

UWS Radiation Safety Guidelines

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FOREWORD

These guidelines are intended as a guide for staff and students involved, either directly or indirectly, with the use of ionising radiation or radioactive material in teaching and/or research.

The guidelines contain procedures and information for specific applications and provide general information about reducing the risks associated with work involving the use of radioactive substances and sources.

Detailed information about radiation, radioactive substances and sources can be obtained from the Occupational Health, Safety & Risk Management Unit (OHSRU) or the Radiation Safety Officer (RSO).

It is a requirement of the University that any work or activity requiring the acquisition, storage and use of radioactive substances or the operation of irradiating apparatus, be approved by the UWS Institutional Biosafety and Radiation Safety Committee (IBRSC).

Whereas the New South Wales Occupational Health and Safety Act 2000 imposes legal obligations on employers and other parties in the interests of ensuring health and safety in workplaces, the Radiation Control Act (1990) and the Radiation Control Regulations (1993) (and all subsequent amendments) specify that a licence holder is ultimately responsible for ensuring safe radiation work practices are strictly adhered to at all times. This does not absolve the employer of responsibility.

The Regulations also stipulate that no person can dispose of any radioactive substances (having an activity as defined by the Regulations) except with the consent of the Director General of the Environmental Protection Authority.

However, the *NSW Waste Avoidance and Resource Recovery Act 2001* Guidelines “Environmental Guidelines: Assessment Classification and Management of Liquid and Non-Liquid Wastes” has precedence over the Radiation Legislation, and as such the responsibility for disposal remains with the licence holder to ensure that radioactive substances complies with and meets all legal requirements of the referred guideline.

These guidelines are intended as a “stand alone” document so that a section(s) can be read independently of other sections. This means that in some cases information contained in one section may be repeated in another to avoid the need to refer to another section(s) of the guidelines.

Comments and feedback regarding the content and scope of these guidelines are welcome and should be forwarded to the Occupational Health, Safety & Risk Management Unit (OHSRU).

1 LEGISLATION

In NSW the main legislative implement for all work involving radiation is the following:

NSW Radiation Control Act 1990 (and all subsequent amendments)
NSW Radiation Control Regulations 1993 (and all subsequent amendments)

It is through these instruments that licencing, 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 the University’s RSO/IBRSC and/or OHS&R Unit is a must.

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

In terms of licencing, the individual and the University (in that order) are responsible for ensuring that licencing (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 licencing requirements and the University’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 (refer to ‘Laboratory Classification, Requirements and Registration’ Section 9), and the activity allowed in such a premise has a defined maximum limit on the level of radiation. 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 comes with a cost and the University may deem that the cost will be the responsibility of the individual or Department.

Unfortunately not all aspects of radiation safety and radiation use are controlled by this legislation. Waste disposal (refer to Section 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

And transport is controlled by:

- NSW Transport of Dangerous Goods (Road and Rail) Act 1998, but mainly by
- ARPANSA RPS 2 Radioactive Materials Transport Code.

It is therefore important that the user is familiar with the legislation, its restrictions, limitations and requirements.

Standards and Codes of Practice

In Australia, there are Standards compiled and published by Standards Australia relating to radiation laboratories. The most relevant standards are:

- **AS2982.1 Laboratory Design and Construction: Part 1 General. 1997**
- **AS2243.4 Safety in the Laboratory: Part 4 Ionizing Radiation. 1998**

As well as for laboratories in general

- **AS2243.(1-10) Safety in the Laboratory Series**

Currently these Standards are not referred to or called up in the NSW Legislation, however, as part of licence conditions, there is a clause requiring compliance with the requirements of AS2243.4 and any other relevant documents.

The following two Guidelines are specifically referred to in current NSW legislation:

- **NSW Radiation Series No. 5 - Recommendations for Radiation Safety Officers and Radiation Safety Committees**
- **Radiation Guideline 6 - Registration requirements & industry best practice for ionising radiation apparatus used in diagnostic imaging**

There are many codes of practices and recommendations, both national and international, the latter being publications by The ICRP and IAEA. The former are from Australian Radiation Protection and Nuclear Science Agency (ARPANSA) and formerly from the NHMRC. The list is as follows, and most publications (ARPANSA & NHMRC) can be downloaded from <http://www.arpansa.gov.au/pubs/>:

ARPANSA

- **RPS 1.** Recommendations for Limiting Exposure to Ionizing Radiation (Printed 1995 - Republished 2002) and National Standard for Limiting Occupational Exposure to Ionizing Radiation (Printed 1995 - Republished 2002)
- **RPS 2.** Code of Practice for the Safe Transport of Radioactive Material (2001)
- **RPS 3.** Radiation Protection Standard - Maximum exposure levels to radiofrequency fields - 3kHz to 300GHz
- **RPS 4.** Recommendations for the Discharge of Patients Undergoing Treatment with Radioactive Substances
- **RPS 5.** Code of Practice and Safety Guide for Portable Density/Moisture Gauges Containing Radioactive Sources (2004)

NHMRC [most relevant publications] (these are being revised and replaced by ARPANSA)

- No 2. Code of practice for the design of laboratories using radioactive substances for medical purposes (1980)
- No 3 Code of practice for the safe use of ionizing radiation in veterinary radiology: Parts 1 and 2 (1982)
- No 4 Code of practice for the safe use of radiation gauges (1982)
- No 8 Code of nursing practice for staff exposed to ionizing radiation (1984)
- No 9 Code of practice for protection against ionizing radiation emitted from X-ray analysis equipment (1984)
- No 10 Code of practice for safe use of ionizing radiation in veterinary radiology: part 3 - radiotherapy (1984)
- No 13 Code of practice for the disposal of radioactive wastes by the user (1985)
- No 18 Code of practice for the safe handling of corpses containing radioactive materials (1986)
- 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)
- No 22 Statement on enclosed X-ray equipment for special applications (1987)
- No 24 Code of practice for the design and safe operation of non-medical irradiation facilities (1988)
- No 28 Code of practice for the safe use of sealed radioactive sources in bore-hole logging (1989)
- No 29 Occupational standard for exposure to ultraviolet radiation (1989)
- No 31 Code of practice for the safe use of industrial radiography equipment (1989)
- No 32 Intervention in emergency situations involving radiation exposure (1990)
- No 38 Recommended limits on radioactive contamination on surfaces in laboratories (1995)

2 RADIATION SAFETY RESPONSIBILITIES & PROCEDURES

2.1 University Radiation Safety Statement & Responsibilities

The University of Western Sydney uses ionizing radiation apparatus, radioactive substances and ionizing equipment on its campuses to enhance research and learning outcomes for its students.

The University 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 that does not breach the legal requirements of the New South Wales Radiation Control Act 1990 and Radiation Control Regulations 1993 (and all subsequent amendments).

Risks⁽¹⁾ will be assessed, documented and exposure doses maintained ALARA (as low as reasonably achievable) for the acquisition, storage and use of radioactive substances or the operation of irradiating apparatus.

The UWS Institutional Biosafety and Radiation Safety Committee (IBSRC) will be adequately resourced to enable the Committee to effectively monitor research and teaching proposals involving the use of radioactive substances or any irradiating apparatus.

All Licence Holders will ensure that their licences remain current and all radioactive substances or radiation apparatus under their control are acquired, stored, used, transported and disposed of in accordance with statutory requirements and the requirements of the University.

All managers will be accountable for ensuring that the use of ionising radiation or radioactive material used in teaching and/or research complies with all of the relevant safety requirements spelled out in the University's Radiation Safety Guidelines.

The University will provide training, information and advice on radiation safety to any person who may be required to visit, work or learn near or around radioactive substances or operational irradiating apparatus.

Every person who visits, works or learns in the University is expected to comply with all radiation safety instructions that may be given by the University (or persons of authority for the University), licence holders, academics and/or technical staff responsible for the safe the acquisition, storage and use of radioactive substances or the operation of irradiating apparatus within laboratories or other facilities.

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 the safety requirements and the emergency management plan.

{1} Under Radiation Safety, Risk Assessment is deemed as being an assessment of the protections and controls (rather than the actual risk which is often very difficult to determine) that are in place or are required to be utilised as is stated under the current legislation, Australian standards, Codes of Practice, Guidelines, and International Recommendations.

2.1.1 Specific Responsibilities:

The University

- Ensuring effective radiation safety management plans and protocols are developed, implemented and continually monitored to ensure that the use of ionising radiation or radioactive material for teaching and/or research purposes can be undertaken in a manner that meets statutory compliance and ensures the health, safety and welfare of persons;
- That safe systems of work are developed, implemented and monitored by management for all work involving the acquisition, storage and use of radio active substances or the operation of irradiating apparatus;
- That the UWS Institutional Biosafety and Radiation Safety Committee (IBSRC) is adequately resourced to enable the Committee undertake its function effectively;
- That training, information and advice on radiation safety is to be provided to any person who may be required to visit, work or learn near or around concentrations of radioactive substances or operational irradiating apparatus;
- That an appropriate radiation emergency management plan is developed, implemented and regularly reviewed.

Vice-Chancellor

The Vice-Chancellor has overall accountability for the safety of all activities conducted by the University and will provide adequate resources and organisation to meet the aims and objectives contained in the Occupational Health and Safety policy. The Vice-Chancellor is empowered to enforce such actions as are considered necessary to protect the occupational health and safety of employees, students, contractors and other individuals, the environment and University premises and plant.

UWS Institutional Biosafety and Radiation Safety Committee (IBSRC)

The IBSRC is responsible for:

- Monitoring research and teaching proposals involving the use of micro-organisms of Risk group 2 or higher, whole micro-organisms, in vivo use of imported biological products, specimens of human origin (including blood products), recombinant DNA and ionising radiation sources;
- Monitoring the effectiveness of the University's radiation safety management program;
- Assisting in the formulation of radiation safety protocols;
- Assisting in the investigation of radiation incidents/accidents.

Occupational Health, Safety and Risk Unit (OHSRU)

The Unit is responsible for assisting Colleges and Schools to:

- meet legal compliance;
- implement the University's Radiation Safety Procedures;
- co ordinate the investigation, reporting and follow up of any incident/accident that involves a breach of legislation, a failure to comply with the Guidelines and/or any radiation accident;
- implement sound Radiation Safety Management Principles;
- ensure the provision of EPA approved appropriate radiation safety training;
- follow the University's procedures for resolving Radiation Safety related issues and disputes.

Deans of Colleges and Heads of School

As senior managers Deans and Heads of School are accountable for ensuring that the use of ionising radiation or radioactive material used in teaching and/or research complies with the occupational health and safety standards and practices spelled out in the University's Radiation Safety Guidelines.

To achieve compliance with the Guidelines, Deans of Colleges and Heads of School must ensure that:

- Academics with Course, Unit and/or Local Unit coordination, and/or Teaching responsibilities, Researchers and/or Research Supervisors and Technical Managers have resources to develop, implement and monitor the strategies, systems and procedures necessary to ensure that the requirements of the University's Radiation Safety Guidelines can be fully implemented;
- No radiation work is carried out within any College or School unless the work has been approved by the UWS Institutional Biosafety and Radiation Safety Committee (IBSRC);
- Any person working with ionizing radiation holds the appropriate licence(s) and the licence(s) are current;
- Academics, Researchers and Technical Managers within Schools fully implement the requirements of the University's Radiation Safety Guidelines in areas under their control and monitor compliance;
- Staff and students receive the appropriate information, instruction and training necessary for them to learn and work in accordance with the requirements of the University's Radiation Safety Guidelines;
- Any behaviour on the part of any person that amounts to a failure to comply with these Requirements is dealt with in accordance with University's disciplinary policies and procedures;
- Any student working with ionizing radiation, exempted from licensing requirements is appropriately supervise;
- Waste is disposed of in accordance with the Legal Requirements and in compliance with the method(s) outlined in the Radiation Safety Guidelines.

Academics and Researchers

Academics (with teaching and/or research responsibilities) and Researchers who develop, supervise or conduct work that involves the use of ionising radiation or radioactive material for teaching and/or research purposes are required to ensure that:

- they carry out a risk assessment (see previous footnote) in conjunction with the design, development and implementation of any radiation work that is included as of the part of the learning;
- their chosen method(s) of achieving the research and learning outcomes do not lead to a contravention of the requirements of the University's Radiation Safety Guidelines;
- radioactive hazardous wastes, apparatus and materials are managed in accordance with the legislative requirements, and the requirements of the University's Radiation Safety Guidelines;
- all radiation incidents, hazards and 'near miss' incidents are reported using the UWS Report of Radiation Accident/Incident Form (RSO Form 9), and that the Radiation Safety Officer (RSO) and/or the OHSRU is notified immediately;
- students have received an appropriate level of radiation safety training to enable them to undertake their learning safely;
- students are formally advised that failure to comply with the requirements of the University's Radiation Safety Guidelines may result in disciplinary action being taken by the University;
- students have access to and wear the personal protective equipment required to undertake the radiation work safely ;
- students are formally advised that unauthorised radiation experimentation work is strictly forbidden;
- students are formally advised that they are required to take personal responsibility for ensuring their own safety and the safety of others.

Technical Managers

Technical Managers are required to ensure that:

- effective strategies, systems and procedures are developed, implemented and monitored to ensure that work and learning in laboratories is undertaken strictly in accordance with the requirements of the University's Radiation Safety Guidelines;
- proper records are maintained to comply with legislation and EPA guidelines;
- risk assessments (see previous footnote) are conducted, documented and maintained for the acquisition, storage and use of radio active substances or the operation of irradiating apparatus in the laboratories or facilities they supervise;
- the Technical Staff they supervise (provided all licensing requirements are fully met) are fully conversant with the requirements of the University's Radiation Safety Guidelines and understand their role in monitoring compliance;
- a failure on the part of any person to comply with the requirements of the University's Radiation Safety Guidelines is reported to the Dean and/or Head of School as the case may be, with a copy of the report being sent to the RSO and/or the OHSRU;

Section 2 – Radiation Safety Responsibilities & Procedures

- work relating to the (re)design, modification, repair and/or upkeep of a laboratory, associated facilities, premises and/or apparatus is undertaken in co-operation with the RSO/IBRSC in a manner that does not compromise the safety of person(s) or property or contravene the requirements of the University's Radiation Safety Guidelines;
- appropriate radiation emergency management plans are developed, implemented and regularly reviewed;
- staff and students are trained in what action(s) they must take should an emergency arise;
- staff and students have access to and wear the appropriate personal protective equipment whilst working with, near or around radioactive substances or the operation of irradiating apparatus;
- radioactive hazardous wastes, apparatus and materials are managed in accordance with the legislative requirements, and the requirements of the University's Radiation Safety Guidelines;

Technical Staff

Technical Staff (provided all licensing requirements are fulfilled) are required to:

- become fully conversant with the requirements of the University's Radiation Safety Guidelines and monitoring compliance within their work area(s);
- report instances of non compliance to the Technical Manager, with a copy going to the RSO/OHSRU;
- establish, monitor and maintain appropriate levels of hygiene and housekeeping for any work involving radioactive substances or the operation of irradiating apparatus;
- assist academics and/or researchers to implement any risk control measures outlined in course/unit or research risk assessments involving the use of ionising radiation or radioactive material for teaching and/or research purposes;
- in consultation with the Technical Manager conduct risk assessments (see previous footnote) on any radiation work that they perform in the laboratory or associated facility (e.g. equipment setup, practical class preparation, etc);
- regularly check, test and document the serviceability of any emergency equipment not under the control of Capital Works & Facilities;
- ensure radioactive hazardous wastes, apparatus and materials are managed in accordance with the legislative requirements, and the requirements of the University's Radiation Safety Guidelines;
- clean, prepare, isolate laboratory equipment prior to approval by RSO (Letter of Clearance) for handover to maintenance personnel to ensure that the maintenance work can be carried out safely by a person(s) other than an *Occupationally Exposed Person*;
- monitor the serviceability of fixtures, portable equipment and apparatus and facilitate repair and/or replacement as required (with advice from the RSO/OHSRU);
- ensure all radiation safety equipment (fixed and portable) remains in a serviceable condition;
- remain abreast of any legislative or industry changes that may materially affect health and safety management;

Section 2 – Radiation Safety Responsibilities & Procedures

- prominently display and maintain emergency management information in each laboratory/facility including the telephone numbers of:
 1. RSO and OHSRU
 2. Fire brigade;
 3. Ambulance
 4. Campus Security;
 5. Hospital;
 6. Police.

Licence Holders

Are ultimately responsible for all of the above, as well as:

- The safe acquisition, storage, use, transport and disposal of all radioactive substances or radiation apparatus that is under their control;
- Ensuring their licences remain current;
- Ensuring their licence conditions include, where appropriate, Authorization to Grant Exemptions to students who meet the requirements of the NSW Radiation Control Act, 1990 and Regulations 1993 (and subsequent amendments);
- Ensuring their licence conditions include, where appropriate, Authorization to Supervise students.

University Staff and Students

Every member of Staff and/or Student who may for any reason need to work or learn near or around prescribed concentrations of radioactive substances or the operation of irradiating apparatus will at all times

- Ensure that their actions do not increase the risk of injury to themselves or others;
- Comply with all radiation safety instructions that may be given by licence holders. academics and/or technical staff responsible for the safe acquisition, storage and use of radioactive substances or the operation of irradiating apparatus in the laboratories or facilities;
- Utilise any safety devices and personal protective equipment in a manner that reduces the risk of injury and/or radiation exposure above prescribed statutory limits;
- Maintain the dress standards appropriate for the work area;
- Ensure there is no consumption or storage of food and/or drink in any laboratories or facilities;
- Adhere to the emergency and evacuation procedures should an emergency arise.

2.2 Consultation

Consultation between the University and Occupationally Exposed Persons is an essential part of effectively managing Radiation Safety in the workplace. The University will consult with employees 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. Employee involvement at all levels is critical for ensuring a safe workplace.

The University will ensure:

- the sharing of relevant information about Radiation Safety with employees;
- that employees be given the opportunity to express their views and to contribute in a timely fashion to the resolution of Radiation Safety issues at the workplace; and
- that the views of employees are valued and taken into account.

2.3 Radiation Safety and Administrative Procedures

Under current Radiation and OHS legislation it is the responsibility of the University to ensure radiation safety training and documentation relating to radiation safety compliance is provided. As such the University of Western Sydney 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. In conjunction with this is the requirement to ensure that all relevant documentation, and 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 staff/student records.

To this end, the following procedures are to be adopted by all University of Western Sydney staff, students and visitors:

- 1. Procedures for Obtaining or Renewing Radiation Licences**
- 2. Licence Exemption Procedures**
- 3. Procedures for Purchasing / Obtaining Radioactive Substances**
- 4. Procedures for Purchasing / Obtaining Irradiating Apparatus**
- 5. Procedure for Completion of Registers of Licence Holders / Radioactive Substances/Irradiating Apparatus**
- 6. Procedures for Notification of Disposal of Radioactive Substances**
- 7. Procedures for Personal Monitoring**
- 8. Procedures for Inspection of Radiation Usage / Storage Sites**
- 9. Procedures for Radiation Accident, Incident and Emergency Response**
- 10. Proposal for a Biological and/or Radiation Research or Teaching Project**

2.3.1 Procedures for Obtaining or Renewing Radiation Licences

The Radiation Control Act (NSW) 1990 requires that all persons using radioactive substances or ionising irradiating apparatus, as defined under the Act, must hold a Licence suitable for that use.

For Student Exemptions, see ‘Licence Exemption Procedures’ in this section.

For existing licences refer to [Procedure for Completion of Registers of Licence Holders](#) and complete the requirements.

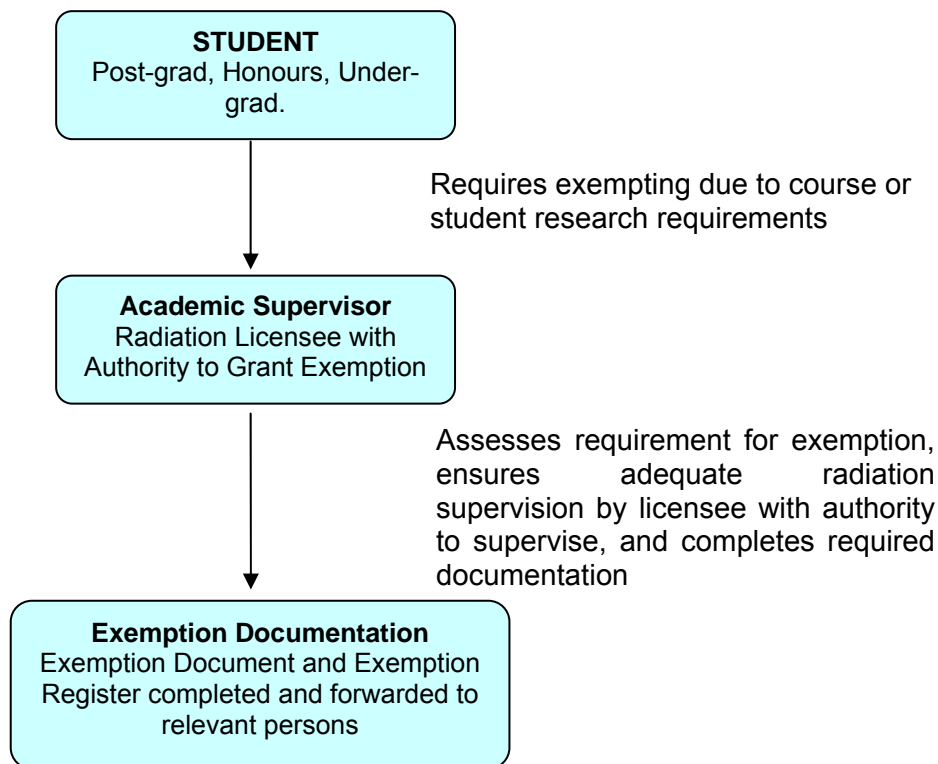
To obtain a Licence, the applicant must:

- obtain the EPA application form from the RSO/OHSRU or the EPA website below: <http://www.environment.nsw.gov.au/radiation/licensing/licenceuse.htm>
- ensure they meet the requirements of training / education / experience (note that training refers to radiation safety training as provided by an EPA approved person).
- undertake appropriate training/course(s) to meet above requirements,
- complete EPA application form (all units used on the form must be in S.I. UNITS).
- forward application form/qualifications to the RSO via the OHSRU for approval.
- on receiving approval from RSO, forward application/qualification (send only photocopies of any degrees, certificates or extracts) to EPA with licence fee.
- on receiving the Licence from the EPA, forward a copy to the OHSRU.

On renewal of the Licence, the Licencee must:

- forward application for renewal to EPA with licence fee.
- on receiving the renewed Licence, forward a copy of the Licence to the OHSRU.

2.3.2 Licence Exemption Procedures



For an Exemption to be granted the following needs to be ensured:

- ONLY STUDENTS, as deemed under Part 2, Clause 8 of the Radiation Control Act (1990), may be granted an exemption by an appropriate licensee
- The exemption must be in writing using **Form RSO 1** (obtain a copy from Appendix A -1)
- The exemption document must specify the radioactive substances or irradiating apparatus
- The exemption must set out the conditions to which the exemption is subject (viz., the class or course, the designated radiation area (DRA) or laboratory in which the work must be done, the times during which the work is allowed, etc)
- The exemption must identify each person, or class of persons, to whom it relates
- The exemption must identify the appropriately licensed person or persons who are to supervise each person, or class of persons, to whom it relates
- The exempting licensee must ensure that a copy of the exemption:
 - ⇒ is given to each person to whom it relates,
 - ⇒ is conspicuously displayed at each place in which the radioactive substances or irradiating apparatus to which the exemption relates are proposed to be used, and
 - ⇒ a copy is kept for the local records(School/Centre level)
- That the University Register of Exemptions is completed using **Form RSO 2** (obtain a copy from Appendix A-2), the original forwarded to the OHSRU for central records and a copy kept by the School/Centre.
- Exemptions must be reviewed/renewed annually.

2.3.3 Procedures for Purchasing / Obtaining Radioactive Substances

Prior to acquiring any radioactive substance, as defined under the Radiation Control Act (NSW) 1990, approval must be obtained from the IBRSC in the first instance (i.e. in the original IBRSC proposal form to undertake work with radioactive substances). Approval must then be sought from the RSO/OHSRU for each acquisition. This includes the purchase of radioactive substances or any other means of acquiring the substance, such as through loans from other institutions.

To obtain approval for radioactive substances:

- obtain a copy of Form **RSO 3, Application to Purchase/Acquire Radioactive Substances**. This can be found as Appendix A - 3.
- complete and forward Form **RSO 3** to the RSO/OHSRU for approval. An IBRSC Approval Number from the original proposal submitted and approved by the IBRSC, must be clearly noted.
- after approval for purchase has been obtained, keep a copy for School/Centre files.
- if the radioactive substance is being acquired from another source, provide copy of RSO and/or IBRSC approval to relevant institution.

For isotopes that are already located and used at the University please refer to the 'Procedure for Completion of Registers of Licence Holders / Radioactive Substances / Irradiating Apparatus' and complete the requirements detailed therein.

2.3.4 Procedures for Purchasing / Obtaining Irradiating Apparatus

Prior to acquiring any irradiating apparatus, as defined under the Radiation Control Act (NSW) 1990, for use by UWS personnel, approval must be obtained from the IBRSC in the first instance (i.e. in the original IBRSC proposal to undertake work with irradiating apparatus). Approval must then be sought from the RSO/OHSRU for acquisition. This includes the purchase of irradiating apparatus or any other means of acquiring the apparatus, such as through loans from other institutions.

To obtain approval for purchasing / obtaining irradiating apparatus:

- obtain a copy of Form **RSO 4, Application to Purchase / Acquire Irradiating Apparatus**. This can be found as Appendix A - 4
- complete and forward Form **RSO 4** to the RSO/OHSRU together with a copy of the UWS Purchase and Service Requisition (PSR) form
- after approval has been obtained, if purchasing irradiating apparatus, keep a copy for School/Centre files before proceeding with the purchase in accordance with UWS Purchasing Procedures and Procurement Procedures and Tender Board Policy.
- **if irradiating apparatus is being acquired from another source, provide copy of approval to relevant institution.**

For equipment that is already located and used at the University please refer to the 'Procedure for Completion of Registers of Licence Holders / Radioactive Substances / Irradiating Apparatus' and complete the requirements detailed therein.

2.3.5 Procedure for Completion of Registers of Licence Holders / Radioactive Substances/ Irradiating Apparatus

The RSO/OHSRU and the IBRSC are responsible for maintaining a Register of all Licence Holders, Radioactive Substances and Irradiating Apparatus that are used or stored within the University of Western Sydney.

The procedures defined below in this document will initiate an entry in the Register.

The Register will maintain its currency by the following:

- the RSO/OHSRU will distribute the forms listed below to all Schools, Departments and Centres in the University on a **biannual** basis and forward a copy of updated Registers to the IBRSC:
 - ⇒ Register of Licence Holders **Form RSO 5**, (Appendix A - 5),
 - ⇒ Register of Irradiating Apparatus **Form RSO 6**, (Appendix A - 6)
 - ⇒ Register of Radioactive Substances, **Form RSO 7**, (Appendix A - 7)
- generating reports from the Register for cross reference with completed Forms.
- generating reports from the Register for expired Licence Holders.
- cross referencing data obtained from RSO or an external radiation expert who has conducted site inspections of radioactive substance or irradiating apparatus sites.
- cross referencing data obtained from School's / Centre's records of their personal dose monitoring of staff / students for exposure to ionising radiation.

2.3.6 Procedures for Notification of Disposal of Radioactive Substances and Waste

The University of Western Sydney has ultimate responsibility for the disposal of radioactive substances used on its premises. However, it is the responsibility of the licence (radiation) holder to ensure the safe disposal of all radioactive substances under their control.

Safe disposal methods will vary for individual substances, and whilst these guidelines document an overview of disposal methods, correct disposal information should be sought from the following:

- Supplier of radioactive substance
- EPA Guidelines “Environment Guidelines: Assessment Classification and Management of Liquid and Non-Liquid Wastes”
- Protection of the Environment Operations (Waste) Regulation 2005
- Environmentally Hazardous Chemicals Act 1985 and Regulation
- University RSO or IBRSC

For more information refer to Radioactive Waste Disposal (Section 13).

Disposal of a radioactive substance may include the decay of the substance to below its reportable level prior to disposal as a non-radioactive waste, or the transfer of the substance to someone external to the University. Full documentation of disposal needs to be completed and retained by the University for its Records.

Disposal of radioactive material cannot occur unless the material is assessed by the RSO and the paperwork is duly signed off by the RSO (this does not relieve the licensee of responsibility).

On final disposal of a radioactive substance (e.g. at completion of work or when substance is no longer required) the Licence Holder must:

- complete the Notification of Disposal section of the original **Form RSO 3**.
- complete **Form RSO 8**.
- Retain a copy of this completed form for School/Centre records, and send the original to the RSO/OHSRU for central records.
- Records must be kept for a period of at least 5 years (consult the RSO for specific details).

2.3.7 Procedures for Documentation of Personal Monitoring

The personal monitoring of individuals who may be exposed to radiation during the course of their work or learning at the University of Western Sydney, as prescribed by the Radiation Control Act (NSW) 1990, is the responsibility of the School/Centre where the radiation work is to be conducted.

The RSO/OHSRU will maintain central records of all personal (staff and student) monitoring at the University.

Schools and Centres with staff and post-graduate students who are required to be monitored must forward a copy of records of monitoring to the OHSRU and keep the originals in local area files.

Schools and Centres are also required to inform the RSO/OHSRU when the monitored individual(s) are leaving the University. The RSO/OHSRU will then generate a dosimetry report and forward it to the monitored individual(s) on their leaving or graduating from the University.

Records of personal monitoring must also be given to any future employer employing the monitored individual as a radiation worker.

The RSO/OHSRU requires a copy of the records of dosimetry readings for staff and students for any or all monitoring periods together with the latest 'total accumulated dosimetry' readings. These records are to be forwarded to the OHSRU immediately after receipt by the School/Centre (for the purpose of investigation if warranted and central records).

For information on the records that are required to be kept for personal monitoring refer to 'Records of Personal Monitoring' (Section 6).

2.3.8 Procedures for Inspection of Radiation Usage / Storage Sites

The IBRSC/RSO will conduct formal site inspections on an annual basis of all sites within the University of Western Sydney that use or store radioactive substances or irradiating apparatus.

The resultant report from such a site inspection will:

- ensure the University of Western Sydney complies with the Radiation Control Act (NSW) 1990 and Regulations (1993) and all subsequent amendments.
- provide data to ensure the Register of radioactive substances and irradiating apparatus is accurate.

The IBRSC/RSO will also conduct ad hoc site inspections, as the Office deems necessary, of all or any sites within the University that use or store radioactive substances or irradiating apparatus.

Such inspections will assist in ensuring:

- compliance with the Radiation Control Act (NSW) 1990 and Regulation.
- the safe use and storage of radioactive substances or irradiating apparatus.
- accuracy of the Register of radioactive substances and irradiating apparatus is current.

Appendix A - 12 — Radiation Safety Checklist may be used by designated University Occupationally Exposed Persons to assess their facilities and safety procedures. It is expected that the results will be better than EPA expectations.

Note: It is essential that ‘Workplace Monitoring’ (Section 6), and ‘Monitoring and Quality Assurance’ (Section 11) is consulted for the mandatory requirements.

2.3.9 Procedures for Radiation Accident, Incident, Emergency Response and Spills

IN ANY SITUATION WHERE THERE IS UNCERTAINTY OF RESPONSE OR ACTION REQUIRED OR THE LEVEL OF RADIATION EXCEEDS MINOR LEVELS OF DEFINED ACTIVITY THEN THE RSO MUST BE CONTACTED.

THESE PROCEDURES MUST BE PROMINENTLY DISPLAYED IN THE LABORATORY OR DESIGNATED RADIATION AREA (DRA).

Scope

The following emergency procedures apply to all laboratories and other areas where radioactive materials or ionizing equipment are used by the University of Western Sydney personnel and apply to all staff, students and visitors.

This is in addition to the OHS requirements on reporting of accidents/incidents.

Definitions

Accident or Incident: An accident or incident is defined as any uncontrolled or non-approved release of radioactive material into the environment, or, contamination/exposure of personnel.

Major Spillage: A major spill is legally defined as a spillage equal to or greater than that level listed for the radioactive substance in Schedule 1 of the Radiation Control Act (1990) and Regulation (1993) if wet, and 1/10 of this level if a dry powder and any release of a gaseous or volatile radioactive substance.

Minor Spillage: A minor spill is defined as any spillage where the activity is less than that of a major spill and only a small radiation or contamination hazard to personnel exists.

Note: See TABLE 1 'PROPERTIES AND SPILL CRITERIA OF SOME COMMONLY USED RADIONUCLIDES' (In Spill Procedures section).

Reporting of Accident and Incidents

All radiation workers shall ensure that accidents, incidents and emergencies involving ionizing radiation are reported, either directly or indirectly through their supervisor, to the Radiation Safety Officer/OHSR Unit.

In the event of a minor spillage the report, using **Form RSO 9** (Appendix A - 9), should be made after the spill has been cleaned up and the area decontaminated. The report should include the location of the incident, the isotope involved and its chemical form and the activity spill.

In the event of a major spillage or where personnel have been contaminated the incident must be reported immediately to one of the emergency response numbers listed below. This immediate report can then be followed up within 24 hours using **Form RSO 9**.

All accidents involving radiation exposure to staff, students or visitors must be reported to the OHRSU immediately, and then followed up with a UWS Accident/Injury/Incident/Hazard

Notification Form in addition to the radiation accident form.

Emergency Response Contact Numbers

RSO - Bill Bartolo:	0427287630	OHSR Unit:	9685 9930/9959 or 9852 5178
UWS Security:	Ext 2300	BRSC Member (Campbelltown)	
IBRSC Member (Parramatta)		BRSC Member (Hawkesbury)	

**Table 1
Properties and Spill Criteria of Some Commonly Used Radionuclides**

Nuclide	Radio-toxicity group	Half-life	Max. energy of main beta ray MeV	Main gamma ray energy MeV	Minor wet spill MBq	Major wet spill MBq
H-3	4	12.3y	0.018		<40	=or>40
C-14	4	5730y	0.156		<4	=or>4
P-32	3	14.3d	1.700		<0.4	=or>0.4
P-33	3	25.4d	0.249		<4	=or>4
S-35	3	87d	0.167		<0.4	=or>0.4
Ca-45	2	163d	0.260		<0.4	=or>0.4
Mo-99	3	2.8d	1.210	0.740	<4	=or>4
Tc-99m	4	6h		0.140	<40	=or>40
I-125	2	60d		0.027	<0.4	=or>0.4
I-131	2	8d	0.610	0.360	<0.4	=or>0.4
Cs-137	3	30y	0.510	0.660	<0.4	=or>0.4

Note: Although both ³²P and ³⁵S are group 3 isotopes, the levels for a major and minor spill of these has been set as for group 2. This is due to the high specificity these isotopes have for their target organs in the body.

Radiation Spill Kit

Emergency equipment to assist safe control of a radiological accident shall be readily available.

Each DRA in which unsealed sources are used shall have a radiation emergency spill kit available and stored in an appropriate location for dealing with spills and contamination. Everyone in the laboratory should know the location of this kit and the purpose/application of its contents. The kit may include:

- gloves and other personal protective clothing and equipment;
- respiratory protection devices (dust masks);
- radiation and contamination monitors, or access to such instruments;
- absorbent material with which to wipe up spills e.g. paper toweling;
- items necessary for personal and area decontamination, such as cotton wool, and

- cleaning materials;
- appropriate decontamination detergent;
- brush and pan;
- temporary barricades and radiation warning signs;
- mop and bucket (optional), and;
- bags (plastic) suitable for containing the radioactive waste for disposal, with suitable labels.

The contents of the emergency kit shall be checked regularly to ensure that they meet the needs of each situation, and are replaced as necessary. The monitoring instruments provided for this purpose should be either rotated through normal laboratory usage, or be the laboratory instruments. Other equipment provided for emergency use shall not be used for any other purpose.

The RSO shall ensure that an emergency kit, comprising items relevant to the emergency needs of each laboratory, is assembled.

Procedure for Minor Spill

Contact RSO for advice if necessary.

All materials used in cleaning and decontamination must be placed in suitable labelled receptacles and stored for disposal.

After completion of all decontamination operations the area must be checked with radiation monitoring equipment, or in the case of ^{14}C and ^3H , with a standard wipe test.

In the event of a minor spillage the operator **wearing laboratory coat, face shield and gloves** shall proceed as follows:

Wet Spill

1. Using a portable radiation monitor, monitor the spill area to define the extent of the spill and the level of contamination.
2. If a liquid spill, the liquid should be absorbed by paper towelling, tissues or similar material.
3. Wash the contaminated area with water and dry with paper towelling or similar material.
4. Again using a portable monitor, monitor the spill area. If points 2&3 were effective, or partially effective, repeat steps 2 to 4 until the affected area has returned to background and go to step 7. If the washing was ineffective, or repeating the washing gained no improvement, then go to step 5.
5. Wash the contaminated area with suitable detergent and dry with paper towel or similar material.
6. Using a portable monitor, monitor the spill area. If this is effective repeat steps 7 to 6 until the affected area has returned to the local background count or dose rate, then go to step 7. If the detergent washing was ineffective, or repeating the washing gained no improvement do not attempt any further decontamination. Isolate the affected area by erecting a temporary barricade and contact the Radiation Safety Officer or OHSRU if the RSO is not available.
7. Report the incident to the RSO/OHSRU using **Form RSO 9** (Appendix A -9).

Dry Spill

1. Carefully wipe up the material with paper towelling or tissues moistened with water.
2. Using a portable monitor, monitor the spill area to define the extent of the spill and the level of contamination.
3. Wash with water and dry with paper towelling or similar material.
4. Monitor the spill area. Repeat until the affected area has returned to background.
5. Report the incident to the RSO/OHSRU using **Form RSO 9** (Appendix A -9).

Procedure for Major Spill, Personnel Contamination or Other Emergency

In the event of a major spillage, contamination to personnel or other emergency situation (e.g. fire), the following procedures shall be followed:-

1. **In the case of a Major Spillage**, the immediate emergency actions are as follows :
 - ⇒ The laboratory or area shall be evacuated at once but contaminated persons should not proceed far into an inactive or safe area until they have been monitored.
 - ⇒ If safe to do so, turn off all laboratory services including fume cupboards and close all doors and windows.
 - ⇒ Isolate the affected area by erecting a temporary barricade and placing radioactive warning signs (these are kept in the local area radiation emergency spill kit - refer to Section 2 for details).
 - ⇒ **Immediately report the situation to the RSO, OHSRU or UWS Security on one of the Emergency Response Contact Numbers listed on page 1-18.**
 - ⇒ If you do not feel confident or capable to deal with this situation, contact the RSO, OHSRU or the IBRSC member on your campus.
 - ⇒ The treatment of serious injury must take precedence over decontamination and containment.
 - ⇒ Normal work must not be resumed until the RSO/OHSRU is satisfied that it is safe to do so and has given its approval.
2. **In the case of Personnel Contamination**, the immediate emergency actions are as follows :
 - ⇒ Remain in the radiation laboratory or area and call for assistance, if there are no phones in the immediate area organize another person to call for assistance or move to the closest phone. If possible do not leave the work area and risk spreading contamination.
 - ⇒ Monitor the whole body and clothing using a suitable contamination monitor.
 - ⇒ If skin or eyes are contaminated wash under running water until assistance arrives.
 - ⇒ If clothing is contaminated, remove garments and leave in work area. Do not proceed far into an inactive or safe area until monitored.
 - ⇒ The treatment of serious injury must take precedence over decontamination and containment.
 - ⇒ **Immediately report the situation to RSO/OHSRU or the IBRSC member on your campus on one of the Emergency Response Contact Numbers.**
3. **In the case of Fire**, the immediate emergency actions are as follows :
 - ⇒ Rescue any persons in immediate danger if it is safe to do so.
 - ⇒ Raise the alarm, warn other workers in the area and begin building evacuation
 - ⇒ **Contact University Security by phoning Ext. 2300, and they will contact Emergency Services.**
 - ⇒ **Contact the RSO/OHSRU or the IBRSC member on your campus.**

Section 2 – Radiation Safety Responsibilities & Procedures

- ⇒ Obtain the Radioactive Substances, Dangerous Goods and Hazardous Substances Inventories for the facility. The Emergency Services personnel will require these.
- ⇒ Attempt to extinguish the fire with hand held appliances only if you have been trained in their use and it is safe to do so.

4. **In all other situations**, the immediate emergency actions are as follows :

- ⇒ The laboratory or area shall be evacuated at once.
- ⇒ Initiate the facilities emergency response procedure for the situation.
- ⇒ Immediately report the situation to the RSO or OHSRU.

Note: If there is any doubt concerning the above procedures, advice and rulings should be sought from the Radiation Safety Officer.

Basic First Aid

In the case of an accident involving radioactive material, the following simple First Aid Instructions may be found useful:

Note: All materials listed below should be stocked in the Designated Radiation Area (DRA).

- **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 water;
- ⇒ 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.

Mouth:

- ⇒ Wash out with copious quantities 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 follow normal First Aid Procedures.

Maximum permissible level of skin contamination for Beta activity is 4kBq/cm² (averaged over 100 square cm).

Note: All accidents involving contamination of personnel must be reported immediately to the RSO/OHSRU.

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

2.3.10 Proposal for a Biological and/or Radiation Research or Teaching Project

Instructions to Principal Investigators

The use of ionizing radiation is governed by the Radiation Control Act (NSW) 1990 and its Regulations. The acquisition of radioactive material or irradiating apparatus must also be approved by the University IBRSC before the material or apparatus is brought into the University or used by University staff/students

The Proposal Form RSO 10 (See Appendix 10) is the IBRSC form 'Proposal for a Biological and/or Radiation Research or Teaching Project'. Relevant sections of the proposal form must be completed for work involving the use of ionizing radiation. It is important that the Principal Investigator/Academic complete these sections in sufficient detail to allow assessment and to prevent undue delays. This form must be signed by the Principal Investigator before submission to the IBRSC for approval prior to commencement of work.

Submission of Proposals

The Principal Investigator/Academic must submit a proposal to the IBRSC at the planning stage of any work in which radiation will be used, with work commencing only AFTER approval has been granted. Where the work is carried out in more than one organisation, the Radiation Safety Officer of the other organisation must be informed.

The RSO/IBRSC will check the information provided regarding the proposed material / apparatus, the physical facilities to be used and the details of the members of the project team. The Committee will then make its 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.

Approval of Proposals and Commencement of Work

Work by the Principal Investigator may commence after a proposal has been assessed and approved by the RSO. Work must be conducted only in approved laboratories or in an area or manner approved by the IBRSC/RSO.

Work must not commence without the specific approval of the IBRSC/RSO.

Note: Receipt of approval by the IBRSC/RSO does not exempt the radiation licence holder(s) from having to complete RSO Form 3, *Application to Purchase / Acquire Radioactive Substances and Notice of Disposal* or RSO Form 4, *Application to Purchase / Acquire Irradiation Apparatus* prior to commencement of the research.

Conduct of Work

The Principal Investigator must ensure that any recommendations of the IBRSC/RSO are met during the course of the work.

Proposals should be submitted to:

**IBRSC/Radiation Safety Officer
c/o – Sharon Falleiro
Office of Research Services (Building K Penrith)
University of Western Sydney**

3 RADIATION FUNDAMENTALS

3.1 Introduction

For the purposes of these guidelines, 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 and 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). (1 amu = 1.66×10^{-24} gm).

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 5.5×10^{-4} amu.

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 16 to 21.

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 (that is 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.

3.2 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. ^{32}P can travel approximately 6 metres 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.

3.3 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:

$$N=N_0e^{-\lambda t}$$

where N_0 is the number of nuclei present initially, N is the number of nuclei present at time t and λ 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:

$$N_0/2=N_0e^{-\lambda T_{1/2}}$$

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

$$A = A_0e^{-\lambda t}$$

This relationship is illustrated in Fig. 1 (see also 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.

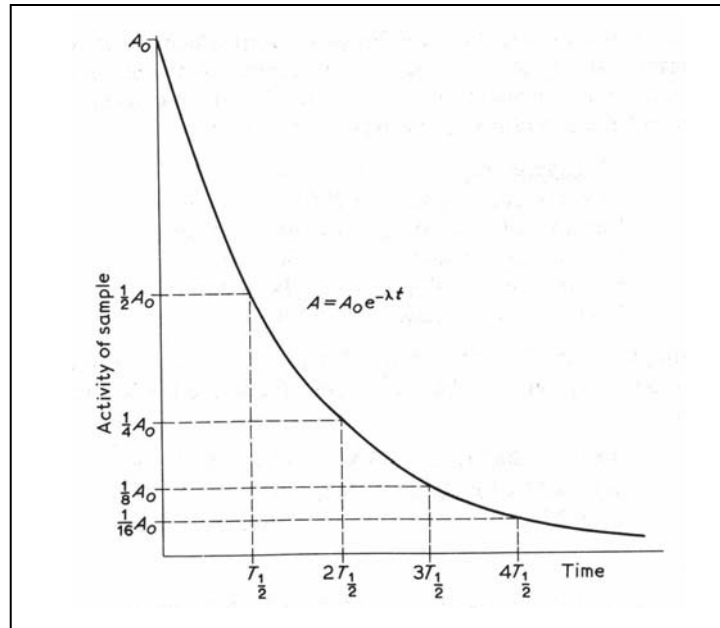


Figure 1. Variation of activity with time

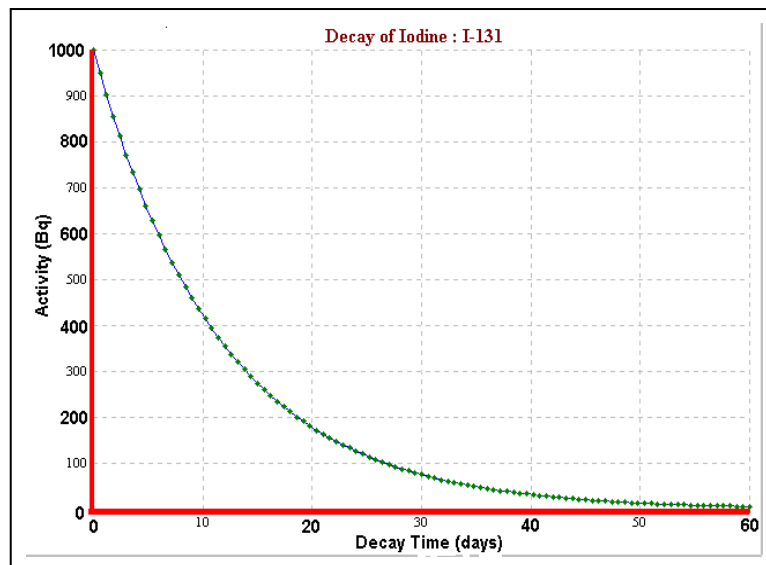


Figure 2. I decay example

3.4 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 3 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 3. 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. Hence 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 ionizing 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 discernable from “natural” cataract development related to age.

3.5 Radiation Units

In Australia we are legally expected to use the SI units for the measurement of radiation as follows:

- 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 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.

Radiation Type	Radiation Weighting Factor (w_R)
Gamma & X-rays	1
Beta particles and Electrons	1
Alpha particles and fission fragments	20
Neutrons	5-20 (depending on energy)

Table 1. Radiation Weighting Factors

For non-uniform irradiation to the human body, an annual effective dose equivalent limit of 50 mSv 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** .

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

Table 3 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.

Tissue/Organ	Tissue Weighting Factor (W_T)
gonads	0.2
Bone Marrow	0.12
Lung	0.12
Colon	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Skin	0.01
Bone Surface	0.01
From ARPANSA Radiation Protection Series No.1, 2001	

Table 2. Tissue Weighting Factors

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

Table 3. Comparison of radiation units

3.6 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 Ionizing Radiation (Printed 1995 - Republished 2002) and National Standard for Limiting Occupational Exposure to Ionizing 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 radiation workers.

The ICRP (in Publication 60) recommends an occupational effective dose limit of 20 mSv per year averaged over a five year period, with no more than 50 mSv 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	Dose Limit	
	Occupational	Public
Effective dose	20 mSv / yr averaged over 5 years (i.e., 100mSv averaged over 5 years with a max of 50mSv in any one year)	1 mSv / yr
Annual equivalent dose to:		
Eye	150 mSv	15 mSv
Skin (average / cm²)	500 mSv	50 mSv
Hands/Feet	500 mSv	

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 (copies are available for reference from the UWS Library E-Resources web page, scroll to “Standards Australia” under “Databases”) 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.

3.7 The Tenets of Radiation Protection

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 - 100µm 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.

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.

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.

3.8 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.

$$\text{Dose} = \text{dose rate} \times \text{time}$$

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.

$$D_1 r_1^2 = D_2 r_2^2$$

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:

- the shield may also serve as structural support.
- heavy lead shielding itself may need to be structurally supported, for example, by a heavy steel frame.
- lead glass windows may be required for transparency.
- ideally, shielding should contain no gaps, hence it should be made of one-piece construction or from interlocking blocks.
- the intensity and type of radiation determines what material is required and its thickness.
- shield design must take into account secondary radiation problems (bremsstrahlung) from high energy beta radiation.
- neutrons are effectively shielded by materials containing large quantities of hydrogen, such as polyethylene.

Section 3 – Radiation Fundamentals

The reduction of exposure by shielding not only requires good design but good management techniques as well. Effective shielding management includes the following items:

- before carrying out an operation involving the use of radioisotopes calculate the shielding requirements using half-value layers or gamma ray constants.
- the quality of the shield should be examined from all directions, including the top and bottom.
- store radioactive materials in appropriately shielded containers with secure lids.
- handle glass vials and test tubes in shielded containers.
- use custom design syringe barrel shields when handling large quantities or activities of an injectable radioisotope.
- 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%.

4 RADIATION SAFETY OFFICER AND DELEGATES

The following material is extracted from NSW Radiation Series No. 5 *Recommendations for Radiation Safety Officers and Radiation Safety Committees* (NSW Recommendations) and from Australian Standard AS2243.4 *Safety in Laboratories—Ionising Radiations*.

NSW has a legal clause on Radiation Safety Officers (RSOs) and Radiation Safety Committees (RSCs). An employer is not obliged to appoint an RSO or RSC unless advised in writing by the Director General of the Department of Environment and Conservation (administered through the EPA). In the absence of this written direction an employer may appoint a person to act as an RSO or RSA (radiation safety adviser). However, in doing so, the employer has the responsibility of ensuring that the appointed person generally complies with the requirements of the NSW Recommendations and the Australian Standard.

4.1 Qualifications

Without written direction from the Director General, an RSO requires a mix of scientific and technical expertise appropriate to the organisation with the recommended minimum qualifications and experience as detailed in the NSW Radiation Series No. 5.

The qualification requirements for an RSO are as follows:

1. a relevant qualification in a discipline appropriate to the activity that they are required to undertake by their employer, for example:
 - an RSO in a large teaching hospital using many modalities of radiation may need to be qualified as a medical physicist or equivalent
 - an RSO in an industrial setting may need to be licensed in industrial radiography, or
 - an RSO employed in a radiological practice may need to be a radiographer;
2. satisfactory completion of an appropriate training course in radiation protection;
3. knowledge of NSW radiation control legislation and of relevant codes of safe practice, including:
 - the *Radiation Control Act 1990* and Regulation (and subsequent amendments)
 - relevant EPA radiation control guidelines
 - relevant documents in the ARPANSA Radiation Protection Series
 - relevant codes of practice
 - relevant Australian Standards
 - other guidance material and information relevant to the duties of an RSO.

Additionally, It is desirable that an RSO have:

1. two years full-time-equivalent experience in operational radiation protection in one or more of the areas that require mandatory personal monitoring under the Regulation, with experience appropriate to their type of employment;
2. demonstrated ability to research and resolve a wide range of diverse technical issues;
3. demonstrated high-quality communication and interpersonal skills across a variety of client groups, and be able to:
 - liaise effectively with all levels of staff employed in the organisation
 - present radiation safety information in a clear manner

- compile comprehensive reports on radiation safety matters encountered in the organisation.

4.2 Functions/Responsibilities

Both the NSW Recommendations and the Australian Standard have a defined list of functions for the RSO as detailed in the sections below.

Recommendations from NSW Radiation Series No. 5

The function of an RSO is to advise and assist the employer to fulfil their responsibilities under the *Radiation Control Act 1990* and the Regulation. The specific functions of an RSO are at the discretion of the individual employer. An example of how an RSO can assist the employer is by developing, implementing and monitoring the effectiveness of a radiation protection program.

The following are functions that an RSO may carry out for an employer:

1. Ascertain the radiological hazards associated with the organisation and advise the employer about suitable radiation protection arrangements that should be implemented so that radiation exposures are as low as reasonably achievable:
 - for occupationally exposed employees in controlled areas
 - for employees in supervised areas
 - for members of the public, including those who have access to areas in or adjacent to the premises.
2. Arrange for the inspection of all monitoring devices in the organisation to determine whether they are in good working order and that they are appropriately calibrated.
3. Inspect and advise the employer on the adequacy of facilities and protocols for employees working with radioactive substances, including radiation monitoring and protective clothing.
4. Recommend the adoption of systems or procedures that ensure suitable external radiation monitors are worn and returned to the issuing organisation at appropriate intervals.
5. Advise the employer when personal monitoring of exposed persons for internal radiation exposure needs to be carried out.
6. Investigate any abnormally high external or internal radiation exposures of persons and report the results to the employer.
7. Recommend implementation of appropriate procedures to control the exposure of pregnant women in accordance with clause 5.1(m) of the aforementioned *National Standard for Limiting Occupational Exposure to Ionizing Radiation*.
8. Arrange for appropriate periodic monitoring of areas, equipment and operations associated with the use of ionising radiation and radioactive substances.
9. Arrange for all employees who work with ionising radiation or radioactive substances to be provided with appropriate induction and continuing radiation safety training, and maintain records of this training.

10. Recommend the adoption of systems or procedures that ensure all appropriate employees in the organisation are licensed as required by the radiation control legislation.
11. Recommend systems or procedures that ensure registration and all other pertinent requirements of the radiation control legislation are met.
12. Liaise with all employees in the organisation who may be exposed to ionising radiation during the course of their work, and their supervisors, to ensure that radiation doses are as low as reasonably achievable.
13. Advise on the provision of engineering controls and maintenance schedules for equipment.
14. Recommend systems or procedures to ensure that local rules for safe work practices with ionising radiation and radioactive substances are prepared and available to appropriate employees.
15. Advise on arrangements for the proper identification and indication of all controlled and supervised areas.
16. Arrange for access by authorised persons to controlled areas.
17. Inspect all areas where ionising radiation or radioactive substances are used, or are proposed to be used, and make reports and recommendations to the employer on radiation safety.
18. Arrange for the display of radiation warning signs as required by the radiation control legislation and for their removal when no longer needed.
19. Investigate, record and report to the employer and the EPA, as appropriate, any accidents or unsafe practices that affect radiation safety.
20. Advise on the safe storage of radioactive materials in accordance with the requirements of the EPA.
21. Advise on the safe storage and disposal of radioactive wastes in accordance with the requirements of the EPA.
22. Arrange for records of effective doses of ionising radiation received by individual workers to be maintained for the period required by the EPA.
23. Arrange for any necessary medical services to be provided. Arrange for medical records to be maintained in accordance with any existing legislative requirements.
24. Devise and establish a protocol for independent safety assessment of:
 - new plant, premises or operations in which ionising radiation or radioactive substances are to be used
 - modifications that may affect radiation safety to existing plant, premises or operations in which ionising radiation or radioactive substances are used.
25. Arrange for radioactive substances to be transported in accordance with the requirements of the radiation control legislation.
26. Arrange for station officers of the local fire brigade to be notified of the location of radioactive substances on the premises.
27. Arrange for the preparation and execution of contingency plans for any foreseeable radiological accidents or emergencies in the organisation.
28. Perform any other tasks necessary to maintain a high standard of radiation safety.

Recommendations from Australian Standard (AS2243.4), the functions so listed are:

1. Supervise the radiation protection in designated radiation areas (DRAs) in order to minimize personal doses;
2. Advise on safe working practices in accordance with regulations and codes of practice;
3. Consult and liaise with the relevant regulatory authority;

Section 4 – Radiation Safety Officer and Delegates

4. Ensure that all necessary licensing and registration matters are processed;
5. Liaise with occupationally exposed persons and their supervisors to ensure that the proposed work with radioactive substances or irradiating apparatus is properly planned;
6. Arrange that areas, equipment and operations are monitored as considered necessary and upon request;
7. Ensure that suitable personal and other monitoring devices are provided where required, kept in good working order, properly used, and calibrated at least once each year;
8. Arrange that, where measured for individuals, records of effective doses are kept for 50 years or such period as required by legislation;
9. Arrange for any required medical services to be provided and for medical records to be kept for 50 years or such period as required by legislation;
10. Inspect areas and installations where ionizing radiations are used or are proposed to be used and make reports and recommendations to management on radiation safety;
11. Record and report to management and the appropriate authorities any unsafe practices or accidents;
12. Notify station officers of the local fire brigade of the locations of any radioactive substances and radiation apparatus;
13. Prepare local rules for dealing with any foreseeable radiological accidents;
14. Ensure that current records of all stocks and locations of radioactive substances and irradiating apparatus are maintained and kept for two years after the date of disposal;
15. Arrange for the safe storage of radioactive substances and for the safe disposal of any radioactive waste;
16. Provide advice to radiation workers, as well as instruction and local rules on radiation safety in an easily understandable form and on an adequate scale for occupationally exposed persons; and
17. Perform any other tasks as may be necessary to maintain a high standard of radiation safety.

5 TRAINING

The University requires that all individuals have undertaken radiation safety training before commencing work with radiation (documentation of prior radiation safety training before joining the University may be acceptable).

Training in this instance does not only refer to technical or academic training in scientific methods for research using radioactive materials. It also includes the training of individuals to understand the properties of radioactive materials and equipment. Training must include radiation safety, which is given some priority due to the difficulty in determining physiological damage that may result following exposure to levels of radiation commonly encountered in the laboratory.

Often the damage or the symptoms of this exposure may take a substantial number of years to be observed, for example cataract formation and cancer. Hence, emphasis on radiation safety and safety training is strongly promoted. It is the worker/researcher who must take primary responsibility for prevention and hence be adequately trained.

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. This also applies for licence exemptions; however there is some leeway in that the trainer can be the licensed supervisor (or a delegate). There still needs to be a formal training document for this type of training with appropriate records of the training to be maintained.

Although not legislated, there is an implied requirement that training should be updated on a regular basis (2, 3, or 5 year periods). This refresher training need not be as extensive as the original training.

Training should cover (as a minimum):

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

The University is required to maintain records of all radiation safety training of its staff 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 (staff or student file). A UWS register of training with a reference to the certificate must also be kept.

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

6 RADIATION MONITORING

6.1 Monitoring Equipment

The determination of the correct equipment for radiation monitoring 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; thus it is important to know your isotopes because it is from this information that the determination is made.

6.1.1 General Principles

The fact that the human body is unable to sense ionizing radiation is probably responsible for much of the general apprehension about this type of hazard. Reliance must be placed on detection devices that respond to the physical or chemical effects of radiation. These effects include:

- a) ionization in gases,
- b) ionization and excitation in certain solids,
- c) changes in chemical systems, and
- d) activation by neutrons.

Most health physics monitoring instruments use detectors based on the ionization of a gas. Certain classes of crystalline solids exhibit increases in electrical conductivity and effects attributable to excitation, including scintillation, thermo-luminescence and the photographic effect. Detection systems are available in which chemical changes are measured but these are rather insensitive. A method that may be applied to neutron detection depends on the activation caused by neutron reactions.

The basic principles of those systems commonly used in practical health physics are briefly described below.

Ionization Chamber

The absorption of radiation in a gas results in the production of *ion pairs* consisting of a *negative ion* (the electron) and a *positive ion*. A moderate voltage applied between two plates (electrodes) in close proximity causes the negative ions to be attracted to the positive electrode (anode) and the positive ions to the negative electrode (cathode). This flow of ions constitutes an electric current which is a measure of the intensity of radiation in the gas volume. The current is extremely low (about 10^{-12} A) and a sensitive electronic circuit known as a d.c. (direct current) amplifier is used to measure it. This system is known as an ionization chamber and the current measured is a mean value due to the interaction of many charged particles or photons.

The design of the chamber and the filling gas used depends on the particular application. In health physics instruments the chamber is usually air filled and is constructed of low atomic number materials. If the instrument is required to respond to beta radiation the chamber must have thin walls or a thin window.

Proportional Counter

If, in an ion chamber system, the applied voltage is increased beyond a certain point, an effect known as *gas amplification occurs*. This is because the electrons produced by ionization are accelerated by the applied voltage to a sufficiently high energy to cause further ionization themselves before reaching the anode, and a cascade of ionization results. Thus a single ionizing particle or photon can produce a pulse of current which is large enough to be detected. Over a certain range of voltage the size of the pulse is proportional to the amount of energy deposited by the original particle or photon and so the system is known as a proportional counter. The term counter means that the output is a series of pulses that may be counted by some means, rather than an average current as obtained with an ionization chamber.

Geiger-Mueller Counter

If the voltage in the ionization system is increased still further the gas amplification is so great that a single ionizing particle produces an avalanche of ionization resulting in a very large pulse of current. The size of the pulse is the same, regardless of the quantity of energy initially deposited, and is governed more by the external circuit than the counter itself. The G-M tube is very widely used in monitoring equipment because it is very rugged and can operate relatively simple output circuits. Again, this is a counting device but it is possible in some cases to use a G-M counter in a circuit that measures the average current flowing through the tube.

Conductivity Detectors

Because changes in conductivity are due to ionization, solid state conductivity detectors are similar in some ways to gas ionization systems. A cadmium sulphide (CdS) detector, for example, is analogous to an ion chamber. It is operated in the mean current mode and is suitable in some applications for the measurement of g dose rate. The main advantage is that it can be much smaller than an ion chamber and yet have a greater sensitivity.

As with gas systems, some solid state detectors, notably germanium and silicon, operate in the pulse mode. Germanium has the disadvantage that it must be operated at very low temperatures. The pulse size in both cases is proportional to the energy deposition within the detector. The main application is in gamma spectrometry, in which by analysing the size of pulses from the detector, it is possible to measure the energy of g-rays.

Scintillation Detectors

Scintillation detectors are based on detection of the fluorescent radiation (usually light) emitted when an electron returns from an excited state to the valence band. The material selected is one in which this occurs very quickly (within about 1 ms). The absorption of a 1 MeV g-photon in a scintillation detector results in about 10,000 excitations and the same number of photons of light. These *scintillations* are detected by means of a photomultiplier tube that converts the light into electrical pulses, which are then amplified. The size of the pulse is proportional to the energy deposited in the crystal by the charged particle or photon. In g-ray work the most common scintillator is sodium iodide (NaI), usually in crystals of about 50 x 50 mm. These are widely used in g-spectrometry but are being supplanted by germanium detectors which offer better energy resolution. Zinc sulphide crystals in very thin layers are used for a-detection.

6.1.2 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

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 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 personnel 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 or 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.

Types of radiation	alpha, beta, gamma, x-ray or neutron
Energy levels	keV or MeV?
Units required	counts, exposure, absorbed dose, dose equivalent
Intensity	mSv/h or Sv/h
Survey type	Radiation monitoring or contamination
Sensitivity	Minimum detectability required
Power source	Mains power or replaceable batteries
Other	Ruggedness and portability of instrument

Table 1 - Primary selection criteria for survey instruments

Special Instrument Problems – Low Energy Beta Emitters

Radionuclides that emit beta particles of energy less than 0.25 MeV 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 ^3H , ^{14}C , ^{35}S and ^{45}Ca : their maximum energy, range and half-thickness are shown in Table 2. These radionuclides are often used as tracers by biologists and biochemists.

NUCLIDE	ENERGY (MeV)	RANGE (mg.cm ⁻²)	HALF-THICKNESS (mg.cm ⁻²)	% ABSORPTION BY A 2 MG.CM ⁻² WINDOW
³ H	0.018	0.55	0.16	100
¹⁴ C	0.155	28.0	2.68	37
³⁵ S	0.167	32.0	2.96	35
⁴⁵ Ca	0.257	60.0	5.07	25

Table 2 - Penetration data for low energy beta emitters.

Most probe windows are far too thick to allow the effective detection of low energy beta emitters, especially ³H. However, there are commercial beta probes that have a sufficiently thin window to allow the detector to respond to ¹⁴C, ³⁵S and ⁴⁵Ca 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.

Special Instrument Problems - Electronic

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

1. **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.
2. **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.
3. **Magnetic Fields** - High magnetic fields will affect the photomultiplier tubes found in scintillation detectors by deflecting the electron beam and giving a false reading.
4. **RF Fields** - Some instruments may pick up signals from radio frequency fields and give spurious (usually high) readings
5. **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.

6.1.3 Legal Requirements and Recommended Practice for Monitoring Equipment

With monitoring equipment, the legal requirements and recommended practices are as follows:

- The instrument requires calibration to the Australian Standard (AS2243.4) annually.
- 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 Beta radiation and Alpha radiation 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 not to be less than 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 that reads 5000cpm from a spot of ^{32}P , with an instrument that has 5% efficiency, equates in reality to about 1.66 kBq of activity.

6.2 Personal Monitoring

Radiation workers (staff or students) who are expected to receive greater than thirty percent of the annual recommended effective dose limit of 20mSv should be subject to continuous individual personal monitoring. They are commonly referred to as an ‘occupationally exposed person’.

The three main devices for 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.

Personal monitors or devices detect and measure cumulative exposure to ionising radiation. They are usually worn at the collar, 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.

Photographic Film Badge

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

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 ^3H , ^{14}C , and ^{35}S , because the beta particles 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 mSv, whilst the TLD is accurate down to approximately 10 mSv.

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.

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 section. 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.

6.2.1 Legal Requirements and Recommended Practice for Personal Monitoring

The radiation doses recorded by personal dosimeters become part of an individual's 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 monitored individual and are required to be kept by the University for a period of at least fifty (50) years after the last entry. The RSO or OHSRU, 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 by any individual 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 be deliberately exposed to radiation or worn when receiving medical or dental x-rays.
- ⇒ They are to be securely stored away from radiation sources at the place of

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employment (that is, not taken home, etc.).

- ⇒ Personal monitoring badges (the actual TLD film) are not to be tampered with or removed from the holder.
- ⇒ Personal monitoring badges should not be subjected 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 radiation.
- ⇒ The TLD is to be returned to the RSO or TLD manager for assessment at the appropriate time.
- ⇒ The RSO, or equivalent, 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.
- ⇒ When a monitored individual leaves the University, they are to be provided with a copy of their radiation exposure records, including cumulative dose records (obtained from RSO/OHSRU).
- ⇒ Records of personal monitoring must be given to any future employer employing the monitored individual as a radiation worker.

6.2.2 Records of Personal Monitoring

Records of radiation exposure must be kept for each individual or occupationally exposed person to whom a personal monitor is issued. Such records must contain the following information:

- ⇒ full name, sex, date of birth of the occupationally exposed person,
- ⇒ current home address, or if no longer at the University, the person's last known home address,
- ⇒ date of commencement of employment/work (and if applicable, date of cessation) as an occupationally exposed person,
- ⇒ the kind of work performed by the person,
- ⇒ details of the types of ionising radiation the person may have been exposed in the course of their work (including information about unsealed radioactive substances),
- ⇒ reference to any radiation accident reports in which the person has been involved or by which the person may have been affected,
- ⇒ details of the personal monitoring device or badge worn by the person,
- ⇒ results of monitoring of the levels of radiation exposure.

6.3 Workplace Monitoring

6.3.1 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

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- ⇒ Contamination of work services and on clothing
- ⇒ Contamination of the air and waste water

The **I.C.R.P.** has a **quality assurance routine for radiation premises** that must be fully documented and 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.

The above quality assurance routine must be adopted as a condition of licence, by all facilities and users of radiation, especially those who work with unsealed sources.

6.3.2 Workplace Surveys

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 each work.

1. 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.
2. Instrument Survey - This survey uses a survey instrument to locate fixed and removable contamination on surfaces, equipment, personnel and clothing.
3. 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.
4. Exposure Rate Survey - This survey uses an appropriately calibrated meter to determine exposure rates (e.g. in mSv/hr) for compliance with regulatory limits.

1. General Use Survey

When working in a radioactive material laboratory, the following items should be checked and maintained. The RSO/IBRSC check for these items during audits and report any deficiencies to the Authorized User for correction:

1. The use of appropriate signage and placards (refer to 'Laboratory Signs and Access' Section 10).
2. The use of proper radioactive waste containers. Containers shall be conspicuously labelled with the appropriate signs
3. Ensure that radioactive waste is not being deposited in the normal trash.
4. Ensure that food and drink is not stored in the laboratory or designated radiation areas.
5. Ensure that food and drink is neither prepared nor consumed in an area used for radioactive material.
6. Ensure that appropriate ALARA principles are being applied (ALARA = As Low As Reasonably Achievable).
7. Ensure that the monitoring program is applied.

The designated manager of the radiation laboratory is responsible for correcting any deficiencies noted above.

2. Instrument Survey Procedures

Instrument surveys should be performed while working with open 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 - ^3H and other low energy beta use, proceed directly to the wipe survey because the low-energy beta radiation will not be detected by portable survey instruments.) Surveys shall be performed and documented at intervals as specified in Table B-1 of this section.

The following procedures shall apply:

1. Select an instrument appropriate for the nuclide being detected. Check the battery condition and function check the instrument with a suitable check source.
2. Slowly scan items and areas with the probe approximately 1 centimetre away from items or surfaces. If radiation levels are greater than two times normal background levels (usually no more than 50 cps), perform a wipe survey. Increased radiation levels in the general area mask lower levels of contamination from instrument detection. For example, a three-fold increase in the background radiation level requires 2-3 times more contamination to be present before the instrument can detect it.
3. If contamination is found, decontaminate the area by following procedures recommended in 'Laboratory/Radioactive Source Safety – Contamination & Decontamination' Section 11.
4. After cleaning, a second survey shall be performed to assure that contamination has been removed.
5. ACTION LEVEL: A wipe survey shall be performed when a survey indicates a reading 2 times background.

3. Wipe Survey Procedures

It is recommended that an instrument survey be performed prior to a wipe survey to minimize 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 B-1 of this section and as follows:

1. Wear gloves.
2. While applying light pressure, run a dry 5cm filter paper or equivalent over the surface being surveyed. A standardized area approximating 100 square centimetres should be covered with each wipe to allow comparisons of results.
3. 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 'Laboratory/Radioactive Source Safety - Contamination and Decontamination' Section 9.
4. If contamination above the allowable contamination level is found, decontaminate the area.
5. After cleaning, a second survey shall be performed to assure that contamination has been removed.
6. ACTION LEVELS: Contamination above the allowable contamination levels defined in 'Laboratory/Radioactive Source Safety – Contamination and Decontamination' Section 11.

To document wipe surveys, the results of the wipe survey should be recorded in Bq/cm^2 and indicate the location of each of the wipes.

4. Exposure Survey Procedures

An appropriately calibrated and specifically designed meter is needed to measure the external radiation levels in air for an exposure survey. Research laboratories do not usually need, or possess, these types of instruments.

Staff trained in the use of exposure meters shall perform an exposure survey whenever necessary:

1. Exposure surveys are performed on large quantities of high energy gamma emitting radionuclides. These are also performed on packages or waste drums prepared for shipment and to determine radiation area classifications.
2. ACTION LEVEL: Action levels are variable and are determined by the regulatory limits.

6.3.3 Table B-1

To determine how often a laboratory needs to perform and record surveys, Table B-1 provides a listing of radionuclides and the quantity in use that initiates the respective daily, weekly or monthly frequency. These documented surveys are in addition to the informal and undocumented surveys that workers perform on their hands, clothing, work area, etc. after use of open sources of radioactivity.

TABLE B-1

Survey Frequency for Research Laboratories Using Unsealed Sources

Radio-toxicity Group (& examples)	Instrument and/or Wipe Surveys (based on scheduled levels)		
	Daily or after use	Weekly	Monthly
<p>1</p> <p>²⁴¹Am ²⁴⁹Cf ²⁴²Cm ²⁴³Cm ²³¹Pa ²¹⁰Pb ²¹⁰Po ²³⁸Pu ²²⁶Ra ²²⁷Th ²²⁸Th ²³²U ²³³U</p>	40 kBq	4 kBq	400 Bq
<p>2</p> <p>²²⁸Ac ^{110m}Ag ¹⁴⁰Ba ²⁰⁷Pb ²¹⁰Pb ⁴⁵Ca ^{115m}Cd ¹⁴⁴Ce ³⁶Cl ⁵⁶Co ⁶⁰Co ¹³⁷Cs ¹⁵²Eu ¹⁵⁴Eu ⁶⁸Ge ¹²⁴I ¹²⁵I ¹³¹I ^{114m}In ¹⁹²Ir ⁵⁴Mn ²²Na ²³⁰Pa ²¹²Pb ²²⁴Ra ¹⁰⁶Ru ⁴⁶Sc ⁹⁰Sr ^{127m}Te ²³⁴Th ²⁰⁴Tl ²³⁶U ⁹¹Y</p>	400 kBq	40 kBq	4 kBq
<p>3</p> <p>¹¹¹Ag ⁴¹Ar ⁷³As ¹⁹⁶Au ¹³¹Ba ⁷Be ²⁰⁶Bi ⁷⁵Br ⁷⁶Br ¹⁴C ⁴⁷Ca ¹⁰⁹Cd ¹⁴¹Ce ³⁸Cl ⁵⁷Co ⁵¹Cr ¹³¹Cs ¹³⁶Cs ⁶⁴Cu ¹⁶⁵Dy ¹⁶¹Er ^{152m}Eu ⁵²Fe ⁵⁵Fe ⁶⁷Ga ¹⁵³Gd ^{195m}Hg ¹⁹⁷Hg ¹²³I ¹¹¹In ¹¹⁵In ¹⁹⁰Ir ⁴²K ⁴³K ^{85m}Kr ¹⁴⁰La ¹⁷⁷Lu ²⁸Mg ⁵²Mn ⁵⁶Mn ⁹⁹Mo ²⁴Na ^{93m}Nb ⁹⁵Nb ¹⁴⁷Nd ¹⁴⁹Nd ⁶³Ni ⁶⁵Ni ¹⁸⁵Os ¹⁹¹Os ³²P ²³³Pa ²⁰³Pb ¹⁴⁷Pm ¹⁴²Pr ¹⁴³Pr ⁸¹Rb ⁸⁶Rb ¹⁸³Re ¹⁸⁶Re ¹⁰⁵Rh ²²⁰Rn ²²²Rn ¹⁰³Ru ³⁵S ¹²²Sb ⁴⁷Sc ⁴⁸Sc ⁷⁵Se ³¹Si ¹⁵¹Sm ¹¹³Sn ¹²¹Sn ⁸⁵Sr ⁹¹Sr ⁹⁶Tc ⁹⁷Tc ⁹⁹Tc ^{125m}Te ¹²⁷Te ²³¹Th ²⁰⁰Tl ²⁰¹Tl ¹⁷¹Tm ²³⁹U ⁴⁸V ¹⁸¹W ¹³⁵Xe ⁸⁷Y ⁹⁰Y ¹⁷⁵Yb ⁶²Zn ⁶⁵Zn</p>	4 MBq	400 kBq	40 kBq
<p>4</p> <p>³⁷Ar ¹¹C ^{58m}Co ^{134m}Cs ⁶²Cu ⁶⁸Ga ⁷¹Ge ³H ¹²⁹I ^{113m}In ^{81m}Kr ⁸⁵Kr ¹³N ⁹⁷Nb ⁵⁹Ni ¹⁵O ^{191m}Os ^{193m}Pt ⁸⁷Rb ¹⁸⁷Re ^{103m}Rh ⁷³Se ¹⁴⁷Sm ^{85m}Sr ^{87m}Sr ^{96m}Tc ^{99m}Tc Th-nat ²³²Th U-nat ²³⁵U ²³⁸U ^{131m}Xe ^{91m}Y ⁶⁹Zn ⁹³Zr</p>	40 MBq	4 kBq	400 kBq

7 BIOLOGICAL MONITORING

This is a very short overview of Biological monitoring requirements 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 , ^3H , ^{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 Radiation Safety Officer (RSO) and/or the OHSR Unit need to be contacted with some urgency. 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.

8 PERSONAL PROTECTIVE EQUIPMENT

8.1 Introduction

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 workers must be supplied with appropriate PPE relevant to the hazards and emergencies associated with the work. However, PPE is to be considered the last resort in protecting the workers from exposure to hazards. Engineering controls should be used first, although 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.

8.2 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, be clean and well maintained.

PPE has limitations and these limitations 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, e.g. beards and breathing apparatus.

8.3 Personal Protective Equipment Program

For maximum efficiency in managing PPE, it is important to establish a personal protective equipment program. An appropriately trained person should be co-opted to assist the RSO/IBRSC at the local level, to manage and oversee the program.

Other responsibilities include analysing the hazards specific to the workplace and checking that the PPE in use provides adequate protection against these. Regular checks should be scheduled to ensure that the PPE is used properly, that it is always used when necessary; that it fits the employees using it, and that it is cleaned, maintained and stored safely. This includes allocating appropriate storage facilities for PPE.

The PPE manager should ensure that all employees using PPE have received training in its

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correct use, limitations, selection and fitting, maintenance and storage. It is useful to establish written procedures to ensure that employees fully understand the safety requirements for using and storing PPE.

8.4 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 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.

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 beta radiation.

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

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.

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.

Goggles



Goggles are very good protection from radiation exposure, 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.

Face Shield



A face shield is very good protection for the face and eyes from radiation exposure, 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 for all work that involves a risk of splashes, sprays, spills or impact.

8.5 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-levens 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.

Half face masks



These are useful for a range of short term operations such as cleanup of spills, inspection and assessment of suspect packages.

A close fit and good seal is a must and beards, etc compromises this seal, 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 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.

Full face masks

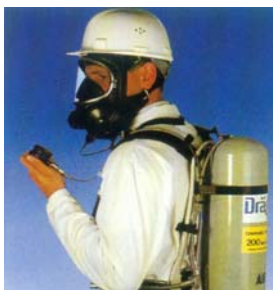


These types of BA protect both from breathing hazards as well as giving eye protection. Again beards etc., compromise their effectiveness.

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.

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.

Advantages of SCBA

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.

Types of SCBA

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

- Demand

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.

- Full flow

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.

So these types of SCBA can be used successfully with a beard!

Fitting the mask

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

8.6 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 for radiation work.**

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:

Section 8 – Personal Protective Equipment

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.

1. The gloves should be lubricated internally with talcum powder.
2. The cuff of each glove should be folded over, outwards, for 4 cm.
3. Put one glove on by grasping only the internal folded-back part with the other hand.
4. 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.
5. Unfold the gloves by manipulating the fingers inside the fold.
6. Gloves should be thoroughly washed before they are removed.
7. 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 staff 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 staff 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.

9 LABORATORY CLASSIFICATION, REQUIREMENTS AND REGISTRATION

9.1 Laboratory Classification

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

9.1.1 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 F1 (AS 2243.4) shows laboratory gradings for normal, wet chemical operations.

**Table F1
Grading of Radioisotope Laboratories**

Radiotoxicity group	Grade of laboratory for specified levels of activity		
	Low level laboratory	Medium level laboratory	High level laboratory
1	<0.2 MBq	0.2 MBq to 20 MBq	>20 MBq
2	<20 MBq	20 MBq to 2 GBq	>2 GBq
3a/3b	<2 GBq	2 GBq to 0.2 TBq	>0.2 TBq
4	<0.2 TBq	0.2 TBq to 20 TBq	>20 TBq

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 F2 (AS 2243.4) can be applied to modify the grading according to the operations performed in the laboratory.

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, ³H-labelled and ¹⁴C-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.

**Table F2
Modifying Factors**

Procedure	Factor
Simple storage	x 100
Very simple wet operations (e.g. using aliquots of stock solutions)	x10
Normal chemical operations (e.g. analysis of simple chemical preparations)	x1
Complex wet operations (e.g. multiple operations, or operations with complex glass apparatus)	x0.1
With Biological/organic materials	x0.1
Simple dry operations (e.g. manipulations of powders) and work with volatile radioactive compounds	x0.01
Complex dry operations (e.g. where powders are likely to become airborne) and work with radioactive gases	x0.001

Example:

A laboratory purchases, stores and uses 25MBq of ³²P labelled Glucose. The grading of the laboratory would be calculated thus:

Radiotoxicity group = 3a
Activity = 25MBq

Initial classification would then be **Low Level** (<2G bq).

However the modifying factors of Complex wet and biological needs to be incorporated, thus giving:

$$<2\text{GBq} \times 0.1 \times 0.1 = 20\text{MBq}$$

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

9.2 Facilities Requirements

The Australian Standard, AS2243.4, briefly summarises the facility requirements as detailed in the following table. These requirements are more fully covered and explained in AS2982.1 *Laboratory Design and Construction*, with an abbreviated version of this section of the Standard given after the table below. Any additional features that improve the safety of the facility should be considered. Reference should also be made to the Ventilation Standard (AS 1668 & 1668.2).

Table

Summary of Laboratory Requirements

Laboratory grade	Typical examples	Description	Control of other aspects
Low-level	Radio-immunoassay area within a small medical diagnostic laboratory using only pre-labelled non-volatile kits. Typically using no more than 400 kBq of Iodine-125 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 or 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 20 MBq of radiotoxicity hazard group 2 up to 2 GBq of group 3 and up to 200 GBq 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 200	Criteria as itemized in AS/NZS 2982.1 Seek RSO advice as above if genetic manipulation involved.	Laboratory shall be dedicated solely to radioisotope work. Overshoes may be required as per RSO

	MBq. Radiochemistry research with typical usage up to 20 MBq of ⁶⁰ Co, up to 400 MBq of ¹¹³ Sn and ⁶⁵ Zn.		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 <i>Australian Code of good radio-pharmaceutical practice</i>	As above
	Preparation of radioisotope therapy doses.		As above.
	Small scale production of commercial radioisotope products		Overshoes required
High-level	Refer AS/NZS 2982.1		

9.3 AS2982.1 “Laboratory Design and Construction”: Part 1 - Requirements

9.3.1 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:

- a. 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.
- b. 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.
- c. 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.
- d. 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).

Section 9 – Laboratory Classification, Requirements and Registration

- e. Secure storage facilities shall be provided for stocks of radionuclides. Shielding shall be provided if recommended by the RSO. Refrigerator storage or freezer storage, or both, may be required in medical and biological radioisotope laboratories.
- f. The advice of the RSO 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.
- g. 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.
- h. Stainless steel sinks are recommended.
- i. 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.

9.3.2 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:

- a. 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.
- b. 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.
- c. A hand washbasin shall be provided and the taps shall be operated automatically, or be operated by knee or foot.
- d. All drainage systems shall be continuous and be appropriately labelled at accessible locations. Poly ethylene and PVC pipes and fittings are resistant to most chemicals and are less likely than metal pipes to become internally contaminated.
- e. 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.

Section 9 – Laboratory Classification, Requirements and Registration

- f. Laboratory ventilation requires careful design with outdoor fresh air quantities increasing as the quantity of radioactivity proposed for use increases. Table 9.1 provides a practical guide to the supply of outdoor air requirements for laboratories assuming a floor area of 10 m²/person and a ceiling height of 2.4 m. 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.
- g. The RSO shall determine whether overshoes and barriers are required.
- h. 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 RSO will need to resolve the different requirements of the radioisotope codes and standards, the sterility standards for clean rooms 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.
- i. Ceilings should be smooth and decontaminable as for walls. Flush light fittings should be used in preference to suspended fittings which will trap dust.
- j. 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.

Table
Minimum Outdoor Air Flow for Radioisotope Laboratories

Type of Laboratory	Minimum outdoor fresh air flow per unit of total floor area L/s.m ²
Biological and chemical	3 to 6
Animal rooms	10
Radionuclide counting rooms	3
Low-level radioisotope laboratories	3 to 6
Medium-level radioisotope laboratories	6 to 9
High-level radioisotope laboratories	>9

NOTE: Heat loads will in many cases increase the total supply air requirements well above these figures.

9.3.3 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. 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.
- b. 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.
- c. Facilities for the decontamination of apparatus.
- d. Warning signs, lights and interlocks, as necessary, in accordance with AS 1216 and AS 1319.
- e. 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/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.

9.4 Registration of premises that keep radioactive substances: Information for occupiers

9.4.1 Introduction

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.

9.4.2 Definitions

Definition of 'occupier'

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

- a. a person in occupation or control of the premises, or
- b. 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.

Definition of '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.

9.4.3 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.

9.4.4 Application for registration

The occupier must submit an application to the EPA using the approved form accompanied by the by the fee prescribed in the Regulation.

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.

9.4.5 Licensing and use of radioactive sources

The occupier's EPA 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. Contact the IBRSC for information.

9.4.6 Classification of premises:

1. 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 - Ionizing Radiation, Appendix F - Grading of Radioisotope Laboratories, as low level, medium level or high level based on the specified levels of activity.

2. 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).

9.4.7 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 EPA 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 EPA 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 RSO or the Radiation Control Section of DEC (EPA) for advice on specific situations because an incorrect or incomplete application may delay registration.

9.4.8 Conditions of registration

When the requirements for registration are met, the EPA 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 EPA if there is any inconsistency following a stock-take in relation to sealed radioactive sources that exceed the 'threshold activity' in the Schedule.

9.4.9 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.

9.4.10 Renewing a registration

The EPA 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.

9.4.11 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.

9.5 Definitions

The definitions of a radioactive substance, sealed radioactive source and sealed source device are:

radioactive substance means any natural or artificial substance whether in solid or liquid form or in the form of a gas or vapour (including any article or compound whether it has or has not been subjected to any artificial treatment or process) which emits ionising radiation spontaneously with a specific activity greater than the prescribed amount and which consists of or contains more than the prescribed activity of any radioactive element whether natural or artificial.

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

9.6 Documentation Required for Designated Radiation Areas (DRAs)

Records that cover the areas of use, monitoring, contamination and inspection of DRAs, are required to be kept by persons in control of these areas. The majority of the documentation required for a DRA where unsealed sources are used, is also required for other forms of radiation, viz, sealed sources, X-ray and laser equipment.

Generally the following are required:

- ⇒ Record of use of facility (log book);
- ⇒ Record of contamination surveys;
- ⇒ Record of leakage and dose rate levels;
- ⇒ Record of monitoring equipment (maintenance, calibration, service);
- ⇒ Inventory of radioactive substances, sources, devices and equipment;
- ⇒ Record of x-ray equipment usage;
- ⇒ Record of Laser usage (refer to "Laser Safety – Records" in Section 15);
- ⇒ Records of disposal of substances and wastes

For the records of use of the facility, the following would be the minimum required:

Date	Time	Person	Isotopes (or Laser wavelength, or X-ray power)	Signature

And a suggestion for the Contamination Survey recording would be:

Date	Person	Survey Method	Contamination (Y or N)	Level of Contamination and Type	Comments	Signature

A similar form could be used for the leakage testing of X-ray apparatus (refer to 'X-ray Diffraction & Fluoroscopy Safety – Radiation Monitoring' Section 14) and also for the recording of external dose rates for workplace monitoring (refer to 'Workplace Monitoring' Section 6)).

The records required for monitoring equipment could simply be kept in a bookkeeper's journal (refer to 'Legal Requirements & Recommended Practice for Monitoring Equipment' Section 6).

For details of the type of records required for **personal monitoring** refer to 'Records of Personal Monitoring' Section 6).

10 LABORATORY SIGNS AND ACCESS

10.1 Laboratory Signs

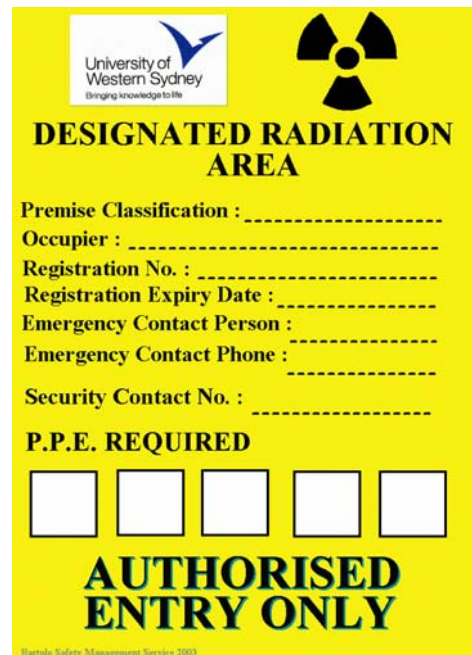
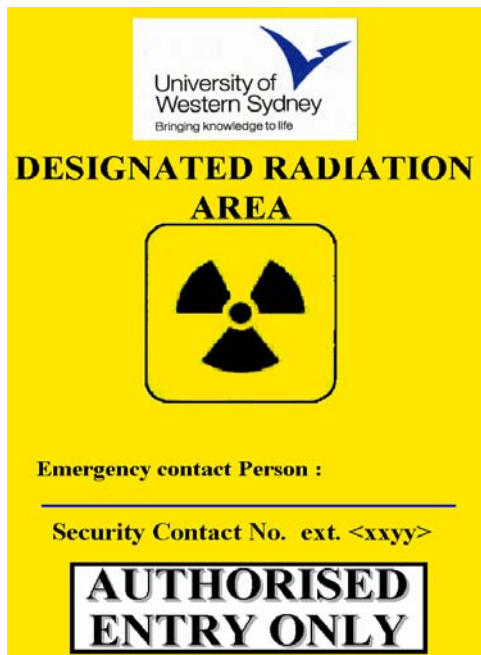
With radioisotope laboratories or any other laboratory that uses radiation, it is a requirement of both legislation and Australian Standards, that the appropriate warning and identification signs are used. These signs are to be displayed at the entryway and at other relevant places within the laboratory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

The symbol below is the internationally recognized tri-foil symbol for ionizing radiation:



This symbol is used extensively and denotes that some form of ionizing radiation hazard exists.

The tri-foil is incorporated in the first sign that the visitor to a laboratory should see before they enter the laboratory. This is in the DRA (designated radiation area) notice that is affixed to the door or entryway. It should look something like one of the following:

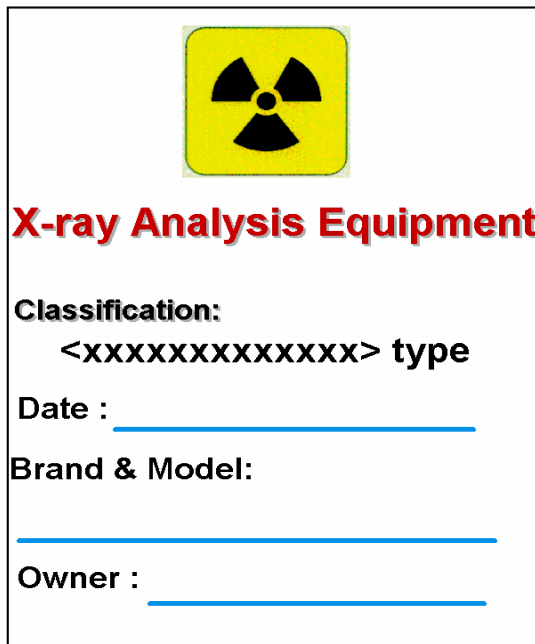


Please note that both these signs indicate that “Entry is only permitted to Authorised Persons”. This is to be strictly followed. Also note that in the right hand sign there is space for the laboratory classification and also the Occupier and Registration Number. As of July 1 2004 it is a legal requirement that premises that use or store radioactive substance are registered, and in the future this registration information will probably need to be prominently displayed. If either of these signs is not used, then the minimum to be displayed at the entryway is the tri-foil symbol and a sign similar to the following:



It is also expected (and recommended) that all other safety and laboratory hazard signs are used as appropriate.

All equipment (other than glassware) is to be labelled with at least the tri-foil symbol, or something similar to the following equipment sign (based on the current NHMRC/ARPANSA 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).



All storage facilities (including waste facilities) that are used for radioisotopes are to be labelled with at least the tri-foil symbol and an inventory must be readily available at or near the facility.

10.2 Radiation Laboratory/Facility Access and Security

10.2.1 Access

Since the escalation of global terrorism, the requirements for access and security are in the process of change. Access to and security of DRA is to be strict, and very well controlled. This applies to all facilities that use or store any radioactive material or ionising equipment. In 2005, the IAEA in cooperation with all its signatories and the international community developed a code of practice (COP) 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 the recommendations of this COP.

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 Staff 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 staff (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.

Maintenance staff, (and/or contractors) however, are not allowed into the facility until they have had some form of radiation safety instruction and have also received a **LETTER OF CLEARANCE** (see **RSO 11** Appendix 11) from the RSO (radiation safety officer) indicating that the facility has been monitored and it is safe for the general public (i.e. the maintenance staff) to enter the facility and only do the work that is required.

10.2.2 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 IAEA security document has a method of classifying isotopes (and quantities) in terms of security/risk factors, which are contained in the *ARPANSA Code of Practice: Security of Radioactive Sources*. The lowest requirement, depending on the classification, will be simple lock and key security, with the ability to be improved within 24 hours of notice of a change in the Terror Alert status. This classification is also going to be applied to transport.

11 LABORATORY/RADIOACTIVE SOURCE SAFETY

11.1 Introduction

(Much of this section is an aggregate of information contained in previous sections, put together for the purpose of giving a “comprehensive” outline that could be used without significant reference to other sections)

The concepts expressed in this section 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 staff.

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 ionizing 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).

HVL: The thickness of an absorber needed to reduce the radiation intensity by a factor of two is called the half value layer (HVL).

TVL: The thickness of an absorber needed to reduce the radiation intensity by a factor of ten is called the tenth value layer (TVL). Approximate lead TVL's and HVL's for some radionuclides are listed below.

Approximate lead TVL's and HVL's for some radionuclides are listed below

Nuclide	Gamma Energy (MeV)	HVL (mm)	TVL (mm)
¹²⁵ I	0.035	0.05	0.16
²⁴¹ Am	0.060	0.14	0.45
⁵⁷ Co	0.122	2.0	6.7
¹³⁷ Cs	0.662	6.5	21
²² Na	1.28	9.6	32
⁶⁰ Co	1.17 & 1.33	12	40

Example: At 1 m, a 1 GBq ⁶⁰Co source produces an exposure rate (approximately) of 0.370 mSv/hr. How much lead shielding is needed to reduce the rate to 0.01 mSv/hr (10 mSv/hr)? 40 mm of lead shielding (one TVL) will reduce the rate to 0.037 mSv/hr. Adding another 12 mm (one HVL) will make it 0.0185 mSv/hr. One more HVL will put the rate at about 0.0093 mSv/hr. So the total lead shielding needed is 40 + 12 + 12 = 64 mm.

Shielding Concerns

When designing shielding there are several points to be kept in mind.

- Persons outside the shadow cast by the shield are not necessarily protected.
- A wall or partition may not be a safe shield for people on the other side.
- Radiation can be "scattered" around corners.

11.2 General Rules

Australian Standard 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 (e.g. spill trays).
- 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 but 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 and 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 staff 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.

11.3 Radiation Safety Specifics

11.3.1 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.

11.3.2 Protection of the Eyes

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 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 should be made of 10 mm thick perspex or acrylic which totally stops beta radiation.

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

11.3.3 Working Surfaces

Polyethylene 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.

11.3.4 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 satisfactorily clean apparatus which is contaminated with a short-lived isotope, arrangements should be made with the department or school RSO for suitable storage until an acceptable radiation level is reached. Typically, this might be in a bin of suitable composition, permanently labelled in paint as follows:

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.

11.3.5 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 generating the waste.

11.3.6 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.

11.4 Monitoring and Quality Assurance

Monitoring and quality assurance involves the following distinct procedures:

- Personal Monitoring
- Area/Contamination Monitoring (refer to 'Contamination & Decontamination' in this section)

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.

11.4.1 Personal Monitoring

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

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

- TLD Monitor must be worn at waist level and under a 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 damaged, exposed to radiation or contaminated. Control TLDs must be stored away from radiation areas.

11.4.2 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 of radiation stores at least once per month.
- Surface contamination monitoring conducted weekly as a minimum.
- Annual calibration of monitoring equipment.

11.5 Contamination and Decontamination

11.5.1 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 (as low as reasonably achievable) principle in 'Radiation Safety Responsibilities and Procedures' (Section 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.

Radiotoxicity Group (refer to Section 13 'Prescribed Activity of a Radioactive Substance')	Maximum levels within laboratory Bq/cm²	Maximum level on skin or items leaving the laboratory Bq/cm²
Group 1	0.1	0.01
Group 2	1	0.1
Group 3a	10	1
Group 3b	100	10
Group 4	1000	100

11.5.2 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 beta particles, X-rays, and gamma rays a sensitive Geiger-Muller counter is satisfactory, although in the case of beta particles a thin window will be necessary to allow the beta 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 are used in the University, '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 beta and weak gamma producing isotopes it will be necessary to conduct a Wipe (smear) Test to assess levels of contamination. A Wipe Test consists of wiping the suspected area with a piece of filter paper that is several centimetres in diameter and then measuring the activity on the paper using a scintillation counter. A formula is then applied to the results to calculate the contamination.

11.5.3 Decontamination Procedure

Loosely attached radioactive material on the bench top or floor may be removed by wiping with damp paper toweling. If this does not achieve a reasonable result (again checked by a Wipe Test) then the use of radiation decontamination detergent will be required.

Every effort should be made to eliminate the contamination so that the activity on the filter paper is finally zero.

If contamination is persistent and firmly attached, and activity still exceeds the above maximum figures, specific decontamination solvents should be used with active wet abrasion. Options 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. Be aware that abrasion renders the surface unusable for further work unless it is stainless steel.

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 unacceptable and the affected area should either be removed or else covered with a screening material such as lead or concrete.

Refer to 'Procedure for Radiation Accident, Incident, Emergency Response and Spills' Section 2 for details of Radiation Spill Kits and procedures for decontamination of spills.

12 STORAGE

Storage of radioactive material is under critical review at the international level and the recommendations will be adopted in Australia in 2006. The review deals with classification of storage requirements and security levels. The level of security will become a major influence in the design of the storage facility when considering the **ARPANSA Radiation Protection Series “Security of Radioactive Sources”**. This document is to be incorporated into local legislation and as such the requirements contained in the document will become mandatory.

The Australian Standard (AS2243.4) on radioactive storage states:

- (a) Radioactive substances shall be stored separately from non-radioactive substances.
- (b) Radioactive substances shall be kept in a locked store that complies with the following:
 - (i) 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.
 - (ii) The store shall be constructed of durable, fire-resistant materials.
 - (iii) The store's interior surfaces shall be constructed of materials which can be decontaminated easily.
 - (iv) The store shall be adequately shielded to ensure that radiation levels outside the store shall not exceed:
 - 5 $\mu\text{Sv/hr}$ for locations accessible to occupationally exposed persons, (assuming the storage facility is within the laboratory or workroom – taken from International documents); and
 - 1 $\mu\text{Sv/hr}$ (when averaged over one week) for locations accessible to non-occupationally exposed persons, and members of the public.
 - (v) A radiation warning sign shall be displayed at the door of the store.
 - (vi) 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.
 - (vii) 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.
 - (viii) 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.

Section 12 – Storage

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



In addition, a current inventory containing the following information is to be attached to the facility:

Date	Isotope	Activity (Bq)	Volume	Details of labelled material	Licensee	School/ Dept.

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

13 RADIOACTIVE WASTE DISPOSAL

13.1 Introduction

The generator of radioactive waste remains the person responsible for this waste from “cradle to grave”, and this responsibility cannot be delegated. Hence, it is the generator who must ultimately ensure that the correct action is taken for the radioactive waste.

The ICRP has three waste concepts, these being:

- Delay and decay
- Concentrate and contain, and
- Dilute and disperse.

The first and second concepts are often used in the laboratory. For instance the simplest way to deal with ^{32}P and ^{125}I waste is to store it in an appropriate manner and location and let it decay away till it is no longer considered radioactive, and as such can be disposed of as either chemical or biological waste (depending on the material). The final concept (dilute and disperse) though not officially banned is disapproved (as it may at times be in breach of the Waste Guidelines (under the *Protection Of Environment Operations Act - POEO*) if the specific activity is at or over 100 Bq/gm – see below).

When applying the first two concepts it is also important to segregate the radioactive waste in terms of half life. Normally radioactive waste will need to be stored for a specific time until it has sufficiently decayed and may be safely disposed. In these circumstances, adequate shielding should be in place and the waste segregated according to its composition, half-life, specific activity, and dangerous goods class. The following examples are a guide:

Five days or less: Na-24, K-42, Cu-64, Tc-99m, Mo-99
Five days to two months: P-32, Cr-51, Fe-59, I-125, I-131, Cs-131
Two months to one year: S-35, Ca-45, Sc-46, Sn-113
Greater than one year: H-3, C-14, Na-22, Cl-36, Co-57, Co-60, Cs-137

Radioactive waste can be very complex to manage for the generator. Disposal via the sewer system is not a suitable option as there are limitations placed on the contamination of the sewer system by the State and Local authority. The Hospitals and Universities Radiation Safety Officers Group (HURSOG) has an agreement with Sydney Water (the Main NSW Authority) that allows contamination of the sewerage up to 100Bq/gm, and this is what all NSW Hospitals and Universities work to as a maximum.

As such the University sets the limit for disposal via the sink/sewerage system as that of the HURSOG Agreement, that is, no radioactivity greater than 100 Bq/gm (or ml) is allowed into the sewerage system. This is only if the isotope has no chemical or biological characteristics that could effect the environment (e.g., heavy metal, carcinogen, etc.) and thus would place it under control of other legislation such as the *Environmentally Hazardous Chemicals Act 1985*.

Under the Radiation Control Act 1990 and Regulations 1993 (and all subsequent amendments) it is a requirement that an institute/university/department/company has received written authority from the

Director-General to dispose of radioactive waste. The D-G has not to this date, had any need to give written authority to any group and as such this is not currently required for compliance.

Also, there are no set limits defined under this legislation, with the only legal requirement being that complete records of disposal are maintained, (refer to 'Procedure for Notification of Disposal of Radioactive Substances and Waste' Section 2).

For all solid and liquid waste (including radioactive waste), that is collected and processed by a licensed waste contractor, the DEC document **Environmental Guidelines: Assessment, Classification & Management of Liquid & Non-liquid Wastes**, must be adopted into waste procedures. This document is enacted through the *Protection of the Environment Operations Act 1997*.

13.2 Radioactive Waste Classification

Under these guidelines radioactive waste is classified as follows:

Hazardous Waste:

If the liquid or non-liquid waste has a specific activity greater than 100 Becquerels per gram and the total activity is more than the prescribed activity of any radioactive element listed in 'The Prescribed Schedule' on the following pages, or

Additionally, for liquids, the specific activity ratio, or total activity ratio, (see formulae below) is greater than 1.

Industrial Waste

If the specific activity ratio, or total activity ratio, (see formulae below) is greater than 1 for non-liquid waste, provided no other chemical or biological characteristic would make it classified as Hazardous.

Non-radioactive

If the other characteristics (chemical or biological) of the waste take precedence and the specific activity ratio, or total activity ratio, (see formulae below) is equal to or less than 1.

The following formulae are used for the classification of radioactive waste.

1. The **total activity ratio** is calculated using the expression:

$$\text{Total activity ratio} = (A1 \times 10^{-3}) + (A2 \times 10^{-4}) + (A3 \times 10^{-5}) + (A4 \times 10^{-6})$$

where A1 to A4 are the total activity of Group 1 to Group 4 radionuclides, as set out in Column 1 of 'The Prescribed Schedule' on the following pages (from Radiation Control Regulation 1993).

2. The **specific activity ratio** is calculated using the expression:

$$\text{Specific activity ratio} = SA1 + (SA2 \times 10^{-1}) + (SA3 \times 10^{-2}) + (SA4 \times 10^{-3})$$

where SA1 to SA4 are the specific activity (of the material) of Group 1 to Group 4 radionuclides, as set out in Column 1 of 'The Prescribed Schedule' on the following pages (from Radiation Control Regulation 1993).

Section 13 – Radioactive Waste Disposal

Once the two activity ratios have been calculated for all radioactive waste and the classification of the waste is determined, then refer to 'Procedure for Notification of Disposal of Radioactive Substances and Waste' (Section 2) for details of documentation requirements and procedures for notification and disposal, if the classification so allows. Waste documentation must clearly indicate the classification of the waste (hazardous, industrial and non-radioactive).

Prescribed activity of a radioactive substance

Column 1					Column 2	
Group 1						
Ac227	Am241	Am243	Cf249	Cf249	40 kilo- becquerels	
Cf250	Cf252	Cm242	Cm243	Cm244		
Cm245	Cm246	Np237	Pa231	Pb210		
Po210	Pu238	Pu239	Pu240	Pu241		
Pu242	Ra223	Ra223	Ra226	Ra228		
Th227	Th228	Th230	U230	U232		
U233	U234					
Any alpha emitting radionuclide that is not included in any other Group in this Schedule						
Group 2						
Ac228	Ag110m	At211	Ba140	Bi207		400 kilo- becquerels
Bi210	Bk249	Ca45	Cd115m	Ce144		
Cl36	Co56	Co60	Cs134	Cs137		
Eu152	Eu154	Ge68	Hf181	I124		
I125	I126	I131	I133	In114m		
Ir192	Mn54	Na22	Pa230	Pb212		
Ra224	Ru106	Sb124	Sb124	Sb125		
Sc46	Sr89	Sr90	Ta182	Ta182		
Tb160	Te127m	Te129m	Th234	T1204		
Tm170	U236	U236	Y91	Zr95		
Any radionuclide that is not alpha emitting and is not included in any other Group in this Schedule						
Group 3						
Ag105	Ag111	Ag111	Ar41	As73	4 mega- becquerels	
As74	As76	As77	Au196	Au198		
Au199	Ba131	Ba133	Be7	Bi206		
Bi212	Br75	Br76	Br82	C14		
Ca47	Cd109	Cd115	Ce141	Ce143		
Cl38	Co57	Co58	Cr51	Cs129		
Cs131	Cs136	Cu64	Cu67	Cu67		
Dy165	Dy166	Er161	Er169	Er169		
Er171	Eu152m	Eu155	F18	Fe52		
Fe55	Fe59	Ga67	Ga68	Ga72		
Gd153	Gd159	Hf175	Hg195m	Hg197		
Hg197m	Hg203	Ho166	I123	I130		
I132	I134	I135	In111	In115		
In115m	Ir190	Ir194	K42	K43		
Kr85m	Kr87	La140	Lu177	Mg28		
Mn52	Mn56	Mo99	Na24	Nb93m		
Nb95	Nd147	Nd149	Ni63	Ni65		
Np239	Os185	Os191	Os193	P32		
Pa233	Pb203	Pd103	Pd109	Pm147		
Pm149	Pr142	Pr143	Pt191	Pt193		
Pt197	Pt197	Rb81	Rb86	Re183		
Re186	Re188	Rh105	Rn220	Rn222		
Ru103	Ru105	Ru97	S35	Sb122		
Sc47	Sc48	Se75	Si31	Sm151		
Sm153	Sn113	Sn121	Sn125	Sr85		
Sr91	Sr92	Tc96	Tc97	Tc97m		
Tc99	Te125m	Te127	Te129	Te131m		
Te132	Th231	Ti200	Ti201	Ti202		
Tm171	U239	V48	V48	V48		
W181	W185	W187	Xe135	Y87		
Y90	Y92	Y93	Yb175	Zn62		
Zn65	Zn69m	Zr9				

Section 13 – Radioactive Waste Disposal

Group 4					
Ar37	C11	Co58m	Cs134m	Cs135	40 mega- becquerels
Cu62	Ga68	Ge71	H3	I129	
In113m	Kr81m	Kr85	N13	Nb97	
Ni59	O15	Os191m	Pt193m	Pt197m	
Rb87	Re187	Rh103m	Se73	Sm147	
Sr85m	Sr87m	Tc96m	Tc99m	Th nat	
Th232	U nat	U235	U238	Xe131m	
Xe133	Y91m	Zn69	Zr93		

14 SEALED SOURCE, SOIL MOISTURE PROBE AND XRD/F ANALYSIS EQUIPMENT SAFETY

14.1 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.

14.1.1 Requirements of Australian Standard 2243.4

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.

14.1.2 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 is 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 exceed 10uSv, in any one hour. 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.

14.1.3 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 ionizing 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 and display 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.

14.1.4 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:

- i) return to the supplier
- ii) transfer to another user
- iii) store in a suitable facility

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

14.1.5 Sealed Source Maintenance

It is expected that each sealed source is checked on a regular basis, either quarterly, six monthly or yearly to ensure that the sealing material maintains its integrity and that it is not degrading. The check involves examining the sealed source for faults such as cracks or chips, and conducting a Wipe Test of the surface to ensure that the radioactive isotope is not 'leaking' by separating from the sealing compound and becoming a free agent. This testing should be left to an expert familiar with large sealed sources or the equipment containing the source.

Comprehensive records must be kept for each sealed source, including results of wipe tests (Contamination Survey), visual inspections etc. Refer to 'Instrument Survey Procedures (Section 6) and 'Documentation Required for DRAs' (Section 9) for details.

14.2 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 submits a report on the review to the University RSO/IBRSC for approval. These procedures are to be reviewed at no greater than a 12 monthly interval.

14.2.1 Working Rules

- (a) 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 $\mu\text{Sv/hr}$ at any point 0.05m from the gauge surface; and
 - ⇒ 10 $\mu\text{Sv/hr}$ at any point 1m from the gauge surface.
- (b) Using the instruction manual (or the supplier/manufacture'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;
- (c) From (b) above the method(s) for conducting the survey, the sealed source wipe test and any other safety tests are to be documented;
- (d) 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 $\mu\text{Sv/hr}$ at the surface of the facility;
- (e) All operators/users of the gauge are to be personally monitored with a Neutron Type TLD and possibly a standard TLD: the TLD is to be worn at the belt level;
 - the control monitor is not to be kept near the gauge at any time;
- (f) 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. Appropriate signs, such as the example in Annex A, should be 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;
- (g) Emergency Procedures are to be documented and the emergency kit kept near (but not with) the gauge at all times;
- (h) All relevant authorizations (licenses, permission to access land for testing, etc) are to be obtained before the testing is to be conducted;
- (i) 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 of the vehicle). The unit is to be secured within the vehicle to prevent theft and loss, and the source(s) kept locked in the shielded position when the unit is not in use. The unit is not to be left unsecured or uncontrolled at any time;
- (j) 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;
- (k) The emergency contacts are:
- **The University Radiation Safety Officer, Ph: 0427 287630;**
 - **OHSR Unit, Ph: 9685 9930 or 9852 5178**
 - **The Radiation Control Branch, EPA/DEC, Ph: 02 9995 5000.**
- (l) The documentation to be maintained is as follows:
- 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 Records

14.2.2 Emergency Procedures

Written emergency procedures are to be developed and kept with the gauge at all times. Users of the gauge are to be trained in the emergency procedures. The manufacturer's instructions should always be the first source of information for the development of these procedures.

14.2.3 Responsibilities of the Licensee or Senior Researcher

The Responsible Person should notify the local area fire authority and police of the storage locations of each portable density/moisture gauge under their control. This is required for storage at permanent locations and is of particular importance when the gauge or gauges are stored at semi-permanent locations (as may be the case in field studies). Where the responsible person is required to organise the training of personnel, by an accredited person, on the use of the gauge (including all safety matters), this should be done at the initial induction of these 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 licensed (or students are exempted and under supervision during use of the gauge) 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.

14.2.4 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 ('as long as reasonably achievable') principle, portable density/moisture gauges should not be stored near regularly occupied or

frequented areas. The dose rate at the surface of this facility is to be less than 5 $\mu\text{Sv/hr}$ 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
- 2.1 Flammable gas
3. Flammable liquid
- 4.1 Flammable solid
- 4.2 Spontaneously combustible
- 4.3 Dangerous when wet
- 5.1 Oxidising agent
- 5.2 Organic peroxide
- 8 Corrosive

As radioactive materials are to be stored (in general) in a storage facility solely dedicated to radioactive storage, and designed as such, consideration needs to be given to ARPANSA and relevant Australian Standards documents, as well as legislative requirements.

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.

14.2.5 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 two sets 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.

14.2.6 Annex A: Radiation warning signs and labels

Radiation warning signs and labels, must conform to AS 1319 - 1994 *Safety signs for the occupational environment*, and AS 2342 - 1992 *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 tri-foil: 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)



EXAMPLE OF A SUITABLE WARNING LABEL FOR ATTACHMENT TO A PORTABLE DENSITY/MOISTURE GAUGE CONTAINING A RADIOACTIVE SOURCE

UNIVERSITY OF WESTERN SYDNEY	
Dept.: _____	Ph: _____
	
RADIATION SOURCE	
PORTABLE MOISTURE GAUGE	
MANUFACTURED BY: _____	_____
MODEL No.: _____	SERIAL No.: _____
MAX DOSE RATE AT THE SURFACE: _____	_____
DATE DOSE RATE MEASURED: _____	_____
RADIOACTIVE SOURCE	
RADIOACTIVE MATERIAL: _____	_____
ACTIVITY: _____	DATE OF MEAS: _____
SUPPLIED BY: _____	_____
ADDRESS: _____	_____
MODEL No.: _____	SERIAL No.: _____
ISO CLASS No.: _____	_____

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 (eg. caesium only, ²⁴¹Am/Be only or both).

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

14.3 X-ray Diffraction and Fluoroscopy Safety

The NH&MRC (soon to be replaced by ARPANSA document) "Code of Practice for Protection Against Ionizing 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

14.3.1 General Working Rules for 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.

- 1) No person shall allow the X-ray tube of an X-ray analysis unit to remain energized unless all warning lights, as required by the Code of Practice (CoP), are operating correctly.
- 2) 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.
- 3) 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.
- 4) 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.
- 5) **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) CoP for enclosed or partly enclosed units.
- 6) The necessary operations of the X-ray analysis equipment shall not be performed by inexperienced persons unless under direct supervision of an experienced operator.
- 7) 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.
- 8) 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.

14.3.2 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 these safety guidelines 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:

- (a) at all times carry out established procedures of operation and maintenance, and
- (b) report to the RSO any actual or suspected case of excessive exposure, endeavour to determine its cause, and take steps to prevent its recurrence.

14.3.3 Safety Guidelines for Partially Enclosed & 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:

- 1) 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:
 - be interlocked, or fixed so as to require the use of tools for removal,
 - incorporate collimator shields, and
 - 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 mGy in one hour.
- 2) It should be so positioned so 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 positioning is not

possible, beam stops or fixed shields shall be placed to adequately protect persons in these areas from the beam.

- 3) **It should be sited in a separate room or cubicle in which there are no other radiation sources.**
- 4) 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 (refer to 'General Working Rules for X-Ray Analysis' in this section). All working rules given in that section shall be implemented whether or not an interlock is inactivated or shielding structure is removed.

14.3.4 Non Complying X-ray Units

Each X-ray analysis unit which does not comply with 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 with 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 requirements as follows:

- 1) The rules required for partly enclosed units shall be included, and implemented whenever the unit is used.
- 2) 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.
- 3) A check-list of step-by-step procedures shall be prepared and used during the following operations:
 - before initiating an exposure
 - during an exposure
 - in terminating an exposure, and
 - during any non-routine operation of the unit, such as alignment of an X-ray beam.
- 4) 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.
- 5) No alteration should be made to the analysing equipment in use with the unit unless the X-ray tube is de-energized.
- 6) Interim working rules shall include the requirements for siting given in the previous sections, with the requirement 'should' being replaced by 'shall'.
- 7) The requirements of the following section (radiation monitoring) shall be incorporated in the working rules with the following amendments:
 - The requirement 'should' in personal monitoring shall be replaced by 'shall'.
 - 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.

14.4 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.

14.4.1 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 is opened.

14.4.2 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:

- 1) 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 10mGy 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.
- 2) If provided with meter indication, the meter shall be either:

- 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
 - 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.
- 3) 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.
- 4) 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:

<i>Type of Unit</i>	<i>Frequency of Monitoring</i>
<i>Enclosed</i>	<i>Quarterly</i>
<i>Partly Enclosed</i>	<i>Monthly</i>

NOTE: These times are for infrequently used research units.

15 LASER SAFETY

15.1 Introduction

The University of Western Sydney has laser apparatus used on campus. As such, users of lasers are encouraged to comply with the relevant standard (AS2211.1-2004), any other relevant codes of practice and the University's Radiation Safety Program.

The objectives of this safety program are:

- To protect persons from laser radiation in the wavelength range 100 nm to 1 mm by indicating safe working levels of laser radiation and by introducing a system of classification (as per the standard) of lasers and laser products according to their degree of hazard.
- To lay down requirements for the user to establish procedures and provide information so that appropriate precautions can be taken.
- To ensure adequate warning is given to individuals of the hazards associated with 'accessible radiation' from laser products through the provision of signs, labels and instruction.
- To reduce the possibility of injury by minimising exposure to unnecessary 'accessible radiation', improving control of the laser radiation hazards through protective features, and providing specific user control measures for the safe usage of laser products.

15.2 References

- *AS/NZS 2211.1:2004 Safety of laser products: Equipment classification, requirements and user's guide.*
- *AS/NZS 4173:2004 Guide to the safe use of lasers in health care*
- *AS 2397-1993 Safe use of lasers in the building and construction industry*
- *AS/NZS 1336:1997 Recommended practices for occupational eye protection* – this standard describes a newer classification and marking scheme for laser eyewear
- ARPANSA 1999 "Visible light lasers used for surveying, levelling and alignment."
- ARPANSA 1995 "Code of Practice for the safe use of lasers in schools".
- ARPANSA 1995 "Code of Practice for the safe use of lasers in the entertainment industry".
- IRPA/ILO 1993 "The use of lasers in the workplace" OHS Series No.68. Geneva, International Labour Office.

15.3 Responsibilities

The University has a line of responsibility as defined in the University OH&S Policy and the UWS Radiation Safety Guidelines that similarly applies to lasers. Within the guidelines of the relevant Standards and International Codes of Practice it is primarily the head supervisor or researcher who is responsible for laser safety. This includes responsibility for all relevant

documentation and institutional procedures.

15.4 Nature of the Laser Hazard

The word **LASER** is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. A simplified meaning of each of these terms is:

- Light** - a loose term used to include visible as well as invisible radiation (e.g. infrared).
- Amplification** - the increase in intensity of light.
- Stimulated Emission** - the physical process that produces the amplification.
- Radiation** - a general term like 'light'.

To appreciate the effects of laser radiation on tissue, a basic understanding of lasers and their properties is required. A correct matching of a particular laser and its characteristics to the application is critical, as different lasers operating in different modes have different effects in different tissues.

As a result of known tissue hazards associated with laser radiation, a number of international and Australian standards which set out requirements for laser safety have been published or revised in recent years (refer to 'References' in this Section). This guideline provides advice on the administrative measures needed to implement these standards in the University.

15.4.1 Modes of Operation

Most lasers operate in one of two principal modes:

Continuous wave (CW): Where the beam is present continuously while in operation. The beam may also be turned off mechanically or electronically for brief periods (e.g. half a second). This is often called pulsed CW mode.

Pulsed mode: Where the laser energy is not continuous, but released entirely over a very short time, such as a millionth of a second, for example Q-switched lasers. Here both mirrors are totally reflecting, confining a large amount of energy in the laser cavity. One mirror is then made totally transmitting, and the energy leaves the cavity in a very brief pulse. This process may be repeated to produce a sequence of pulses. A special form of pulsed mode where the exciting energy source is pulsed is used in carbon dioxide lasers, and is often called superpulse or ultrapulse mode.

15.4.2 Biological Effects

Laser Interactions with Tissue: Lasers are able to produce a range of biological responses in tissue, determined by the various processes of energy conversion within biomolecules.

Optical Interactions: When light falls on tissue, it may undergo one or more of the following four processes:

- (a) reflection,
- (b) scatter, i.e. a change in direction,
- (c) absorption, where the energy is transferred to the tissue,
- (d) transmission, where no energy is lost during passage through the tissue.

Parameters which are important in determining laser interaction with tissue are wavelength, power density and pulse duration.

Laser-tissue interactions include thermal, photodisruption, electromechanical (or photomechanical), photochemical and biostimulation. There is much variation in the uses of these and other terms in the literature.

Thermal: The thermal mechanism involves conversion of laser energy into heat. With the laser's ability to be focused to points of a few micrometres or millimetres in diameter, the resulting high power densities can create very high temperatures. The wavelength of the incident radiation determines the depth of penetration, the amount of tissue removal and the degree of bleeding control (haemostasis). Nd:YAG radiation penetrates about 4 mm, argon about 2 mm, and carbon dioxide <0.01 mm.

The temperature reached determines the effect : <45°C, no effect, 45-65°, protein denaturation/coagulation, >100°C, boiling of cellular water and eventual ablation of tissue. Scatter of the laser radiation and conduction of heat in tissue may also play a role in determining the extent of thermal damage in tissue.

Photoablation / Photodisruption / Photolysis: This involves direct breaking of molecular bonds and subsequent release of biological material. As an example, excimer lasers which operate at several ultraviolet wavelengths can produce photoablation in tissues without any appreciable thermal effect.

Ultraviolet radiation is very strongly absorbed by biomolecules so penetration depths are small, of the order of a few micrometres.

Electromechanical (or Photomechanical): The interaction requires an extremely high power density delivered in extremely short pulses, with a duration of nanoseconds (ns). Very high temperatures lasting only the length of the pulse are created, resulting in a shockwave akin to the thunder which follows a lightning flash. A localized mechanical rupture of tissue occurs.

Photochemical: The photochemical mechanism is a chemical process initiated by the absorption of visible ultraviolet or infra-red radiation. These reactions convert light energy into chemical energy. Everyday examples are the tanning of skin by sunlight and the taking of photographs.

Biostimulation: Low intensity lasers are purported to produce a stimulatory effect in tissue. Biostimulation lasers, operating in the red or infra-red region have been reported to produce microcirculatory effects and to stimulate certain cellular processes. There are many thousands of these lasers in regular use in specialties such as physiotherapy and acupuncture.

15.5 Options for Hazard Control

As with ionizing radiation, laser hazards may be controlled by the use of engineering controls, administrative controls and personal protective equipment, either singly or in combination. As

a general principle engineering controls are preferred where appreciable hazards exist, although these may need, in some cases, to be supplemented by the use of appropriate eye protection.

Low powered lasers, such as those incorporated in consumer products (e.g. laser pointers), usually have a high degree of inherent safety and no additional safety measures are needed. The lasers used in research are often high power units and while engineered safety features are required, written safe working procedures (or SOPs) are also important – particularly in research applications where equipment configurations may need to be altered frequently. This increases the importance of the safety awareness of users as more reliance must be placed on procedural safety measures and the use of personal protective equipment such as appropriate safety goggles.

Those responsible for laser use need to be aware that while laser controls are not addressed specifically in current legislation, injuries caused by a laser could fall within the domain of common law liability. In addition, failure to implement appropriate safety standards would constitute a breach of the employer’s obligations set out in the *OHS Act 2000*. This reinforces the importance of compliance with well recognised Australian Standards based on international recommendations.

15.6 Laser Classification

The most recent version of the Australian Standard, *AS/NZS 2211.1:2004*, has adopted the EIC system of classification of lasers.

The previous system of classification was described as follows:

“Lasers are divided into hazard classes, depending on the power output and the risk of damage from accidental exposure. The classes are:

Class 1 - *intrinsically safe*

Class 2 - *low power devices emitting visible light - not completely safe, but the blink reflex will protect the eye*

Class 3a - *similar to Class 2, except that, if the beam is focused onto the eye by, say, binoculars, the beam could be hazardous*

Class 3b - *either the blink reflex is not fast enough to prevent damage, or the beam is invisible and therefore the blink reflex cannot work*

Class 4 - *high power devices capable of causing immediate injury to the eye or skin – diffuse reflections may be hazardous”*

The EIC system now used in Australia classifies lasers as follows:

Class 4	Unsafe for eyes Unsafe for skin
Class 3B	Unsafe for eyes Generally safe for skin
Class 3R	Safe with (0.25 s.) aversion response no viewing aids
Class 2M <small>Visible wavelengths only</small>	Safe with no viewing aids
Class 2 <small>Visible wavelengths only</small>	Safe with (0.25 s.) aversion response including viewing aids
Class 1M	Safe with no viewing aids
Class 1	No precautions required

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15.7 General Safety Precautions

Signs - Laser warning signs as described in *AS/NZS 2211.1:2004* must be placed on all entrances to a room where a laser is in use. Illuminated warning signs may also be used. The illuminated signs may have two functions – for example a steady light indicates that the power to the laser is on, and that the laser may be used at any time. A flashing light indicates that the laser is in use.

Hazard Area – Known as the Nominal Ocular Hazard Area (NOHA) is the region around a laser where eye protection is required. Normally this is the entire room in which a laser is used, but may be less for specific lasers (e.g. ophthalmic lasers where the NOHA may only be a metre from the laser).

Eye Protection - Eye protection **appropriate to the laser type in use** must be worn in the NOHA. Refer to *AS/NZS 1336:1997* for details. It is important to note that there is no universal protective eyewear, and that staff must check that the correct protection is available (the wavelength for which the eyewear is designed is marked on the frame). Spare eyewear must be placed outside the laser room for staff wishing to enter.

Fire Precautions - Because many lasers have the ability to ignite flammable materials, staff must be aware of the location of a nearby fire extinguisher.

Window Coverings - Visible and near visible laser beams (effectively all except CO2 lasers) will pass through window glass, and opaque coverings must be placed on windows when these lasers are used.

Master Keys - The master key for each laser shall be kept by the laser supervisor in a secure place when not in use, and the laser can only be energised by an authorised person.

Maintenance - Maintenance shall only be performed on the laser by appropriately authorised and trained persons, and these persons shall ensure that the laser is left in a safe condition following maintenance.

Records - A record of each procedure must be completed in a 'Laser Log Sheet' where the following is to be recorded:

- Date;
- User (name);
- Equipment (manufacturer, model, type);
- Procedure;
- Duration;
- Problems/comments; and
- Signature of User

15.8 Administrative control requirements

An administrative control framework is needed to ensure that the procedures and conditions necessary for a safe working environment are put in place. Where lasers of class 3 (all 3 subdivisions) and class 4 are used, more detailed (and in some cases, site-specific) safe

working rules and emergency procedure manuals will need to be developed. Advice can be obtained from the University Radiation Safety Officer regarding the content of such local safety guidelines.

To aid in managing the risk associated with the use of lasers, the following controls are to be implemented where lasers are used:

1. The head of a department or research centre where lasers are used is responsible for ensuring that these safety guidelines are implemented.
2. Each school, department or research centre which uses lasers of classes 3 or 4 shall keep a local register of the equipment in their possession (obtain copy of Laser Equipment Registration Form, **RSO 12** from Appendix 12). The register is to include full details of make, model, serial number, power output, classification and the designated purpose for use of each particular laser. Where a laser is employed as a research tool capable of multiple uses, this should be indicated. A copy of the completed Laser Equipment Registration Form must also be forwarded to the OHSRU for central records.
3. The Head of a school, department or research centre where lasers are used shall appoint a person with appropriate knowledge to act as a Laser Supervisor and any such deputies as may be required to cover absentee situations.
4. Every laser of Class 3 or 4 shall have affixed to it (in addition to such labels required under appropriate Australian Standards) the name of the Laser Supervisor and a telephone number at which they may be contacted.
5. Appropriate safe operating procedures (SOPs) must be available in each school, department or research centre in which lasers of classes 3 or 4 are used. The SOPs must list the hazards associated with the particular lasers used in the area, the conditions under which they can be used and the precautions/control measures necessary to ensure safety.
6. Lasers for use in surveying, building or construction must be used in compliance with Australian Standard *AS 2397-1993 Safe use of lasers in the building and construction industry*. As with *AS/NZS 2211.1:2004*, a copy is to be kept by the Laser Supervisor and made available to users.
7. Lasers used in the health care professions have particular hazards unique to those applications. The use of lasers in dental and medical practice must comply with Australian Standard *AS/NZS 4173:2004*. This standard emphasizes the need for training of laser operators and the importance of quality assurance procedures in achieving and maintaining safe working conditions in diagnostic and therapeutic applications.
8. All persons who use Class 4 or Class 3B [other than class 3B (restricted)] lasers are to complete the Laser User Registration Form **RSO 13** (refer to Appendix 13), keep a copy for local records and forward a copy to the OHSRU for central records. Users of these laser classes shall also receive eye examinations in compliance with *AS/NZS 2211.1:2004*, (including users in the health care professions addressed by *AS/NZS 4173*) at the following times:

Section 15 – Laser Safety

- (i) At the commencement and termination of work with lasers of these classes.
 - (ii) Following any apparent or suspected laser exposure in excess of the relevant maximum permissible exposure (MPE) as given in *AS/NZS 2211.1*.
 - (iii) Following any serious injury to, or illness of the eye.
9. Eye examinations must be performed by an optometrist or ophthalmologist and should follow the details given in the appropriate standard and be recorded on the form in Appendix F of *AS/NZS 2211.1:2004*. A copy of this form must then be forwarded to the OHSRU for central records.
10. Pre-placement or periodic examination of the skin is generally not considered essential or cost effective but an examination of the skin by a medical practitioner should be conducted after an accidental exposure in excess of the maximum permitted exposure (MPE) in conjunction with a full biophysical investigation of the accident. Details of all examinations shall be recorded and a copy forwarded to the OHSRU.

16 REFERENCES

16.1 Legislation

- NSW OHS 2000 Act and Regulations
- NSW Radiation Control Act 1990 (and all subsequent amendments)
- NSW Radiation Control Regulations 1993 (and all subsequent amendments)
- NSW Protection of the Environment Operations Act 1997
- NSW Protection of the Environment Operations (Waste) Act
- NSW Waste Avoidance and Recovery Act 2001
- NSW Environmentally Hazardous Chemicals Act 1985
- NSW Transport of Dangerous Goods (Road and Rail) Act 1998

16.2 Codes of Practice

- ARPANSA Web Page – <http://www.arpansa.gov.au/>
- ARPANSA RPS 1: Recommendations for Limiting Exposure to Ionizing Radiation (Printed 1995 - Republished 2002) and
- National Standard for Limiting Occupational Exposure to Ionizing Radiation (Printed 1995 - Republished 2002)
- ARPANSA RPS 1: Code of Practice for the Safe Transport of Radioactive Material (2001)
- ARPANSA RPS 5: Code of Practice and Safety Guide for Portable Density/Moisture Gauges Containing Radioactive Sources (2004)
- NHMRC (now by ARPANSA) RHS No.4: Code of practice for the safe use of radiation gauges
- NHMRC (now by ARPANSA) RHS No.9: Code of practice for protection against ionizing 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)
- NHMRC (now by ARPANSA) RHS No.32: Intervention in emergency situations involving radiation exposure (1990)
- NHMRC (now by ARPANSA) RHS No.38: Recommended limits on radioactive contamination on surfaces in laboratories (1995)

16.3 Australian Standards

- AS/NZS 2982.1 – 1997. Laboratory Design and Construction Part 1: General Requirements
- AS/NZS 2243.1 – 2005. Safety in laboratories Part 1: Planning and operational aspects
- AS2243.4 – 1998. Safety in Laboratories Part 4: Ionizing radiations
- AS2243.5. Safety in Laboratories Part 5: Non-ionizing radiations

16.4 Other

- Cember, H., *“Introduction to Health Physics”* 3rd Edition. McGraw-Hill. New York. 1996
- GE Nuclear Energy. *“Nuclides and Isotopes – Chart of the Nuclides”*. Fifteenth Edition. GE San Jose, USA. 1996
- Haski, R., Cardilini, G, & Bartolo, W.C.F. *“Laboratory Safety Manual”*. CCH Publishing, Sydney, Australia. 1992
- Higson, D.J., “Are there risks from low level radiation?” *Radiation Protection in Australasia* Vol 19, No. 1, pp.20-25, 2002
- IAEA Safety Series No. 115: *“International Basic Safety Standards for Protection against Ionizing Radiations and for the Safety of Radiation Sources”*. Vienna 2003
- IAEA Safety Standards Series No. RS-G-1.1. *“Occupational Radiation Protection”*. Vienna. 1999
- International Commission on Radiation Protection. *“2005 Recommendations Of The International Commission On Radiological Protection”*. ICRP Draft Publication. ICRP Website. 2004.
- Martin, A., and Harbison, S. *“An Introduction to Radiation Protection”* 4th Edition. Chapman and Hall, London. 1996
- Turner, J. E., *“Atoms, Radiation and Radiation Protection”*. John Wiley, New York. 1995
- Wrixon, A.D., Barraclough, I., and Clark, M.J., *“Radiation, people and the environment”*. IAEA, Vienna, 2004

17 APPENDIX

The following Appendix contain relevant forms that are to be used as required by all UWS staff and students in order to comply with the procedures detailed in these guidelines.

- 17.1 A1 - [Student Exemption to the Radiation Licencing requirements of the Radiation Control Act \(1990\)](#)
- 17.2 A2 - [Licence Exemption Register](#)
- 17.3 A3 - [Application to Purchase/Acquire Radioactive Substances](#)
- 17.4 A4 - [Application to Purchase/Acquire Irradiating Apparatus](#)
- 17.5 A5 - [Register of Licence Holders](#)
- 17.6 A6 - [Register of Irradiating Apparatus](#)
- 17.7 A7 - [Register of Radioactive Substances](#)
- 17.8 A8 - [Disposal of Radioactive Substances/Waste](#)
- 17.9 A9 - [Report of a Radiation Accident/Incident](#)
- 17.10 A10 - [Proposal for a Biological and/or Radiation Research or Teaching Project](#)
- 17.11 A11 - [Letter of Clearance for Maintenance Personnel](#)
- 17.12 A12 - [Laser Equipment Registration Form](#)
- 17.13 A13 - [Laser User Registration Form](#)
- 17.14 A14 - [Radiation Safety Checklist: Laboratory Design and Construction](#)
- 17.15 A15 - [Radiation Safety Checklist: General](#)

APPENDIX 1: RADIATION SAFETY

Student Exemption
to the Radiation Licencing requirements of the Radiation Control Act (1990)

I, _____, Radiation Licence Number _____ Hereby give approval to _____, Student No. _____, a student at UWS enrolled in the course of _____, undertaking the subject _____, for use of the radioisotope(s) _____ in the laboratory, Building No. _____ and Room No. _____

The days this student is allowed to do this work are: **MON TUE WED THU FRI** and only during the times of _____

This exemption is in force for the following period:

(Note: Exemptions are for a period of no greater than 12 months)

The radiation supervisor(s) for this work:

Name: _____ Licence No. _____

Name: _____ Licence No. _____

(Optional) This approval is subject to the following conditions:

Signed

Date

APPENDIX 2: RADIATION SAFETY

Licence Exemption Register

SCHOOL/CENTRE _____

When exemptions are granted, the following form is to be completed, a copy taken for the School/Department records, and the original forwarded to the OHSR Unit for central records.

LICENCE EXEMPTION REGISTER						
STUDENT NAME	STUDENT NO.	COURSE OR CLASS NO	TIME OF VALIDITY	LICENCEE	SUPERVISOR	DATE

APPENDIX 3: RADIATION SAFETY

Application to Purchase/Acquire Radioactive Substances

Details of Licence Holder:

Surname: First Name:

School / Centre:

Radiation Licence Number: Type / Conditions:

*delete section which is not required

- *A Application for permission to purchase, store and use reportable quantities of radioactive substances (NB. This RSO/IBRSC approved application must be kept for local records and a copy sent to OHSRU for central records)
- *B Application to acquire (other than through purchases), store and use reportable quantities of radioactive substances

Substance (Radioactive Isotope):

Quantity:(in SI Unit)

Chemical Composition / State (e.g. Powder):

Location of Storage of Substance:

Laboratory / Facility Name:

Building No.: Room No.:

Specific Location in above:

Briefly describe the main uses of the radioactive substance:

.....
.....
.....

Expected duration of use: From **To**

How will substance be disposed of?

When will substance be disposed of?

Signature of Applicant

Date

RSO/IBRSC APPROVAL:

Project Approval No. (from original IBRSC Proposal)

.....

RSO/IBRSC Chairperson Date.....

Notification of Disposal

Date of Disposal: _____

Licence Holders signature: _____

Appendix 4: Radiation Safety

Application to Purchase/Acquire Irradiating Apparatus

(Purchasing is to be in accordance with UWS Purchasing and Procurement Procedures and Tender Board Policy)

Surname: First Name :

School/Centre :

Radiation Licence No. : Type/Conditions:

.....

*delete section which is not required

***A Application for permission to purchase and use irradiating apparatus**

(NB. This RSO/IBRSC approved application must be kept for local records and a copy sent to the OHSRU for central records)

***B Application to acquire and operate irradiating apparatus, other than equipment already registered**

Apparatus:

To be completed if the above named person does not hold a Licence under the Radiation Control Act 1990.

Name of Licence holder:

Radiation Licence No.: **Type/Conditions:**

Licence Holder's Signature:

Location of apparatus:

Laboratory / Facility Name:

Building No. Room No.

.....

Specific Location in above

Briefly describe the main uses of the apparatus:

.....
.....
.....
.....

Expected duration of use (if not long term): From to.....

Signature of Applicant **Date**

RSO/IBRSC APPROVAL

Approval No.: RSO/Chairperson:.....Date:.....

APPENDIX 5: RADIATION SAFETY

Register of Licence Holders

Please complete this form for each member of School/Centre who holds a licence under the Radiation Control Act (NSW) 1990 to possess/use radioactive substances and/or possess/operate irradiating apparatus.

Return the completed form to the RSO/OHSRU.

SCHOOL/CENTRE:

NAME	TYPE OF LICENCE AND CONDITIONS (Include Licence No, Type, Conditions – e.g., level of activity)	EXPIRY DATE
<i>E.g. Dr John Smith Phone 3x xxx</i>	<i>Licence No. R 12345 Type R5, R8, R14 Conditions: H3 40MBq, C14 80MBq, I125 20MBq Other details</i>	<i>30/11/04</i>

APPENDIX 6: RADIATION SAFETY

Register of Irradiating Apparatus

Please complete this form for each member of School/Centre who holds a licence under the Radiation Control Act (NSW) 1990 to possess/operate irradiating apparatus.
Return the completed form to the RSO/OHSRU.

SCHOOL/CENTRE

IRRADIATING APPARATUS Inc. no. if applicable	LOCATION (Inc. Building no. and room No.)	PERSON RESPONSIBLE And Licence No.
<i>E.g. Toshiba Tomo Unit No. I-12345</i>	<i>Building 10, room 147</i>	<i>Dr John Smith Lic. No. I 12345</i>

APPENDIX 7: RADIATION SAFETY

Register of Radioactive Substances

Please complete this form giving details of all radioactive substances, as prescribed under the Radiation Control Act (NSW) 1990, which are used or stored by member(s) of the School/Centre.

Return the completed form to the RSO/OHSRU.

SCHOOL/CENTRE

RADIOACTIVE SUBSTANCE	LEVEL OF ACTIVITY	LOCATION OF STORAGE/USE (Inc. Building no., room No. and specific location in room)	PERSON RESPONSIBLE And Licence No.
<i>E.g. Toshiba Tomo Unit No. I-12345</i>	<i>Building 10, room 147</i>		<i>Dr John Smith Lic. No. I 12345</i>

APPENDIX 9: RADIATION SAFETY

REPORT OF RADIATION ACCIDENT/INCIDENT
(A UWS Accident/Injury/Incident/Hazard Notification Form must also be completed)

Responsible Person or Licensee:

Date Reported to OHS/RSO: Confidential

First Name(s): Surname:

Licence No.: Renewal Date:

Accident/Incident Type:

- | | |
|---|--|
| <input type="checkbox"/> Hazard | <input type="checkbox"/> Spill |
| <input type="checkbox"/> Loss | <input type="checkbox"/> Equipment Fault |
| <input type="checkbox"/> Equipment Misuse | <input type="checkbox"/> Human |

Location & Time Details:

Campus: Building

Room: Date/Time:

If Unsealed Source, Isotope & Form:

contaminated Area (m²):

If Equipment, equipment details:

Contamination/Emission period (mins/hrs):

Persons Involved (name):

Person(s) possibly exposed: 1)

2)

3)

Witness(es): 1)

2)

Estimates of Possible Exposures:

- Person 1: Personal Dosimeter Estimate
- Person 2: Personal Dosimeter Estimate
- Person 3: Personal Dosimeter Estimate

Details of any Medical Examinations:

Add extra pages for medical details

Details of accident and Subsequent Investigation:

For both Responsible Person and RSO; Add extra pages if necessary

Recommendations to rectify or prevent further occurrence:

For RSO only; Add extra pages if necessary

Signed by Reportee: Date:

RSO/OHSU ACTION

RSO

Date:

UWS BIOSAFETY AND RADIATION SAFETY COMMITTEE

Proposal for a Biological and/or Radiation Research or Teaching Project

- Use this application for permission to carry out laboratory teaching or research involving the use of human blood, tissues or other biological material or recombinant DNA or ionising radiation sources or other activities with significant biosafety hazard.
- Refer to the information package (currently being developed) for assistance in understanding the issues associated with the use of animals in research and teaching.
- Reference should be made to the [Standard Operating Procedures](#) (SOP's) and the [Occupational Health & Safety Policies and Procedures](#) in the completion of this application.
- **If the proposal involves the importation of biological material directly from an overseas company, complete the Section D 'Notification to import biological material directly from an overseas company' (page 10). Please note this is a notification to the BRS Committee only. An application for a permit is submitted directly to [AQIS](#).**
- Projects must not start before receipt of written Biosafety and Radiation Safety approval.
- Changes to any item marked Δ must be reported to the BRSC Ethics Officer immediately. Phone the BRSC Executive Officer on (02) 47360884.
- The form must be word-processed with signatures in black ink.
- Incomplete forms or applications on previous versions of the application form will not be accepted.
- Appendices should show project title and question number.
- ALL sections must be completed – mark N/A on those not applicable.
- The BRSC will approve teaching proposals for periods of up to three years, subject to the nature of the project remaining substantially unaltered and the nominated facilities remaining unchanged during the period of approval. All other research proposals will be approved for a defined period of time as specified by the committee.
- Lodge this proposal at least 1-2 months prior to the start of the project.
- Submit 13 copies along with the original (14 in total) to the BRSC Ethics Officer.
Postal address: UWS, Office of Research Services, K1.118, Penrith Campus, Locked Bay 1797, Penrith South DC NSW 1797.

Does your project involve:	Please tick	Approval number (if applicable)	Date of approval (if applicable)	Expiry date (if applicable)
The use of animals in Australia or overseas	<input type="checkbox"/> Yes <input type="checkbox"/> No			
Human participants	<input type="checkbox"/> Yes <input type="checkbox"/> No			

- Please tick which sections of this application form have been completed: A B C D E

It is the responsibility of the principal investigator to obtain approvals from the appropriate university committee, state or commonwealth authority before commencement of the project. Where approval has been received, please enter in the relevant information. For information on requirements and approvals, refer to: <http://www.uws.edu.au/about/adminorg/devint/ors/ethics>

SECTION A - ADMINISTRATION

1. Short project title or name of the teaching course being offered.

2. Principal investigator

Name of principal investigator:

School/company name:

ΔContact phone/fax, email address:

ΔAfter hours phone/fax:

Relevant qualifications, experience and training:

Radiation licence no.
(note if exempted or N/A)

Expiry date:

Δ. Address for correspondence:

Signature:

Date:

3. Others directly involved in the project.

Name of co-investigator:

School/company name:

Degree being undertaken:

ΔContact phone/fax, email address:

ΔAfter hours phone/fax:

Relevant qualifications, experience and training:

Radiation licence no.
(note if exempted or N/A)

Expiry Date:

Δ. Address for correspondence:

Signature:

Date:

Δ**3a.** Please attach details (including relevant qualifications, experience and training) for all persons (such as associate investigators) involved in this project. Appendices should show project title and question number.

3b. Declaration to be signed by Head of School / Research Centre Director

In signing, I certify that the project is appropriate to the general facilities available, and that I am prepared to have the project carried out in my School/Centre.

Full name of signatory:

Signature:

Date:

4. Project details: Please indicate whether this application is for:

4a. Type of project: Please tick which one is applicable.

- Research involving human blood or tissues or other biological material.
- Teaching involving human blood or tissues or other biological material.
- Recombinant DNA. If yes, please tick the type of dealing (as per the Gene Technology Act 2000 and Gene technology Regulations 2001)
 - Exempt dealing. Please list the item 1-5 of [Schedule 2](#), Part 1 of the Regulations.
 - Notifiable low risk dealings.
 - Licensed dealing without intentional release.
 - Licensed dealing with intentional release.
- Other:
- Radiation work.

4b. A new project? Yes No

4c. A project which has (previously or simultaneously) been submitted to this or another IBC?
Yes No

4d. Has an application for this or a similar project been refused by this or another IBC?
Yes No

If Yes, provide details:

4e. A significantly revised current protocol? Yes No
 If Yes, quote the approval number.

4f. Source and grant identifier number of project funds. *Please include one copy of the grant application when you submit this application to the BRSC.*

4g. Research category codes

Please choose a broad type of category and up to 4 research codes. Codes must be entered at the most detailed level (6 digit subject level – must not end in zero) <http://www.uws.edu.au/about/adminorg/devint/ors/rodevelopment/codes>

Type of Activity (a)	%	RFCD Code (b)	%
Pure Basic			
Strategic			
Applied			
Experimental			

4h. Is any of the specified information contained in this application confidential, commercial information? Yes No

4i. Project duration (indicate the proposed date, month and year).
 Project commencement date:
 Project completion date:

SECTION C – FOR BIOLOGICAL AND RECOMBINANT WORK ONLY

9. Location(s) of project.

List the areas/laboratories at UWS in which the samples are to be handled. Include campus location, building number and laboratory number

9a. Will this project be undertaken in a NSW health facility? Yes No
If Yes, have all personnel associated with the project complied with the Occupational screening and vaccination against Infectious diseases, as detailed in NSW Health Departmental Circular? Yes No

9b. Will this project be undertaken in an off-campus facility? Yes No
If Yes, list the facility and the name of the approving IBC or safety committee.

10. Containment Level

Does the work require special containment? Yes No
If **Yes**, what level?

10a. Are personnel involved in this project authorised to enter physical containment PC2/PC3/PC4 laboratories? Yes No

10b. Have personnel involved in this project been inducted and trained in the PC2/PC3/PC4 work practices and signed a declaration stating their compliance with the practices when working in such facilities? Yes No

10c. Describe the storage facilities and security that will be used in the containment area?

10d. Has the containment area got adequate signage? Yes No
If **No**, please elaborate:

Are aerosols likely to be produced? Yes No
If **Yes**, will a biological safety cabinet (Class II) be used? Yes No

Origin

Does this project involve the use of material of human origin? Yes No

If **Yes**, please provide an explanation of the reasons the information cannot be obtained using material derived from sources other than human.

11a. If a cell line is to be used, list the type of cell line.

11b. Does the project involve the use of biological material to be imported directly from an overseas company?

Yes No

If **Yes**. Please complete and attach the 'UWS notification to import biological material directly from an overseas company' to this application.

11c. Has approval to import the material from [AQIS](#) been obtained? Yes No

If Yes, provide the AQIS approval number:

12. Dealings with genetically modified organisms

12a. Has an [OGTR form for DIR, DNIR, NLRD](#) been attached to this application for approval?

Yes No

12b. List the host/vector system used

Host	Vector

13. Microorganisms or other biological material

Identify the types of microorganisms used or potentially present in samples to be used and their risk group as defined by Australian Standards AS2243.3, Safety In laboratories - Microbiology (2001) [This standard can be viewed via the [UWS Library website](#) through E-Resources]

13a. Bacteria

13b. Parasites

13c. Fungi

13d. Viruses

13e. Exotic animal viruses

13f. Other

14. Cytotoxic substances

14a. Will the project involve the use of cytotoxins (carcinogens, mutagens, teratogens)?

Yes No

14b. What is the nature of the preparation or product?

Carcinogen

Mutagen

Teratogen

14c. List the substance to be used in this project.

Name of
substance

Form ordered

Quantity
ordered

Storage
location (room
and campus)

14d. Is the carcinogen you intend to use on [Section 3](#) of the OHS Regulation 2001?

Yes No

If **Yes**, have you lodged a formal notification and received acknowledgement from the Work Cover Authority of NSW? Yes No Pending

If **Yes**, please attach a copy of the notification and acknowledgement received to this application.

15. Risk management information

15a. Risk Assessment: List any hazardous constituents such as hazardous chemicals, biological hazards and identify the health risks to staff and students associated with the use of these constituents requested in this application.

15b. Risk control: Provide details of actions proposed to be taken by the applicant to minimise and manage risks identified in 15a. Include details on how and where gmos will be stored on completion of the project.

15c. Has a 1:15 staff to student ratio been applied for teaching proposals involving basic microbiology or biological hazardous materials or potential pathogens?

SECTION D – NOTIFICATION OF INTENTION TO IMPORT BIOLOGICAL MATERIALS DIRECTLY FROM AN OVERSEAS SUPPLIER

16. The Principal investigator:

Name:

School / centre:

Address for correspondence:

Contact phone:

Fax:

E-mail:

After hours contact:

Signature:

17. Please provide a brief description of the imported material:

18. Please provide a general statement of use:

18a. Provide the AQIS approval number for the product (if available):

19. Please indicate the laboratory location and level of containment for use:

19a. Is access to a Registered 'Quarantine Approved Premise' (QAP) required?
 Yes No

19b. If **Yes**, please provide QAP location details?

20. Is this notification part of a BRSC approved project? Yes No

20a. If **Yes**, please provide the title of the project and the approval number.

Note:

1. Importation of any biological material directly from an overseas supplier requires permission from Australian Quarantine and Inspection Service (AQIS). **An application for a permit is submitted to [AQIS](#).**
2. All such importers of biological materials must comply with conditions outlined by AQIS for use and disposal.

SECTION E - FOR RADIATION WORK ONLY

21. Details of unsealed isotopes to be used:

Radionuclide	Physical form	Chemical form	Max. activity	MBq per experiment	Purpose

22. Details of sealed sources or irradiating apparatus to be used:

Radionuclide and activity	Apparatus – make/model/serial No.	KV/mA

23. Give a brief description of how radioactive material will be stored and disposed:

24. Location(s) of project

Define the areas/laboratories at UWS in which samples are to be handled (include campus location, building number and laboratory number):

Will this project be undertaken in an off campus facility? Yes No

If **Yes**, has the project been approved by that facility's RSO? Yes No

Provide the name of the RSO and the outcome of the review.

25. Do you have approval to use this facility (room, laboratory, apparatus)?

(Attach written confirmation if not located at professional place of work) Yes No

Is this facility a registered designated radiation area? Yes No

If **Yes** specify **EPA registration no.**

26. Radiation safety details:	
Identified hazards	Control Methods
External alpha/beta	
External X/gamma/neutron	
Laser	
Internal	
Environmental contamination	
Other	
Personal	
Area	
Contamination	
<p>26a. Miscellaneous information</p> <p>Emergency procedures:</p> <p>Copy of SOPs and emergency procedures available: <input type="checkbox"/> Yes <input type="checkbox"/> No</p>	

<p>27. Additional risk management information for projects involving the use of radioactive materials: Describe your formal experience handling radioactive materials, including location, radio-isotope(s) and amounts handled.</p>

28. List safety training courses completed. (Also include those completed by personnel you will be supervising)		
Name	Location/Institution	Month/Year

29. List monitoring equipment			
Make	Model	Detector	Calibration date

APPENDIX 11: RADIATION SAFETY

Letter of Clearance

UWS Capital Works & Facilities
.....
<Local Maintenance Supervisor>

Date:

Dear Sir

RE: Maintenance/refurbishment work in DRA Room
.....
<indicate what work is to be conducted>

The laboratory area involved in the proposed work has been monitored for radiation levels as well as radiation contamination, and has been found to have the following radiation values:

Activity :Bq
Dose rate: μ Sv
Date monitored:
Authorised Person:

As the levels are below those that the ICRP consider safe for the general Public then the maintenance work may be conducted between the following dates:

..... to

If there are any problems with this or the work please contact the Radiation Safety Officer.

Yours sincerely,

University Radiation Safety Officer.
OHSRU
University of Western Sydney

APPENDIX 12: RADIATION SAFETY

Laser Equipment Registration Form

This form is to be used for registration of all laser equipment of Class 3 and 4.
A completed copy must be forwarded to the RSO/OHSR Unit for central records and a copy kept for local records .

Faculty/Depart./Unit:					
Name:					
Date:					
Laser Class	Power (if known)	Laser Type (eg, YAG, CO2, KTP)	Brand & Model	Supplier	Location on Campus

APPENDIX 13: RADIATION SAFETY

Laser User Registration Form

This form is to be used for registration of those individuals using lasers of Class 4 or Class 3B [other than class 3B (restricted)] lasers. The information provided will assist the University to continue surveillance of users, procedures and to arrange medical examinations if required. A completed copy of this form must be forwarded to the RSO/OHSR Unit and a copy kept for local records .

Surname:		First Name:	
Are you a.....?	<input type="radio"/> Staff Member <input type="radio"/> Student		
Staff/Student No.:			
Faculty/Depart./Unit:			
Date you will commence using Lasers:			
Date you will cease using Lasers:			
Class(es) of Lasers to be used:			
Is this.....?	<input type="radio"/> A new registration		
	<input type="radio"/> Notification of change to the original registration		
Laser Safety Training Completed:	<input type="radio"/> Yes <input type="radio"/> No	Date Trained:	

IMPORTANT NOTE:

Please notify the OHSR Unit by completing a new registration form or e-mail whenever conditions change i.e. class of laser.

APPENDIX 14: RADIATION SAFETY

Radiation Safety Checklists

Laboratory Design and Construction Checklist

The answer to each of these questions should be “yes”, unless otherwise indicated.

Design and construction	Yes	No
Is the laboratory protected from direct sunlight?		
Are the fume cupboards in accordance with AS 2243.8 — <i>Safety in laboratories — Fume cupboards</i> ?		
Are lunch and rest rooms not included in the laboratory area?		
If limited access is required, is the relevant area signposted at the entrances?		
Is the lighting supplied at a reasonable level for the tasks (as per AS 1680.1 — <i>Interior lighting</i>)?		
Do the overhead lighting fixtures consist of closed units sealed to the ceiling?		
If hazardous substances are used, is a safety shower/eyewash facility installed?		
Is a handwashing basin and services provided near the main entry of the laboratory?		
Is there a safety noticeboard for such things as emergency procedures and hazard notices?		
Is the laboratory well signposted with signs complying with AS 1319 — <i>Safety signs for the occupational environment</i> ?		
Is the laboratory well placarded?		
Is the laboratory physically separated from other laboratory types and work areas?		
Is an autoclave (if required for the purpose of the laboratory) available close by but separated from the laboratory work area?		
Is the ventilation system adequate for the purpose of the laboratory and comply with relevant standards and legislation?		
Is the ventilation system such that it limits the concentration of airborne contaminants?		

Does the local exhaust ventilation comply with AS 1668.2 — <i>The use of ventilation and airconditioning in buildings — Ventilation design for indoor air contaminant control</i> to avoid exhaust being drawn back into the building etc?		
Are hazardous chemical storerooms ventilated to at least the minimum requirement of AS 1940 — <i>The storage and handling of flammable and combustible liquids</i> ?		
Are the floors smooth, impervious, chemically resistant, compatible with the operations and operator comfort, slip resistant, and easy to clean?		
Are floor joints avoided or sealed against chemical penetration?		
Are floor openings or accesses designed to prevent penetration of liquids?		
Are the floors covered up the walls and other permanent structures?		
Are the walls smooth, impervious, chemically resistant (for the type of the laboratory), and easy to clean?		
Are ceilings smooth, non-absorbent, easily cleaned and with flush light fittings?		
Are the benchtops smooth, impervious, chemically resistant, scratch resistant, easy to clean, anti-static (where appropriate), glare resistant and have joints that are sealed to prevent chemical penetration?		
Are the benches and fixtures supported in such a manner as to facilitate cleaning of the floor beneath them?		
Is the shelving chemically compatible with the goods stored?		
Are there controls on the gas reticulation to ensure gases are at the lowest practical pressure?		
Are there automatic, fail-safe cut-off or flow restrictors provided on the gas reticulation?		
Do the vacuum systems discharge externally to the building and clear of any outdoor air intakes?		
Do hydraulic services (water and waste) comply with AS 3500 — <i>Plumbing and drainage segregation guidelines</i> to prevent cross-contamination?		
Are drinking outlets only provided outside the laboratory area?		
If a safety shower or eyewash equipment is provided, is it supplied with potable water?		
Are dilution pits and vents for the liquid waste system located away from mechanical ventilation outdoor air intakes?		
Does the electrical wiring and services comply with AS/NZS 3000 — <i>Electrical installations (known as the Australian/New Zealand Wiring Rules)</i> ?		
Are the general power outlets provided with residual current protection?		
Are the general power outlets located at a minimum of 300 mm above bench height?		

Radiation Safety Checklist

(Apply in conjunction with design and construction checklist.)

The answer to each of these questions should be “yes”, unless otherwise indicated.

Management	Yes	No
For radiation aspects, is there a clearly defined chain of responsibility?		
Are documented radiation safety policy and procedures provided?		
Are staff given appropriate radiation safety training before first starting work?		
Are staff given regular refresher radiation safety training?		
Are records of training kept?		
Are all relevant codes of practice applied to the work?		
If personal dosimeters are issued are records kept, and available to staff?		
Is suitable radiation/contamination monitoring equipment provided?		
Are all ionising equipment and radiation sources regularly checked and maintained?		
Are designated radiation areas (DRAs) under the supervision of a radiation safety officer (RSO)?		
Is access to DRAs limited only to authorised persons?		
Is shielding used when appropriate?		
Duties	Yes	No
Is there an appropriately qualified radiation protection adviser (RPA) or RSO?		
Do the responsibilities of the RPA include: advising on safety, licensing matters, planning, monitoring, documentation and reporting, procedures, storage and disposal?		
Are staff aware that they are required to report to the RSO any instances of known or suspected unsafe practices or incidents/accidents?		
Are staff familiar with local safety procedures and guidelines, as well the appropriate legislation and codes of practice?		
Dose aspects	Yes	No
Are the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) dose constraints for workers and the general public maintained?		
Are members of the public protected from radiation so as to limit their exposure to that set by ARPANSA?		
Are radiation workers regularly checked to ensure that the annual dose limits are not exceeded, and/or are supplied with a personal monitor?		
Are appropriate controls, eg shielding, distance and time, used to limit exposure?		

Are safe work practices adopted to make appropriate use of time, distance and shielding?		
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X-ray and sealed source safety	Yes	No
Is ionising equipment contained in appropriate enclosures?		
Are visible and audible signals provided inside and outside enclosures to provide warning before and during irradiation?		
Does the enclosure have interlocks preventing staff from being within the confines of the enclosure?		
Is there a record for each sealed source of the following: serial number or identification, the nature, date of receipt and activity upon receipt, and the date and manner of disposal?		
Are "fail-safe" mechanisms provided to prevent generation of x-rays when: the shutter is open without analysing components and beam stops in position, the housing is removed from the x-ray tube or the x-ray tube is removed from the housing, an enclosure is detached from the housing, and the beam stop is removed?		
Is x-ray and other radiation producing equipment in a room solely dedicated to this equipment?		
Does the design of the room housing radiation producing equipment include structural shielding requirements?		
Does the design include provision for services such as ventilation, air conditioning etc?		
Are the requirements of the <i>Code of practice for protection against ionizing radiation emitted from x-ray analysis equipment (1984)</i> ?		
Unsealed source safety	Yes	No
Does the laboratory comply with the grading system in AS 2243.4 — <i>Safety in laboratories — Ionizing radiations</i> ?		
Are warning signs displayed at the doors?		
Is unauthorised entry into the radiation laboratory prohibited?		
Are records maintained that includes: nature and activity of each substance, date of receipt, and place of storage or use?		
Is all work with radioactive materials segregated from other work, and where possible, carried out in a laboratory reserved solely for this purpose?		
Are procedures regularly reviewed by the RSO?		
Is the standard of cleanliness higher than that of a "normal" laboratory?		
Are radiation and contamination surveys conducted regularly?		
Is personal protective equipment (PPE) used at all times when doing radioactive work (even for very low levels of activity)?		
Are standard isolation procedures used in regards PPE used in radiation laboratories (ie laboratory coats etc remain in the DRA)?		
Are spill trays and absorbent bench coverings used to limit contamination and spills?		

Are procedures that may produce dusts, vapours or gases conducted in a fume cupboard?		
Are appropriate waste segregation and disposal procedures used?		
Is cleaning of DRA's carried out only by suitably trained persons?		
Is a written clearance from the RSO required to carry out maintenance work on fixtures and facilities?		
Is the counting apparatus in a separate room?		
Are the radiation storage sites lockable, secure and shielded?		
If the radiation storage site is accessible to non-radiation workers is the dose rate at the outside surface less than 1 microsievert (mSv) per hour?		
Are all containers of radioactive material labelled with the department/laboratory, radionuclide, activity, description of contents, date and name of license holder?		
Has the RSO been consulted on the appropriate monitoring equipment required for the work?		
Is the monitoring equipment calibrated annually?		
Does the calibration comply with national radiation standards and in a manner approved by the regulatory authority?		
Where necessary, for assessing worker intake, is appropriate worker monitoring conducted?		
Are emergency procedures in place?		
Are there documented guidelines to handle small and large spills?		
Is appropriate radiation emergency equipment readily available?		
Are ducts and pipes servicing the radioisotope laboratory clearly labelled?		
Is the working space allocated to each radiation worker approximately 10 square metres?		
Is the radioisotope laboratory placarded with the identification of the laboratory, main potential hazards, PPE to be worn, after hours contact name and phone number?		
Are the sinks stainless steel?		