the barrier with automatic or knee- or foot-operated taps;

iv) personnel monitoring facilities;

v) a ventilation system to ensure that airflows are directed from the change room to the active area;

vi) a shower; and

vii) written instructions.
<table>
<thead>
<tr>
<th>Laboratory grade</th>
<th>Typical examples</th>
<th>Description</th>
<th>Control of other aspects</th>
</tr>
</thead>
</table>
| Low level        | Radio-immunoassay area within a small medical diagnostic laboratory using only pre-labelled non-volatile kits. Typically using no more than 400kBq of $^{125}$I per week in pre-dispensed kits | - Continuous floor covering but not coved up to walls. Melamine, PVC, stainless steel or similar flat-topped benches without raised edges.  
- Semi-gloss washable paint. No particular effort to conceal exposed pipes and conduits  
- Window exhaust fan may provide sufficient air change  
- Fume cupboard not necessary  
- A hand-basin should be provided. However, a lever action tap over a laboratory sink may be acceptable to the regulatory authority  
- Flushing sink may not be needed, depends upon type of work | - Access limited to laboratory workers.  
- Normal laboratory coats satisfactory.  
- No requirement for overshoes.  
- Radioisotope area often occupies a small section of bench space within a larger laboratory in which non-radioactive work is also carried out.  
- Work area delineated by radioactive marking tape holding down absorbent paper on which work should be carried out in trays |
|                  | Larger radio-immunoassay laboratories in pathology practices and hospitals | Criteria as itemized in AS/NZS 2982.1 | Access limited to laboratory workers |
|                  | Teaching, medical and research laboratories in medical schools, hospitals, universities, CSIRO and similar institutions. Typical usage up to 20MBq of radiotoxicity hazard group 2 up to 2GBq of group 3 and up to 200GBq of group 4 | - A fume cupboard in accordance with AS 2243.8 will be required in most of these laboratories  
- Advice shall be sought from the RSO as some of the medical and Biological / molecular / biology /pathology laboratories will need to meet additional criteria for small scale genetic manipulation work | Wrap-over type laboratory coats with fastenings using hook and loop fastening fabric should be provided,  
coats should also be colour identified for radioisotope work  
Laboratory should be dedicated to radioisotope work only |
| Medium level     | Radio-iodination procedures in research laboratories and institutions with typical $^{125}$I activity up to 200MBq. Radiochemistry research with typical usage up to 20MBq of $^{60}$Co, up to 400MBq of $^{113}$Sn and $^{65}$Zn | Criteria as itemized in AS/NZS 2982.1  
Seek RPA advice as above if genetic manipulation involved | Laboratory shall be dedicated solely to radioisotope work.  
Overshoes may be required to RSO advice. Colour- coded laboratory coats with fastenings using hook and loop fastening fabric essential. Access restricted to radioisotope workers |
|                  | Preparation of nuclear medicine diagnostic doses | Criteria itemized in AS/NZS 2982.1  
Compliance with appropriate parts of Australian Code of good radio-pharmaceutical practice | As above  
Overshoes required |
|                  | Preparation of radioisotope therapy doses | | |
|                  | Small scale production of commercial radioisotope products | | |
| High level       | Refer AS/NZS 2982.1 | | |

Table 12 Summary of Laboratory Requirements
21.4. Registration of Premises: Information for Occupiers

From 1 July 2004, under section 8 of the Radiation Control Act 1990, premises on which a radioactive substance that is not contained in a sealed source device is kept or used, must be registered. It is the responsibility of the occupier to ensure that the premises are registered.

21.4.1. Definitions

occupier In the Radiation Control Act 1990, ‘occupier’, in relation to premises, means:

- a person in occupation or control of the premises, or
- if the premises have different parts occupied or controlled by different persons, the person in occupation or control of the part concerned.

The occupier may or may not be the owner of the premises.

radioactive substance Section 8 of the Act refers to ‘premises on which a radioactive substance that is not contained in a sealed source device is kept or used’. A radioactive substance includes a sealed radioactive source that is not contained in a sealed source device.

A ‘radioactive source’, means either a radioactive substance or a sealed radioactive source that is not contained in a sealed source device. Some conditions only relate to a sealed radioactive source. Where this is meant, the term sealed radioactive source is used.

sealed radioactive source Means a radioactive substance sealed in a capsule, or closely bound in a solid form, so as to prevent the possibility of escape or dispersion of the radioactive substance, and to allow the emission of ionising radiation.

sealed source device Means equipment or a gauge, instrument or device that contains a sealed radioactive source, and permits the controlled emission of radiation, but does not include a container used solely for the storage or transport of a sealed radioactive source.

21.4.2. Why Register Premises?

The reason for registration and conditions of registration is to ensure that the occupier:

- complies with standards to help minimise the exposure of persons and the environment to harmful ionising radiation from a radioactive source that is kept or used on the premises
- keeps a record of the radioactive sources that are kept or used on the premises and the purpose for which they are used
- keeps a record of exposure of occupationally exposed persons and other individuals to radiation from radioactive sources that are kept or used on the premises
- does not dispose of a radioactive source except as permitted and keeps a record of the disposal of radioactive sources.

21.4.3. Application for Registration

The occupier must submit an application to the DECC using the approved form accompanied by the fee prescribed in the Regulation, which is $155.00 for new applications. The occupier must complete all sections of the application form that apply to the premises. The premises must be registered in the name of the legal occupier and the occupier's name and address must be provided.

Premises may be registered in the name of an individual or a corporation, including a statutory corporation (for example, an area health service or a university). The occupier must provide their registered office address (if a corporation) or street address (if an individual) and an address for correspondence, if it is different to the occupier's street address.

21.4.4. Licensing and use of radioactive sources

The occupier's DECC licence number must be provided on registration applications where a licence number is requested, not the licence number of a company director or employee. For a corporation to register its premises it must have a 'licence to sell/possess' radioactive substances in accordance with section 6 of the Act.
21.4.5. Classification of premises

- Premises where unsealed radioactive substances are kept or used: Where a radioactive substance that is not a sealed radioactive source is kept or used on the premises, the occupier must determine the classification of premises. Premises are classified according to the Australian Standard AS 2243.4 - 1998, Safety in Laboratories, Part 4 - Ionising Radiation, Appendix F - Grading of Radioisotope Laboratories, as low level, medium level or high level based on the specified levels of activity.

- Premises on which a sealed radioactive source is kept or used: Where a sealed radioactive source that is not contained in a sealed source device is kept or used on the premises, the occupier must provide details of each sealed radioactive source that exceeds the 'threshold activities for sealed radioactive sources' associated with the radionuclides listed in the Schedule (the schedule is also on the application for registration).

21.4.6. Registration of multiple rooms and laboratories

Registration may apply to a single room or individual laboratory, or two or more rooms or individual laboratories that are contiguous (attached or near one another) and owned or controlled by the same person, depending on how they are classified and the type of radioactive sources that are kept or used on the premises.

In general, the DECC will register up to three low level classification rooms or laboratories in which a radioactive substance other than a sealed radioactive source is kept or used, or where one or more sealed radioactive sources are kept or used and each sealed radioactive source is below the 'threshold activity' in the attached Schedule.

The DECC will generally register singly, rooms on which a radioactive substance is kept or used that are graded medium or high level, or where a sealed radioactive source that exceeds the 'threshold activity' in the Schedule is kept or used. Rooms used exclusively for storage will be registered separately.

This approach of registering one or more rooms or laboratories separately will be applied flexibly. The occupiers should contact the Radiation Control Section for advice on specific situations because an incorrect or incomplete application may delay registration.

21.4.7. Conditions of Registration

When the requirements for registration are met, the DECC will issue a certificate of registration for the premises. The conditions attached to the certificate are mandatory requirements. Conditions may vary depending on the type of premises or purpose for which the premises is used. The occupier is required to provide details relating to sealed radioactive sources of the kind identified in the Schedule that are received at the premises or disposed of, sold or given away, including the sources identified in the application.

The occupier must perform an annual stock-take of radioactive sources kept or used at the premises. The occupier must notify the DECC if there is any inconsistency following a stock-take in relation to sealed radioactive sources that exceed the 'threshold activity' in the Schedule.

21.4.8. Duration of Registration

The duration of registration is two years. The certificate of registration shows the date when the registration expires and is due for renewal.

21.4.9. Renewing a Registration

The DECC will send a renewal notification about six weeks before the registration expiry. The renewal application form must be returned with the prescribed fee if the occupier intends to continue to use the premises to keep or use radioactive sources. The fee for renewing a registration is $105.00.

21.4.10. New premises

The occupier must apply to register any new premises. Each of the premises where radioactive sources are kept or used must be registered before radioactive sources can be kept or used there.
22. Laboratory Signs and Access

22.1. Laboratory Signs

With radioisotope laboratories or any other laboratory that uses radiation, it is a requirement, both legislative and Standards, that the appropriate warning and identification signs are used. These signs are to be displayed at the entryway and at other relevant places within the laboratory or facility.

The first sign that all should be aware of is the international trefoil symbol:

![International Trefoil Symbol](image)

This is the symbol that denotes some form of ionising radiation hazard. Its use is extensive.

As of December 2013 premises that use or store radioactive substance need to be listed on the University’s Radiation Management Licence. The trefoil is incorporated in the first sign that the visitor to a laboratory should see before he enters the laboratory. This is in the DRA (UOW Designated Radiation Area Sign) notice that is affixed to the door or entryway. The sign has been developed to meet the conditions of the UOW Radiation Management Licence.

The remaining safety and laboratory safety signage requirements can be seen in the UOW Laboratory Safety Guidelines.

All equipment (other than glassware) is to be labelled with at least the trefoil, or something similar to the following equipment sign (this is based on the current ARPANS Code of Practice). Even the area of the bench that is used for radioisotope work is to be outlined with radiation warning tape (used to hold down the benchcote).

![Equipment Sign](image)

All storage facilities (including waste facilities) that are used for radioisotopes are to be labelled with at least the trefoil and an inventory.
22.2. Radiation Laboratory/Facility Access and Security

22.2.1. Access

Since the escalation of terrorism and the incident of Sept 11 2001, the requirements for access and security are in the process of change. Access and security is to be strict, and very well controlled. This goes for all facilities that use or store any radioactive material or ionising equipment. The IAEA in cooperation with all its signatories and the international community is developing (in 2003/2004) a code of practice on security and access. As Australia is a signatory and member nation of the IAEA it will be legally binding that all users of radiation adopt these recommendations. Currently, it is expected that no person, other than those specifically authorised, have access to the facility. Visitors are to be accompanied if there is a need to enter the facility. Students and employees do not automatically have access rights to radiation facilities.

When it comes to cleaning or facilities maintenance, there are legislative requirements and recommendations from Standards and Codes of Practice that outline the procedures for this. It is expected that the cleaning of a radiation facility is left to employees (laboratory/engineering/etc.) employed to work in the facility (i.e., classified occupationally exposed persons); cleaning staff are only allowed to clean floors of low level (and some medium level) classified premises, and then only after they have been trained in what they are allowed to do in the facility and after some form of radiation safety training appropriate to their duties.

With maintenance employees, that is a different matter. These employees (or contractors) are not allowed into the facility until they have had some form of radiation safety instruction and that they have also received an local area induction from the laboratory supervisor indicating that the facility has been monitored and it is safe for the general public (i.e. the maintenance employees) to enter the facility and do only the work that is required.

22.2.2. Security

The security of radioactive materials is another issue. It is currently expected in Australia that all isotopes are kept under LOCK and KEY when not being used. The draft IAEA security document has a method of classifying isotopes (and quantities) in terms of security/risk factors. The lowest requirement will be simple lock and key, rising to immovable safe like structures with very limited access to the key (or combination). This classification is also going to be applied to transport.

23. Laboratory/Radioactive Source Safety

The concepts expressed in this chapter can be applied to situations other than just laboratories. In addition to the physical design and fixtures in a laboratory, the safe operation of that laboratory depends on the adoption of appropriate work practices by the employees.

There are three fundamental rules to remember:

- **Time**: the less time spent in a radiation environment the smaller the radiation exposure. The dose accumulated by a person is directly proportional to the amount of time they spend in the radiation area. The less time spent in a radiation environment the smaller is the radiation dose.

- **Distance**: the greater the distance from a source of radiation the smaller the radiation exposure. The greater the distance from a source of radiation the smaller is the radiation dose. For distance, the inverse square law applies, i.e. for an isotopic point source of radiation the dose rate at a given distance from the source is inversely proportional to the square of the distance. Thus if you double the distance from a source, the dose rate decreases by a factor of four.

- **Shielding**: if a suitable absorbing material is placed between you and the source of ionising radiation, the less your exposure. Shielding is the practice of placing an attenuating medium between the source of ionising radiation and the worker. The attenuating medium, or shield, then minimises the radiation that would ordinarily reach the worker. The level of shielding required depends on the type and energy of radiation emitted and its intensity. If shielding is to work effectively it must be properly designed and made from materials of the appropriate density. Dense (high atomic number) materials (e.g. lead and depleted uranium) make the most effective shields for highly penetrating radiation such as gamma radiation. For lesser penetrating radiation such as beta particles low atomic number materials can be used (e.g. perspex or aluminium).

The thicknesses of an absorber needed to reduce the radiation intensity by a factor of two and by a factor of ten are called the half-value layer (HVL) and the tenth-value layer (TVL), respectively. Approximate lead TVL’s and HVL’s for some radionuclides are listed below.
<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Gamma Energy (MeV)</th>
<th>HVL (mm)</th>
<th>TVL (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{125}$I</td>
<td>0.035</td>
<td>0.05</td>
<td>0.16</td>
</tr>
<tr>
<td>$^{241}$Am</td>
<td>0.060</td>
<td>0.14</td>
<td>0.45</td>
</tr>
<tr>
<td>$^{57}$Co</td>
<td>0.122</td>
<td>2.0</td>
<td>6.7</td>
</tr>
<tr>
<td>$^{137}$Cs</td>
<td>0.662</td>
<td>6.5</td>
<td>21</td>
</tr>
<tr>
<td>$^{22}$Na</td>
<td>1.28</td>
<td>9.6</td>
<td>32</td>
</tr>
<tr>
<td>$^{60}$Co</td>
<td>1.17 &amp; 1.33</td>
<td>12</td>
<td>40</td>
</tr>
</tbody>
</table>

Table 13 Lead Shielding Thickness Layers

Example: At 1 metre, a 1GBq $^{60}$Co source produces an exposure rate (approximately) of 0.370mSvh$^{-1}$. How much lead shielding is needed to reduce the rate to 0.01mSvh$^{-1}$ ($10\mu$Svh$^{-1}$)?

40 mm (one TVL) will reduce the rate to 0.037mSvh$^{-1}$. Adding another 12 mm (one HVL) will make it 0.0185mSvh$^{-1}$. One more HVL will put the rate at about 0.0093mSvh$^{-1}$. So the total lead shielding needed is $40 + 12 + 12 = 64$mm.

When designing shielding there are several points to be kept in mind:
1. Persons outside the shadow cast by the shield are not necessarily protected.
2. A wall or partition may not be a safe shield for people on the other side.
3. Radiation can be “scattered” around corners.

23.1. General Rules
AS2243.4 details safety procedures to be followed when working with unsealed sources. These include:

- Radiation working areas should be segregated from other areas of the laboratory;
- No eating, drinking, smoking or storing food or drink in the laboratory;
- No mouth pipetting;
- All radiation work should be planned carefully in advance and if any doubt about the mechanisms or timing of operations are experienced then a "dry run" should be conducted;
- An exceptional degree of cleanliness should be maintained within and around the active working area. A clean-up should be conducted at the end of every procedure. At the end of each day the area should be completely cleaned and checked (monitored) for any contamination;
- All radiation work should be conducted in secondary containment facilities;
- Personal protective equipment consisting of at least a laboratory coat, appropriate gloves, and safety glasses should be worn at all times. In addition, if a lead apron is available then it should be used in all work with gamma emitting isotopes;
- Work should be conducted as quickly as possible without rushing to the extent that materials are knocked over;
- All laboratories in which a radiation working area exists should have a radiation warning label on the door of the laboratory and another on the designated work area. There should also be a brief note warning other persons not to use the area;
- Equipment to be used in active areas should be retained only for that purpose and be labelled accordingly;
- The use of distance is one of the simplest methods for reducing radiation dose, and the use of instruments such as forceps should be encouraged. Never directly handle radioactive materials without appropriate instruments, tools and personal protective equipment;
- All radioactive preparations should be clearly marked with details of the chemical compounds, isotope, activity, date and the name of the user using a self-adhesive label bearing the radiation symbol;
- Suitable shielding materials as required, should be used in all experimental situations and when storing radioactive materials or waste;
- All operations that may produce a vapour, gas, spray or dust should be carried out in a specially designated fume cupboard. This applies especially to iodination procedures;
- Adequately labelled bins lined with a strong plastic should be used for solid active wastes, e.g. gloves, absorbent material, cleaning equipment and disposable laboratory equipment. Liquid waste of high specific activity should be stored in suitable, adequately labelled containers;
- When using natural uranium, care should be taken to avoid inhalation of dust containing these materials, or air which has been standing over them in an enclosed volume;
When leaving the laboratory, wash hands thoroughly. Monitor hands, clothing and shoes to ensure no contamination is present;

Radiation working areas should be cleaned by laboratory employees working in that area. Cleaning staff should not service these areas;

Maintenance work to fixtures and plant should be carried out only after the RSO or equivalent has given clearance;

For good working practice, counting apparatus should normally be housed in a separate room. No radioactive materials, other than prepared samples, should be taken into the counting room. Gloves worn during sample preparation should be removed before entering the counting room;

A suitable monitoring instrument shall be available and used throughout all radiation work.

### 23.2. Radiation Safety Specifics

#### 23.2.1. Gloves

The primary purpose of gloves is to prevent contamination of the skin and not to provide shielding, so thin disposable rubber gloves which allow greater dexterity are always preferable to thicker gloves. However, the recommended practice for the handling of unsealed radioactive sources is double gloving. Double gloving provides greater protection by ensuring that if the outer layer of glove is penetrated or torn then there is still the second layer that will allow the replacement of the first without the risk of contaminating the skin.

If the dose of radiation to the hands is an important factor, remote handling methods must be employed.

#### 23.2.2. Protection of the Eyes

The lens of the eye is susceptible to damage by radiation. Energetic $\beta$ emitters (e.g. $^{32}\text{P}$) are a particular danger in this regard. The temptation to look into the open neck of a vessel containing a radioactive substance must be resisted since, under certain circumstances, the radiation is canalized by the shape of the vessel. If it is essential to see into the vessel, a mirror should be used and, if necessary, the illumination increased.

Wearing appropriate eye protection in laboratories is the minimum expected at all times and this is especially required when working with radiation.

In work with $\beta$ sources, a tall shield of transparent plastic is recommended. The design should be such as to give shielding protection to the eyes, face and body (as well as clear vision in every direction). For $\beta$ sources, the shield is made of 10 mm thick perspex or acrylic which totally stops betas.

For very low energy $\gamma$ sources (e.g. $^{125}\text{I}$), similar transparent screens are available in Pb-impregnated acrylic. The acrylic is 12 mm thick and has a lead equivalency of 0.5mm. For $^{125}\text{I}$ such a screen provides $10^3$ x attenuation of the 0.035 MeV gammas. Note that the attenuation of such screens is poor for higher energy gammas.

#### 23.2.3. Working Surfaces

Poly-ethylene sheet or plastic backed absorbent bench cover minimises the effect of accidental spillage of active material. Porous surfaces (such as an untreated wooden bench) are not suitable for radiation work.

Any spilt material must be removed immediately it occurs. Failure to do this may result in further, and more serious, accidents. Tissues used for the clean-up should be held in sponge forceps to avoid contamination of the hands and must be placed in the radioactive-waste bin.

Stainless-steel or plastic trays provide an additional means of containment and all the radioactive manipulations should be carried out inside them. The use of “benchcote” or similar in the tray is recommended. This liner should be discarded as radioactive waste at the end of each experiment.

Depending on the chemical form of the contaminant and the nature of the surface, surface decontamination can be achieved with solutions of detergent, ammonium citrate, dilute hydrochloric acid or kerosene. Be very careful not to spread the contamination.

#### 23.2.4. Contaminated Apparatus

A medium level laboratory must have a complete and exclusive set of apparatus always kept there. Carrier-free isotopes are very likely to become strongly adsorbed on to glassware, and it is frequently difficult or impossible to remove them. For this reason disposable plastic apparatus is strongly recommended, if its use is practicable. It is most important that disposable apparatus should be washed thoroughly before it is placed in the radioactive-waste bin.
Contaminated glassware must not be returned to the general laboratory glassware but should be immediately washed in water and then totally immersed in an appropriate laboratory detergent solution. If this habit of immediate treatment is acquired it will save a great deal of time by preventing radioactive material from drying on the apparatus and thus becoming much more difficult to remove. Care should be taken to ensure that radioactive material is not accumulated in the cleaning fluid.

If this procedure is unsuccessful, expert advice should be sought. Cleaning procedures which may result in the release of gaseous radioactive material must not be used because of the inhalation hazard.

Before being put away, each article which had been contaminated should be tested with a monitor, though it should be remembered that an external monitor will not detect contamination inside glassware by substances emitting very soft radiations. If contamination is still present, the apparatus must be re-cleaned until an acceptable level of activity is reached. At this stage, immersion in a solution of carrier - that is, the inactive form of the radioactive compound one is trying to remove may be of value.

If it proves impossible to clean satisfactorily apparatus which is contaminated with a short-lived isotope, arrangements should be made with the local Safety coordinator for suitable storage until an acceptable radiation level is reached. Typically, this might be in a bin of suitable composition, permanently labelled in paint:

**RADIOACTIVE APPARATUS - DO NOT REMOVE BEFORE DATE ON LABEL**

Each article placed therein should be clearly labelled with the date of contamination, the isotope and the date on which the radioactivity will have decayed to a safe level.

### 23.2.5. Contaminated and General Waste

The laboratory should contain separate solid waste bins for contaminated (radioactive) waste and for general (non-radioactive) waste. The contaminated waste bin must be clearly labelled and must be of a suitable shielding material (or, in the case of lead shielding, set inside a suitable shielding material).

Disposal of contaminated waste is the responsibility of the radiation workers.

### 23.2.6. Evaporation of Radioactive Solutions

Extra precautions should be taken when heating a radioactive solution. Widespread contamination is caused by fine invisible spray from a liquid which is being heated, and the spread of contamination is much greater if the solution is boiled.

If heating is necessary, use a container with an efficient seal or place inside a second sealed container.

When it is necessary to evaporate a solution (and this should be avoided if possible), the solution should be placed in a closed system fitted with a condenser or in a rotary vacuum evaporator. If time permits, freeze-drying is probably the best method for concentrating a radioactive solution. Evaporation in an open system, if this is unavoidable, must be done in a fume cupboard and should be conducted at the lowest possible temperature on a water bath fitted with ceramic rings (for easy decontamination). Infra-red heating from above is preferable as a means of reducing the spread of contamination during evaporation.

### 23.3. Monitoring and Quality Assurance

The importance of regular and systematic monitoring cannot be over-emphasized. For many experiments both monitoring of the environment and personal monitoring are necessary, but great care must be taken to ensure that the monitor being used will give a reliable measurement of the particular type of radiation which may be present.

#### 23.3.1. Personal Monitoring

TLD Monitor - All persons handling gamma or hard beta emitting isotopes must apply to the RSO for being included on the monitoring schedule. Issue of TLDs will be according to need.

- TLD Monitor must be worn at waist level and under the lead apron if wearing one.
- The person wearing the TLD must care for it against damage, loss, contamination etc., as it is the only means of monitoring any regular or accidental radiation exposure.
- Persons responsible for the distribution of TLDs must take every care so that TLDs, while in their possession are not in any way exposed to radiation, contaminated or damaged. Control TLDs must be stored away from radiation areas.

At the UOW, personal monitoring is routinely undertaken for all radiation workers (rather than only those
receiving more than 30% of the effective dose limit). The TLD badge is routinely used.

23.3.2. Area Monitoring
All laboratories are required to have, or have access to, calibrated monitors for the radioisotope being used.

Part of area monitoring is quality assurance; some of these procedures are required under the legislation. The following actions are strongly recommended:

- A physical inspection conducted at least every 12 months; to ensure the minimum standards of facilities and safety (by a knowledgeable person independent of the laboratory).
- Measurement of external dose rates at least once per month of radiation stores.
- Surface contamination monitoring conducted weekly as a minimum.
- Monitoring equipment calibration done annually.

23.4. Contamination and Decontamination

23.4.1. Maximum Levels of Contamination
Contamination of laboratory surfaces or workers with radionuclides must always be kept at the minimum practicable levels (hopefully indistinguishable from zero) in keeping with the ALARA principle in Radiation Fundamentals (Chapter 2).

However, an operational definition needs to be established as to the maximum amounts of such contamination that would be tolerable. For the purpose of University requirements, the table below reproduces the derived working limits given in AS2243.4-1998.

<table>
<thead>
<tr>
<th>Radio-toxicity Group</th>
<th>Maximum levels within laboratory Bq/cm²</th>
<th>Maximum level on skin or items leaving the laboratory Bq/cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>0.1</td>
<td>0.01</td>
</tr>
<tr>
<td>Group 2</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>Group 3a</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Group 3b</td>
<td>100</td>
<td>10</td>
</tr>
<tr>
<td>Group 4</td>
<td>1000</td>
<td>100</td>
</tr>
</tbody>
</table>

23.4.2. Assessment of Contamination Levels
Contamination is invariably the result of accidental release of radioactive material. A measure of contamination is made from the number of counts/second recorded by a sensitive detector calibrated for the radioisotope.

For β particles, X-rays, and γ rays a sensitive Geiger-Muller counter is satisfactory, although in the case of β particles a thin window will be necessary to allow the β particles to enter the counting chamber. For Q particles, a suitable scintillation counter is needed.

None of these instruments is a linear device and therefore the exact relationship between counts/second and activity depends on the isotope being measured. Furthermore, since a variety of monitors is used in UOW 'typical' count rates cannot be stated reliably. It is therefore strongly recommended that all contamination monitors be calibrated for each isotope being used in the laboratory. In most instances this can be done by holding the monitor at a known distance close to but not touching a filter paper which has a known quantity of the isotope absorbed onto it.

For soft β and weak γ producing isotopes it will be necessary to conduct a wipe test (smear test) to assess contamination and levels of contamination.

23.4.3. Decontamination Procedure
Loosely attached radioactive material on the bench top and floor may be detected using the Wipe (smear) test. This consists of wiping a known area of the bench with a filter paper (with known area) and monitoring the filter paper. Some authorities suggest that the paper should be damp or lightly oiled. If loosely held radioactive material can be removed in this way, spread of the contamination may result if it is left without further treatment. Every effort should be made to eliminate it so that the activity on the filter paper is finally zero.

If persistent, firmly attached activity exceeding the above maximum figures still remains on the bench top or floor, then specific decontamination solvents should be used with active wet abrasion. Options could include
aqueous detergent, acid, base, or chelating solutions and organic solvents depending on the chemical nature of the contaminant and the surface to which it is adhering.

If decontamination is unsuccessful, the area of contamination should not be used during the decay of the isotope. If the isotope is long-lived its permanent presence is intolerable and the affected area should either be removed or else covered with a screening material such as lead or concrete.

### 24. Storage

AS2243.4 on radioactive storage states:

- Radioactive substances shall be stored separately from non-radioactive substances.
- Radioactive substances shall be kept in a locked store that complies with the following:
  - The store shall be sited to minimize the risk of flooding and other natural or man-made hazards. If there is any possibility of accidental flooding (for example, from burst water pipes or leaking roofs), provision shall be made for all substances to be stored above floor level, and for water to be drained.
  - The store shall be constructed of durable, fire-resistant materials.
  - The store's interior surfaces shall be constructed of materials which can be decontaminated easily.
  - The store shall be adequately shielded to ensure that radiation levels outside the store, at locations that are:
    - accessible to occupationally exposed persons, shall not exceed 5 µSv/hr (assuming the storage facility is within the laboratory or workroom – taken from International documents); and
    - accessible to non-occupationally exposed persons, and members of the public, shall not exceed 1 µSv h⁻¹ when averaged over one week.
- A radiation warning sign shall be displayed at the door of the store.
- The store shall be provided with spillage trays on which the containers of liquid radioactive substances shall be placed. Each tray shall have sufficient volume to retain the whole of the contents of the containers on the tray, and to enable their recovery.
- The store shall be provided with an air extraction system if any radioactive gases or vapours are emitted from the substances held in the store. Applicable only if a walk-in type store.
- The store shall be kept locked (under lock and key with the key being the responsibility of the displayed licensee) except when radioactive substances are being transferred into or out of the store.

The sign that is to be displayed on the store facility is:

![Radiation Store Sign]

Along with this sign, a current inventory containing the following information is to be attached to the facility:

<table>
<thead>
<tr>
<th>Date</th>
<th>Isotope</th>
<th>Activity (Bq)</th>
<th>Volume</th>
<th>Details of labelled material</th>
<th>Licensee</th>
<th>Dept.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

This inventory is to be kept current on at least a weekly and no more than monthly routine.
25. Radioactive Waste Disposal

Refer to the UOW Radiation Safety Guidelines

26. Sealed Source, Soil Moisture Probe and XRD/F Analysis Equipment Safety

26.1. Sealed Sources

A sealed source refers to radioactive material that is firmly bonded within metals or sealed in a capsule or similar container of adequate mechanical strength so that the active material cannot be dispersed into the environment under foreseeable conditions of use and wear. Typically, sealed sources are double encapsulated.

26.2. The Australian Standard Code of Practice

AS2443.4 details safety considerations when working with sealed sources. These include:

- Handling sealed sources by remote means such as tongs or forceps and for the minimum possible time.
- Locating shielding as close as practicable to the source of radiation. Precautions should be taken to protect laboratory workers and persons in adjacent areas from direct and scattered radiation.
- Every sealed source should be labelled with, and a record kept of the following:
  i) the serial number or identification code.
  ii) the nature of the source, its date of receipt, and its activity upon receipt.
  iii) details of any relocations both within and out of the laboratory.
  iv) the date and details of disposal.
- When not in use, store sealed sources in secure and adequately shielded containment, which is labelled with the international radiation symbol and other relevant information.
- Where a source could potentially release a radioactive gas, the storage area must be adequately ventilated. Exhaust ventilation should be run for an adequate time before entering the area.

Sealed sources may be used in either an enclosed or open installation.

26.3. Safety Guidelines for Enclosed Installations

Permanent enclosures for any source of radiation and the materials being irradiated should be designed so that:

- No person can be within the enclosure during an irradiation.
- Interlocks prevent persons from entering the enclosure during an irradiation.
- Any person accidentally shut in an enclosure be able to leave by a suitable exit or be able to immediately enter an adequately shielded refuge.
- An irradiation is capable of being prevented or quickly interrupted from within a large enclosure. It should not be capable of being reset from outside the enclosure.
- Persons outside the enclosure are adequately protected.
- During operation, the dose rate at any accessible outside surface of any large enclosure should not, in any one hour, exceed 10uSv. If non-radiation workers have access to the outside area, the dose should not exceed 0.5uSv.
- When not in use, sealed sources should be housed, by remote control, within adequate shielding inside the enclosure.
- Fail-safe® interlocks and control systems should be provided on all enclosed installations. If electrically operated, the system should be rendered inoperative or non-hazardous in the event of loss of electrical power.

26.4. Safety Guidelines for Open Installations

Open installations, because of the nature of their requirements such as the use of a portable apparatus, cannot be provided with the same safeguards as for enclosed installations. In an open installation, the source of ionising radiation and the materials being irradiated should be confined as far as possible within a specific area. This area should be outlined by suitable barriers, follow the requirements of an enclosed facility plus the following with warning signs so that:

- only authorized persons have access to the area.
- persons outside the area are not exposed to the source of radiation.
• authorized persons enter the area for the minimum time needed to make essential adjustments to the equipment.
• if possible, the apparatus be capable of adjustment by remote handling methods.

There are several NHMRC Documents that deal with sealed sources or medical applications that would be of use for developing safety procedures. Please note that these are in the process of being revised and replaced by the ARPANSA Radiation Protection Series.

26.5. Unwanted Sealed Sources
In some cases the sealed source may still be highly radioactive. If this is the case, the following alternatives should be considered:
• return to the supplier;
• transfer to another user;
• store in a suitable facility.

In all cases, the Statutory Authority should be notified of the decision to be taken.

26.6. Sealed Source Maintenance
It is expected that each sealed source is checked on a regular basis, either quarterly, six monthly or yearly. This check is to ensure that the sealing material maintains its integrity and that it is not degrading. The check is examining for faults such as cracks or chips and that the surface is wipe tested to ensure that the radioactive isotope is not “leaking”, that is separating from the sealing compound and becoming a free agent.

There are to be comprehensive records for each sealed source that must include Wipe test results, etc.

26.7. Guidelines for the Safe Use of Neutron Moisture Gauges
The following is based on the relevant sections of Safety Guide: Portable Density/Moisture Gauges Containing Radioactive Sources, Radiation Protection Series No. 5 (May 2004). It is expected that the licensee or senior researcher in charge of the project that involves the use of these instruments reviews these procedures regularly and a report on the review is submitted to UOW RSO/RSC for approval. These procedures are to be reviewed at no greater than a 12 monthly interval.

26.7.1. Working Rules
• The expected radiation levels around each portable density/moisture gauge are to be such that the dose received by the operator is kept at less than 60% of the annual dose limit, and the dose rate 1 metre from the gauge should be no greater than the following: When the source(s) is/are in the shielded position, the radiation levels must not result in an ambient dose equivalent rate or directional dose equivalent rate, as appropriate, exceeding,
  – 250 µSv h⁻¹ at any point 0.05m from the gauge surface; and
  – 10 µSv h⁻¹ at any point 1m from the gauge surface;
• Using the instruction manual (or the supplier/manufacturer’s recommendations), safe methods for the use of the gauge are to be employed at all times. No more than 3 people are to be involved in the direct use of the gauge at any time, all other persons are to be at least 3 metres from the instrument;
• From (b) above the method(s) for conducting the survey, the sealed source wipe test and any other safety tests are to be documented;
• When not in use the gauge is to be housed in a secure and shielded storage facility with the appropriate warning signs, this storage facility is to have a dose rate of less than 5 µSv h⁻¹ at the surface of the facility;
• All operators/users of the gauge are to be personally monitored with a Neutron Type TLD and the TLD is to be worn at the belt level;
  – the control monitor is not to be kept near the gauge at any time;
• When soil testing is being conducted, the general public and those not directly operating the unit are to be kept a minimum of 3 metres from the site, the use of appropriate signs such as the example in Annex A being displayed at the four compass points of the testing site. An individual from the testing team is to be appointed as the site supervisor, so as to maintain safe distance, the appropriate use of signs and equipment as well as all safety records;
• Emergency Procedures are to be documented and the emergency spill kit kept near (but not with) the gauge at all times;
• All relevant authorizations (licences, permission to access land for testing, etc.) are to be obtained before the testing is to be conducted;
During transport (see Transport Section following), and when in the field but not being used, the gauge is to be transported in its packaging as far from the driver and passengers as possible (preferably in the boot or whatever). The unit is to be secured within the vehicle to prevent theft and loss, always lock the source(s) in the shielded position when the unit is not in use. The unit is not to be left unsecured or uncontrolled at any time;

- The integrity of the gauge is to be maintained by regular servicing by an authorized service agent/company. This will also include calibration of the source on an annual or bi-annual time frame. Records of all services and calibrations are to be maintained;
- The emergency contacts are:
  - UOW Radiation Safety Officer, Ph: 4221 3931;
  - The Radiation Control Branch, DECC, Ph: 02 9995 5000.

The documentation to be maintained are:
- Storage Log Book, that is a record of the time the gauge is in the storage facility;
- User/Use Log Book, that is a record of all use or display of the unit, when and by whom;
- Service, Repair and Calibration Log Book
- Instrument Accident/Incident Record

26.8. Emergency Procedures
Written emergency procedures are to be developed and kept with the gauge at all times. Users of the gauge are to be familiar with the emergency procedures. The manufacturer’s instructions should always be the first source of information for the development of these procedures.

26.8.1. Responsibilities of the Licensee or Senior Researcher (of the Group)
The Responsible Person should notify the appropriate fire authority and police of the storage locations of each portable density/moisture gauge under this person’s control. This will be of particular importance where the gauge or gauges are stored at semi-permanent or permanent locations.

Where this person is required to provide instruction (including all safety matters, however to gain a licence the training must be conducted by an approved provider) to personnel, this should be done at the induction of those personnel and at intervals of not greater than 12 months. Instruction might need to be more frequent where there have been changes to legislation or other safety requirements that are relevant to those personnel.

NSW legislation requires that users are licenced (or students are exempted and under supervision during use) and are suitably trained by a D.E.C. approved trainer.

One of the licensee’s responsibilities is to ensure the integrity of the sealed source, and a trained, experienced service technician should be employed for this purpose.

Service technicians involved with repair of portable density/moisture gauges might also need to be equipped with a suitable contamination monitor, particularly if they are performing wipe tests. Contamination monitors should also be considered where there is a possibility that a source capsule can become ruptured.

26.8.2. Storage of Gauges
When in storage, the gauge should be locked in its transport case.

As far as practicable and taking into account the ALARA principle, portable density/moisture gauges should not be stored near regularly occupied or frequented areas. The dose rate at the surface of this facility should be less than 5 \( \mu \text{Sv/h} \) if only occupationally exposed persons have access, or less than 0.5\( \mu \text{Sv/hr} \) if accessible by the general public. Furthermore, portable density/moisture gauges should not be stored in the same storage area as dangerous goods of the following Dangerous Goods Classes:

1. Explosives 4.3 Dangerous when wet
2.1 Flammable gas 5.1 Oxidising agent
3. Flammable liquid 5.2 Organic peroxide
4.1 Flammable solid 8 Corrosive
4.2 Spontaneously combustible
Consideration should be given to separation of these classes when designing a store from the ‘ground up’ or as is more often the case, when designating an existing store as a storage area for portable density/moisture gauges. Also, portable density/moisture gauges should not be stored with undeveloped X-ray or photographic film or foodstuffs.

The name and contact details of the Radiation Safety Officer, or other relevant person, should be placed on the store in a conspicuous location.

**26.8.3. Transport of Gauges**

When transported on public roads, the gauge, wherever possible, should be locked in its carry case and be fixed in location within the vehicle with the shutter mechanism facing away from the vehicle occupants or facing downwards.

Loading restrictions also exist for the transport of portable density/moisture gauges with other dangerous goods with the class restriction being the same as those given for storage as outlined above. The Australian Dangerous Goods Code (ADGC), as amended from time to time, specifies the criteria for the transport of mixed dangerous goods on the one conveyance. The ADGC should be checked before a portable density/moisture gauge is transported with any other dangerous goods on the one conveyance. In general though, mixing incompatible classes of dangerous goods on the one conveyance would not be permitted unless there is segregation of at least 12 metres and for some mixed classes, 24 metres, or that there was some form of APPROVED segregation device used.

Where other compatible dangerous goods are being transported on or in a vehicle, it may be necessary to have three sets (both sides and rear of vehicle) of placards indicating that the vehicle is carrying a portable density/moisture gauge and another class of dangerous goods.

While the packaging, labelling and paperwork required for the transport of radioactive material is uniform throughout Australia, the authorization process across the jurisdictions may not be. If transporting a portable density/moisture gauge across a jurisdictional boundary, it is highly recommended to ascertain the authorisation requirements of each jurisdiction through or into which the portable density/moisture gauge will be transported.

**26.9. Radiation Warning Signs And Labels**

Radiation warning signs and labels, must conform to AS/NZS 1319 *Safety signs for the occupational environment*, and AS/NZS 2342 *Development, testing and implementation of information and safety symbols and symbolic signs*. Examples of suitable warning signs and labels are given below.

Colours for radiation warning signs and labels:

- Background: yellow
- Marking and trefoil: black

Example of a suitable warning sign for posting in the area adjacent to portable density/moisture gauge when in use (55 x 22cm minimum size):

![WARNING
PORTABLE RADIATION GAUGE IN USE](image)

Example of a suitable warning label for attachment to a portable density/moisture gauge containing a radioactive source:
The information included on this label should reflect the gauge’s use (e.g. Density only, moisture only (version depicted above) or combination) and its total radioactive contents (e.g. caesium only, 241Am/Be only or both).

(Note: the lower part of this label may be unpainted metal with black lettering).

26.10. X-ray Diffraction and Fluoroscopy Safety
The ARPANSA Code of Practice for Protection Against Ionising Radiation Emitted from X-ray Analysis Equipment (1984) and AS2443.4 detail safety considerations when working with sealed sources. These include:

- Locating shielding as close as practicable to the source of radiation. Precautions should be taken to protect laboratory workers and persons in adjacent areas from direct and scattered radiation.
- Indicator warning lights
- Development of Safety Procedures
- Training
- Interlocks
- Placarding of DRA’s (designated radiation areas)
- Monitoring

26.10.1. Safety Guidelines for Enclosed Installations (NHMRC/ARPANSA)

User responsibilities
The user shall be responsible for the safe use of the X-ray analysis equipment at all times and shall ensure that:

- all legislative requirements are satisfied;
- all safety features required are implemented and are regularly serviced and maintained in good working order;
- the requirements outlined in this safety manual are completed and maintained;
- no X-ray analysis unit is operated while a safety feature is removed, modified or inactivated except under the approval of the Government Authority;
- in the case of an actual or suspected exposure to the intense primary beam, the persons involved are referred for medical examination, medical reports are retained, and full details of the incident are reported to the statutory authority as soon as possible (within 7 days of the incident by law);
- the signs required are prominently located and are maintained in a clean, intact and legible state;

Operator responsibilities
Each operator of an X-ray analysis unit shall:
▪ at all times carry out established procedures of operation and maintenance; and
▪ report to the RSO any actual or suspected case of excessive exposure, endeavour to determine its
cause, and take steps to prevent its recurrence.

General Working Rules for all X-ray analysis units

▪ Each person who uses an X-ray analysis unit shall avoid exposing any part of the body to a primary X-ray beam
▪ No person shall allow the X-ray tube of an X-ray analysis unit to remain energized unless all warning lights, as required by this Code, are operating correctly.
▪ No X-ray tube shall be energized:
  – while outside its protective tube housing, or
  – with an unshielded aperture in the tube head or protective barrier.
▪ No sample, collimator, monochromator or analysing crystal shall be changed or adjusted while a primary X-ray beam passes through that collimator or is incident on that sample or crystal unless:
  – the sample, collimator, monochromator or crystal, during and after the change or adjustment, is within a shielded enclosure, and
  – the change or adjustment is done by remote means from outside the enclosure.
▪ Immediate measures shall be taken to remove potentially hazardous situations arising from X-ray beams that may be emitted due to equipment defect, misalignment or any other reason.
▪ A list of additional working rules shall be drawn up for each X-ray analysis unit where necessary to ensure safety. This is of particular importance for units which do not meet the requirements of the ARPANSA (1984) Code for enclosed or partly enclosed units.
▪ The necessary operations of the X-ray analysis equipment shall not be performed by inexperienced persons unless under direct supervision of an experienced operator.
▪ Alignments or adjustments shall not be carried out visually while the X-ray tube is energized, unless a viewing system is used which is shielded or designed to prevent exposure of the eye or other parts of the body to the primary beam.
▪ The X-ray analysis unit shall not be operated, by inactivation of an interlock or with part of its enclosure removed without prior approval of the statutory authority or unless the X-ray tube is wholly enclosed by the tube housing with all apertures completely covered by interlocked shutters and/or fixed covers.

26.10.2. Safety Guidelines for partially enclosed and Open Installations (NHMRC/ARPANSA)

For units that do not meet the requirements of enclosed apparatus then more stringent controls and requirements are to be implemented. Partly enclosed units which incorporate fixed shields and/or barriers shall be designed to give a clear and positive warning if the barriers or shields are incomplete. A clear and unambiguous notice shall also be displayed on or near the unit indicating the hazards of operating the unit while barriers or shields are incomplete.

Each partly enclosed unit shall satisfy the relevant requirements for enclosed units plus the following additional requirements:

▪ It shall be so constructed that it incorporates an enclosure or enclosures which partly enclose the primary X-ray beams sufficiently to ensure that no person may inadvertently expose any part of their body to a primary beam. The enclosure shall:
  i.) be interlocked, or fixed so as to require the use of tools for removal.
  ii.) incorporate collimator shields, and
  iii.) contain appropriate shielding material or be located at a sufficient distance from the X-ray tube that the dose of radiation at any accessible point five centimetres from the surface of each partial enclosure shall not exceed $25\mu\text{Gy}^{-1}$.
▪ It should be so sited that if for any reason a shutter is opened while an entrance to an enclosure is uncovered or barriers are incomplete, the resultant primary beam is directed away from areas that may be occupied. If such sitting is not possible, beam stops or fixed shields shall be placed to adequately protect persons in these areas from the beam.
▪ It should be sited in a separate room or cubicle in which there are no other radiation sources.
▪ It should be so constructed that all operations are most easily and quickly carried out with all shields in place and all interlocks in operation.
Working Rules for partly enclosed units

The working rules for each partly enclosed unit shall include those given for enclosed units. All working rules given in that section shall be implemented whether or not an interlock is inactivated or shielding structure is removed.

X-ray units not complying with the requirements for an enclosed unit

Each X-ray analysis unit which does not comply with (i.e. does not meet the requirements for an enclosed or partly enclosed unit) shall not be used until modified to meet those requirements, unless the user has prior approval of the statutory authority to do so for an interim period. When such approval is given a set of working rules approved by the statutory authority shall be drawn up for use pending the required modifications or replacement by a unit that complies. These working rules shall be designed to achieve the same standard of safety as the required modifications of the equipment, shall be prominently displayed on or near the X-ray analysis unit, and shall be rigorously implemented. The interim working rules shall include rules and requirements as follows:

- The rules required for partly enclosed units shall be included, and implemented whenever the unit is used.
- Supplementary interim rules shall be included to minimize the risk that any person will be exposed to a primary X-ray beam from the unit or otherwise receive a dose of radiation in excess of the recommended dose limit.
- A check-list of step-by-step procedures shall be prepared and used during the following operations:
  i.) before initiating an exposure
  ii.) during an exposure
  iii.) in terminating an exposure, and
  iv.) during any non-routine operation of the unit, such as alignment of an X-ray beam.
- The unit shall not be operated if any person other than those essential to its operation occupies the cubicle, room or area in which the unit is placed.
- No alteration should be made to the analysing equipment in use with the unit unless the X-ray tube is de-energized.
- Interim working rules shall include the requirements for siting given in the previous sections, with the requirement 'should' being replaced by 'shall'.
- The requirements of the following section (radiation monitoring) shall be incorporated in the working rules with the following amendments:
  i.) The requirement 'should' in personal monitoring shall be replaced by 'shall'.
  ii.) Periodical monitoring shall be performed not less than once in each month and the unit shall be thoroughly examined for hazards and all safety features checked at least once in each week. This requirement is the same as that for a partly enclosed unit.

26.11. Radiation Monitoring

Radiation monitoring is an essential aid in the control of radiation hazards in the vicinity of X-ray analysis units. However, the accurate measurement of radiation from these units is often difficult and a person seeking to do such measurement needs specialized equipment, careful technique, and an understanding of the principles involved. The performance of measurements following an accidental exposure of a person to a primary beam is important as a realistic assessment of the dose received is needed to assist in the prediction and treatment of radiation injury. However, radiation monitoring required during use of X-ray analysis units need not be as accurate. In this case simple measurements directed towards prevention of exposure to primary beams and reduction of leakage and scattered radiation to suitably low levels are adequate. The following rules should apply:

- Accurate measurements of radiation exposure or dose, or their rates, in primary, scattered or leakage beams should only be attempted by, or under the supervision of, a person competent to perform such measurements.
- Accurate measurements of leakage and scattered radiation should only be attempted if difficulty is encountered in ensuring the radiation levels are well below the requirements of legislation and guidelines.

26.11.1. Personal Monitoring

Localized personal monitors are usually inadequate indicators of exposure to the narrow beams of radiation which may be emitted from X-ray analysis units. However, personal monitors have been found useful in the discovery of some cases of exposure of persons to primary beams from X-ray analysis units and in the assessment of whole body dose due to exposure of leakage and scattered radiation from such units. The following requirements for personal monitoring are therefore recommended:
Each person working in the vicinity of X-ray analysis equipment should wear a suitable personal monitoring device on the chest throughout all exposures made with the unit.

Additional personal monitoring devices should be worn on a wrist or finger of all persons using X-ray analysis equipment, other than enclosed units except when an enclosed unit is operated with an interlock inactivated or part of an enclosure opened.

26.11.2. Monitoring of Equipment

The user of each X-ray analysis unit shall ensure that regular radiation monitoring of the unit is carried out to detect unintended radiation emissions and to assist in preventing such emissions. The following requirements shall apply to such radiation monitoring:

Each instrument used for dose rate monitoring shall comply with the following requirements:

- Its sensitivity shall be adequate to give a positive indication with a time response of not more than 20 seconds for a true dose rate of 10\(\mu\text{Gy h}^{-1}\) when measured in a field of radiation uniform over the sensitive volume of the detector and having an effective energy within the range of the unit.

- If provided with meter indication, the meter shall be either:
  1. calibrated in arbitrary units only, and the appropriate method of conversion from these units to exposure rate or dose rate for a radiation field uniform over the sensitive volume of the detector indicated on the instrument, or
  2. calibrated in units of exposure rate or dose rate, with a statement clearly displayed on the instrument that its calibration is correct only for a radiation field uniform over the sensitive volume of the detector.

- Each of these radiation surveys shall be conducted with the X-ray tube of the analysis unit operated at the maximum rated voltage and the maximum rated current for that voltage, and with no filtration in the primary beams other than the inherent filtration.

- Periodical radiation monitoring shall be carried out on each X-ray analysis unit that is operated on a regular basis. The frequency of monitoring should be not less than that given in the following schedule, but some variation of this schedule may be warranted with certain units or periods of use:

<table>
<thead>
<tr>
<th>Type of Unit</th>
<th>Frequency of Monitoring</th>
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<tbody>
<tr>
<td>Enclosed</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Partly Enclosed</td>
<td>Monthly</td>
</tr>
</tbody>
</table>

NOTE: These times are for infrequently used research units.

27. Legislation

In NSW the main legislative implement pertaining to radiation includes the following:

- NSW Radiation Control Act 1990 (and all subsequent amendments)
- NSW Radiation Control Regulations 2003 (and all subsequent amendments)

It is through these instruments that licensing, registration (specific “equipment”, premises, etc.), accreditation of experts, safety, inspections, and infringement prosecution are performed. If radiation is being considered for use in a project or experiment it would be wise to consult the legislation to ensure that all necessary requirements and limitations are incorporated into the project/experiment. Consultation and communication with University’s WHS Unit is a must.

It is also under this legislation that this manual is compiled, but it is not a required part of the institute’s legal commitments. This is due to the fact that the Director-General has not informed UOW in writing to compile and maintain a radiation safety manual. However, once there is a manual it is expected (legally) that all members of UOW comply with the requirements of the manual.

In terms of licensing, the individual and UOW (in that order) are responsible to ensure that licensing (and appropriate training) is obtained. It is the licenced person’s responsibility to ensure compliance with all relevant legislation, codes of practice, Australian Standards and any other material that may be deemed relevant.

Part of the licensing requirements and UOW’s responsibility is to ensure that no radiation work is conducted other than in registered premises (where appropriate and relevant). The premises will be registered as Low, Medium or High Radiation Facility (see chapter 9), and the activity allowed in such a premise is now limited up to a maximum. That may mean that the work could be required to be done in another location so as to
meet the restrictions of the registration, or the facility may need to be re-registered as a different classification – this will cost and UOW may deem that the cost will be the responsibility of the individual or Unit.

Unfortunately not all aspects of radiation safety and radiation use are controlled by this legislation. Waste disposal (see Chapter 13), for instance, is controlled by the following:

- NSW Waste Avoidance and Recovery Act 2001;
- NSW Protection of the Environment Operations Act 1997 including:
  - Waste Guidelines: Waste Classification and Management of Liquid and Non-liquid Wastes;
- NSW Environmentally Hazardous Chemicals Act 1985;
- Federal AQIS Requirements.

Transport is controlled by:

- NSW Transport of Dangerous Goods (Road and Rail Transport) Act 2008, but mainly by

Thus it important that the user is familiar with the legislation, its restrictions, limitations and requirements.

28. Related Documents

- Radiation Approval Form
- Licence Exemption Notification
- Radioactive Waste Disposal Guidelines (includes Radioactive Waste Label)
- Safe Work Procedures Guidelines
- Emergency Management Procedures
- Radiation Control Regulation 2003
- NSW Radiation Control Act 1990
- EPA Environmental Guidelines: Assessment, Classification & Management of Liquid & Non-liquid Wastes
- Recommendations for Limiting Exposure to Ionising Radiation
- Code of Practice for the Safe Transport of Radioactive Material
- Code of Practice for Protection Against Ionising Radiation Emitted From X-ray Analysis Equipment

29. References

29.1. Legislation

- NSW WHS Act 2011
- NSW WHS Regulation 2011
- NSW Radiation Control Act 1990 (and all subsequent amendments)
- NSW Radiation Control Regulation 2003 (and all subsequent amendments)
- NSW Protection of the Environment Operations (Waste) Regulation 2005
- NSW Waste Avoidance and Recovery Act 2001
- NSW Environmentally Hazardous Chemicals Act 1985
- NSW Transport of Dangerous Goods (Road and Rail Transport) Act 2008

29.2. Codes of Practice

- ARPANSA RPS 1: Recommendations for Limiting Exposure to Ionising Radiation (Printed 1995 - Republished 2002) and National Standard for Limiting Occupational Exposure to Ionising Radiation (Printed 1995 - Republished 2002);
- ARPANSA RPS 2: Code of Practice for the Safe Transport of Radioactive Material (2008);
- ARPANSA RPS 5: Code of Practice and Safety Guide for Portable Density/Moisture Gauges Containing Radioactive Sources (2004);
- NHMRC (now by ARPANSA) RHS No.9: Code of practice for protection against ionising radiation emitted from X-ray analysis equipment (1984);
- NHMRC (now by ARPANSA) RHS No.13: Code of practice for the disposal of radioactive wastes by the user (1985);
- NHMRC (now by ARPANSA) RHS No.21: Revised statement on cabinet X-ray equipment for
examination of letters, packages, baggage, freight and other articles for security, quality control and other purposes (1987);

- NHMRC (now by ARPANSA) RHS No.22: Statement on enclosed X-ray equipment for special applications (1987);
- NHMRC (now by ARPANSA) RHS No.24: Code of practice for the design and safe operation of non-medical irradiation facilities (1988);
- NHMRC (now by ARPANSA) RHS No.28: Code of practice for the safe use of sealed radioactive sources in bore-hole logging (1989);
- NHMRC (now by ARPANSA) RHS No.31: Code of practice for the safe use of industrial radiography equipment (1989);
- ARPANSA RPS No.7: Recommendations for Intervention in Emergency Situations Involving Radiation Exposure (2004);
- NHMRC (now by ARPANSA) RHS No.38: Recommended limits on radioactive contamination on surfaces in laboratories (1995).

29.3. Australian Standards

- AS/NZS 2982:2010 Laboratory Design and Construction
- AS/NZS 2243.1:2005 Safety in laboratories - Planning and operational aspects
- AS/NZS 2243.4:1998 Safety in Laboratories - Ionising radiations
- AS/NZS 2243.5:2004 Safety in Laboratories - Non-ionising radiations – Electromagnetic, sound and ultrasound

29.4. Other

- Wrixon, A.D., Barraclough, I., and Clark, M.J., “Radiation, people and the environment”. IAEA, Vienna, 2004
### 30. Version Control Table

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