National University of Singapore

Office of Safety, Health and Environment

NUS LABORATORY

IONIZING RADIATION SAFETY MANUAL

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Amendment

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00	1 Mar 2012	New manual	Pramoth
01	24 Mar 2015	1. Section 2.2 Revised from NUS Radiation Safety Policy to NUS General Safety and Health Policy 2. Revision of Centre for Radiation Protection and Nuclear Science to Radiation Protection and Nuclear Science Department 3. Revision to contact phone number for UHC in Section 27.2	Pramoth

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1 INTRODUCTION

Research and Development at National University of Singapore (NUS) involves extensive use of different sources of ionizing radiation. The sources of ionizing radiation are broadly classified into radioactive materials and radiation producing machines. This Ionizing Radiation Safety manual is intended to provide guidance for establishing safe work procedures and prudent practices that will improve safety while using all ionizing radiation sources. This manual forms a part of the Radiation Safety Program (RSP) administered by Office of Safety, Health and Environment (OSHE) to ensure safe use of radiation at NUS. The program ensures that any activity involving use of radiation is conducted in a manner as to protect and minimize one's risks to health, safety and property.

This Manual should be used in conjunction with other laboratory safety manuals, i.e.:

- **NUS General Laboratory Safety Manual** – provides safety and health requirements on issues common to all laboratories, for example, commissioning and decommissioning of laboratory, laboratory sign posting, personal protective equipment, first aid, contractors management, etc.

- **NUS Laboratory Chemical Safety Manual** – provides safety and health requirements for working with chemical substances, such as flammable materials, toxic chemicals, acids and base, peroxides, poisons, etc.

- **NUS Laboratory Biorisk Management Manual** – provides safety and health requirements for working with materials of biological origin, including genetically modified organisms (GMOs) in laboratories.

All personnel involved in ionizing radiation work are required to read and understand the content of this manual before they start work. They should be sufficiently trained and be equipped with the necessary knowledge, skill and techniques to to prevent or minimize conditions thatthreaten the safety and health of his/her own and others in the vicinity. The possession and use of ionizing radiation sources are subjected to licensing. Staff and students must ensure that they are licensed/ authorized to work with irradiating apparatus/ sources or be adequately supervised while working with such sources.

2 RADIATION SAFETY PROGRAM ADMINISTRATION

2.1 APPLICABLE LEGISLATION ON RADIATION

The Radiation Protection and Nuclear Science Department (RPNSD), part of National Environment Agency, is the national authority for radiation protection and nuclear safety in Singapore. It administers and enforces the Radiation Protection Act and Regulations through a system of licensing, notification, authorization, inspection, and enforcement. For more information, visit http://app2.nea.gov.sg/topics_radiation.aspx.

Radiation Protection (Ionising Radiation) Regulations, regulates the manufacture, possession, use and disposal of all sources of ionizing radiation.

Annual dose limit for radiation workers and members of public are specified in the Second Schedule of the Radiation Protection (Ionising Radiation) Regulations (see Appendix A).

The use of radionuclide activity and activity concentrations above which the Radiation Protection (Ionizing Radiation) Regulations apply is provided in First Schedule (see Appendix B)

The Annual Limit of Intake(ALI) for various radionuclides for a radiation worker are specified in Third Schedule of the Radiation Protection (Ionising Radiation) Regulations (see Appendix C).

The radioactive contamination limits are specified in Fifth Schedule of the Radiation Protection (Ionising Radiation) Regulations (see Appendix D).

Radiation Protection (Transport of Radioactive Materials) Regulations regulates transport of radioactive materials on public roads, highways and waterways. The Regulations also specify requirements for packaging and packages.

2.2 NUS GENERAL SAFETY AND HEALTH POLICY

The NUS Senior Management has defined the NUS General Safety & Health Policy that formally expresses NUS's commitment to ensuring a high standard of occupational safety and health for its staff, students, visitors and contractors. The policy emphasizes safety ownership and establishment of safety and health culture. The policy also provides the responsibilities of various stakeholders in ensuring a safe working environment. Staff and students must comply with the requirements of this policy. The policy can be accessed through the following link:

http://www.nus.edu.sg/osh/policies.htm

2.3 NUS SAFETY DIRECTIVES

The NUS Safety Directives provide safety and health governance on specific issues. Refer to the following website for the Directives:

http://www.nus.edu.sg/osh/policies.htm

The Institutional Laboratory Safety Committee (ILSC) is the University level committee to oversee the development and implementation of the Radiation Safety Program. The Office of Safety, Health and Environment (OSHE) is the administrator of this Program.

2.4 ROLES AND RESPONSIBILITIES

2.4.1 NUS PRESIDENT

The President of the NUS represents the University as the Employer. The ultimate responsibility for safety and health in the University rests with the President. The President may delegate the authority and responsibility to the ILSC, Deans, Administrators, and HODs for the effective supervision of the occupational safety and health of staff and students under his/ her management.

The ILSC and OSHE can report any incident or conditions of non-compliance to the NUS President, Senior Deputy President, Provost, Deputy Presidents and Vice Presidents, who are entitled to partially or fully close the laboratories or facilities until all safety issues are addressed.

2.4.2 NUS INSTITUTIONAL LABORATORY SAFETY COMMITTEES (ILSC)

Institutional Laboratory Safety Committee (ILSC) has been formed to serve as an advisory to review standards and guidance documents related to general laboratory safety at the university level.

The ILSC is appointed by the Provost. The Terms of Reference for the ILSC are:

i. Review and approve the NUS Radiation Safety Program and NUS Chemical Safety Program documents including safety manuals, SOPs and directives and recommend revisions to OSHE.

ii. Review any radiation safety audit and inspection findings conducted by OSHE or other independent parties on faculties and departments.

iii. Serve in an advisory capacity to OSHE on all chemical, radiation and physical safety related matters pertaining to laboratories.

iv. To endorse risk assessments that cannot be effectively evaluated at the departmental or faculty level, including appeals by PIs.

The Committee will be assisted by the Occupational Safety and Health Management Division of OSHE.

2.4.3 DEANS AND HEAD OF DEPARTMENTS

All Deans and HODs of respective lab-based faculties and departments will ensure that their respective faculty or departmental radiation SOPs, standards and guidance documents as well as components of the Radiation Safety Program implemented at departmental and faculty level are in order and reviewed periodically. Deans or HODs should empower Faculty Safety & Health Officers and personnel appointed to assume safety responsibilities (herein called the "Departmental Safety Committee"), to coordinate the NUS Radiation Safety Programme at the faculty and departmental level.

The HOD shall appoint a competent person to coordinate waste disposal in the Department.

2.4.4 PRINCIPAL INVESTIGATOR AND SUPERVISOR

Principal investigators are directly responsible for compliance with all regulations governing radiation safety in the laboratory, and for safety of individuals working under their supervision. Principal investigators are obligated to:

- Be aware of and comply with requirements (regulatory and University) pertaining to the use of radiation sources and also establish and maintain a safe working environment.
- Ensure all required radiation licenses exist and are current before any work with radiation is commenced. Ensure that all the radiation workers in his group have valid radiation worker licenses.
- Ensure that all personnel have completed relevant OSHE radiation safety trainings before any work with radiation is commenced. Maintain relevant training records.
- Ensure that individuals are properly supervised and trained on laboratory specific safe work practices. Ensure that all individuals are aware of and trained on all relevant safety documents (SOPs, manuals etc.,). Ensure all individuals are aware of procedures for identifying emergency situations and following emergency response protocols.
- Perform a risk assessment of experiments and protocols involving use of radiation sources. Identify risks, evaluate existing risk controls, ensure existing risk levels are acceptable and also identify and implement any additional controls required to minimize risk. .
- Maintain an accurate record of the inventory of all sources of radiation in his/her lab. Records/logs on receipt, use and disposal of all sources of radiation should be current and updated as and when required.

- Ensure all sources of radiation are stored and used in a manner that minimizes exposure to themselves and other individuals.
- Implement controls to ensure all sources of radiation are accessed and used only by individuals licensed to access/use them. Prevent unauthorized removal or tampering or loss of all radiation sources.
- Post appropriate warnings and labels as required by this manual to ensure adequate communication of radiation hazards.
- Notify Faculty Safety and Health Officer of any changes in license application information including changes in radiation use, addition or termination of radiation workers, or changes of areas where radiation sources are used or stored.
- Ensure that radiation safety surveys, including contamination surveys, exposure surveys and leak tests, are conducted as required by this manual, and maintain records for review.
- Ensure necessary resources needed to ensure good safety practices and adequate infrastructures for the safe operation of the lab are available. This includes (but are not limited to) any shielding, waste containers, exposure and contamination monitors, and any other resources that are required for minimizing radiation exposure.
- Ensure all radiation monitoring devices owned by the group are calibrated annually.
- Ensure all sources of radiation are transferred/disposed and also ensure no residual contamination exists before vacating any radiation use area or lab. PI should maintain any relevant records for review.
- Report all incidents/accidents related to radiation work which include (but not limited to) loss of radioactive material, spills or discharges, real or suspected intakes of radioactive material by laboratory personnel, and real or suspected increased exposure to radiation during use of radiation producing machines. PIs should cooperate with any incident investigation by regulators and OSHE.
- Ensure the radioactive wastes are properly sealed and placed in the designated bags and properly disposed. The PI shall appoint a competent person to coordinate waste disposal in the laboratory.
- Maintain records related to training, exposure and contamination surveys, leak tests of sealed sources, inventory of radiation sources, transfer and transport of radiation sources, radioactive waste disposal and decommissioning labs.
- Ensure all visitors and maintenance personnel accessing restricted radiation use areas are warned of radiation hazards in the laboratory and follow applicable safety rules.

2.4.5 FACULTY SAFETY & HEALTH OFFICER

Faculty Safety and Health Officer (FSHO) are responsible for verifying PIs compliance with NUS Radiation Safety program and directives. FSHO is obligated to:

- Ensure that all radiation producing machines and radioactive materials used in the Faculty have the appropriate radiation licenses.
- Maintain a database of all radiation licenses pertaining to possession and use of radiation producing machines and radioactive materials in the Faculty
- Serve as intermediary in communication between regulators and license holders on license applications, amendments,renewals and cancellations.
- Facilitate radiation monitoring badge exchange between regulators and license holders and also communicate dosimetry report to license holders.
- Review radiation dosimetry reports of radiation workers and inform PI and RSO if the ALARA limits set forth in this manual are exceeded.
- Ensure periodical radiation surveys are being performed by PIs and also review the surveys to determine if dose rates and contamination levels do not exceed limits set in this manual.
- Ensure all PIs comply with radiation lab commissioning and decommissioning procedures and verify the commissioning/decommissioning compliance. Ensure all radiation licenses are cancelled after any decommissioning of labs or equipments or after any individual terminates radition work.
- Inform all incidents reported by PI to Radiation Safety Officer and help RSO in incident investigation process.
- Maintain records related to exposure records from regulators, internal radiation safety inspections and incident investigations.

2.4.6 RADIATION WORKERS

All individuals working directly with sources of radiation are termed as radiation workers. Since the workers, are the direct handlers of radiation sources, they have an important role in ensuring safety and compliance. For this reason, it is critical that they be aware of the risks, safe practices and requirements for use of radiation.

Radiation workers are obligated to:

- Comply with this Radiation Safety Manual, regulatory requirements, as well as other university, faculty and departmental specific safety manuals and SOPs.
- Adhere to all risk controls identified and implemented by the PIs

- Obtain radiation worker license from regulators prior to working with sources of radiation.
- Successfully complete relevant OSHE Radiation Safety Training prior to working with sources of radiation. Radiation workers also must comply with refresher training requirements.
- Wear radiation monitoring badges at all times while using sources of radiation.
- Practice principles of maintaining radiation dose ALARA (As Low As Reasonably Achievable) in their work, and minimize the potential for exposures, contamination or release of radioactive materials.
- Monitor radiation exposure in radiation work areas and ensure the radiation levels are below regulatory limits.
- Monitor spread of radioactive material contamination and leakage of sealed sources and clean any contamination or spills that occur in their work area
- Report immediately any radioactive material spills, radiation equipment failure or any other accidents/incidents to Principal Investigator.
- Return the radiation dosimeter on time and report any loss or contamination of the dosimeter to the FSHO. They also should immediately return radiation dosimeters at end of employment or end of radiation work to FSHO.
- Assist RSO with coordinating the radioactive waste disposal program

2.4.7 RADIATION SAFETY OFFICER (RSO)

The Radiation Safety Officer is responsible for implementing the Radiation Safety Program established by OSHE. The RSO has been provided with the administrative authority by the ILSC to enforce the radiation protection activities at NUS. RSO has the authority to temporarily suspend an unsafe activities involving radiation deemed to be unsafe subject to review by the safety committee. Duties of the Radiation Safety Officer include (but not limited to)

- Develop and implement safety policy, manual, procedures and directives subject to the approval by ILSC.
- Liaise with regulatory agencies, faculties and departments in the ongoing implementation of the University's Radiation Safety Program.
- Restrict or suspend use and/or possession of sources of radiation whenever a significant deviation from established regulatory and university requirements has occurred or when there is threat to health or property.

- Perform bi-annual radiation safety inspection in all labs using radiation and report any non-compliance to the PIs and ILSC.
- Review and advise on work practices of radiation workers who received dose above ALARA levels set forth in this manual.
- Perform an investigation of all incidents/accidents related to radiation work at NUS and submit investigation reports, as required, to the regulators, ILSC and to Senior Management.
- Ensure that effective corrective actions are developed, implemented, and documented if violations of regulations, or license or registration conditions, or program procedures are identified.
- Supervise and coordinate the radioactive waste storage and disposal program with licensed radioactive waste collectors, the Faculty Safety & Health Officers and RPNSD.
- Maintain a central database of all radiation license information related to radiation use at NUS.
- Develop, edit as necessary and provide all safety trainings related to safe use of radiation at NUS.
- Perform random surveys to monitor exposure levels and contamination levels in labs using sources of radiation.

2.4.8 UNIVERSITY HEALTH CENTRE (UHC)

The UHC is the medical service provider for the Occupational Health Program of the University. UHC provides any medical examinations that are required for obtaining radiation licenses from regulators. UHC also provides ongoing annual medical examination for individuals who received more than three tenths of the dose limits under Part I of the Second Schedule of the Radiation Protection (Ionising Radiation) Regulations 2001 (see **Appendix A**)

3 RISK ASSESSMENT

All PIs are obligated to perform a thorough evaluation of risks and hazards associated with their projects and identify and implement controls to minimize such risks. Where applicable, the risk assessment should cover the following:

- use of irradiating apparatus
- use of radioactive materials
- transfer and transport of radioactive materials (from one location to another)

- storage of radioactive materials
- disposal of radioactive wastes

3.1 PROJECT RISK ASSESSMENT SCHEME

All PIs are responsible for the conduct of risk assessment prior to the commencement of research projects. PIs can only commence work after their risk assessment has been approved. Refer to Research Safety Compliance Form information at https://inetapps.nus.edu.sg/osh/portal/iorc.html for the detailed risk assessment methodology, and submission and approval procedure.

The Project Risk Assessment is gradually being phased out, it will be replaced by the Laboratory OSH Certification Scheme as described below.

3.2 LABORATORY OSH CERTIFICATION SCHEME

The Laboratory OSH Certification Scheme was launched to certify PIs who have effectively implemented laboratory-based safety and health management system. Upon award of the certification to the NUS Occupational Health and Safety Management System Standard for Laboratories, PIs would generally not be required to submit risk assessments on a per-project basis. For more information, refer to

http://www.nus.edu.sg/osh/programmes/ohscert.htm.

4 LICENSES

The use of radioactive material and radiation producing machines are enforced by RPNSD by means of licensing and imposing penalties on violations. Separate licenses are required for possession, for use and for working with different sources of radiation.

All license applications, amendments, renewals and cancellations should be performed only by the FSHO to enable OSHE to track radiation use at NUS. All completed license applications and the cheque for the license fees should be sent to FSHO who will then forward them to RPNSD.

Blank license forms can be downloaded from the following link. http://app2.nea.gov.sg/TemSub.aspx?pagesid=20080720226768161463&pagemode=live#radiation

The information on the license fees for different licenses can be found in the following link. http://app2.nea.gov.sg/regulatory_info.aspx#licences The license fee covers the cost of any radiation monitoring badge that may be required for radiation use. Upon approval of license application, the license and the radiation monitoring badge will be sent to the FSHO. All license approval letters, renewal letters and radiation monitoring badges will be sent by RPNSD to the FSHO. RPNSD requires approximately 45-60 days for processing license fees and issuing the license. So it is advisable that users plan ahead of the radiation use

NEA administers a license qualifying test for all L5 and L6 license applicants. The passing of this test is a prerequisite for obtaining the license. NEA will contact the applicants on the schedule and details of the test. OSHE's Ionizing Radiation Safety Training includes the information that can help applicants successfully pass this license qualifying test.

L5, L6 and R1 license applications require a medical certificate completed within the past 12 months to be attached. Please contact OSHE occupational health clinic for scheduling an appointment for medical check up. Please refer to Section 5 on Medical Surveillance for more information.

Any change in the license information would require a license amendment. The change in information along with the cheque for license amendment should be sent to FSHO immediately. The license should be amended within two week of any change.

4.1 RADIOACTIVE MATERIALS LICENSE

This section applies to all radiation licenses required for using

1. Unsealed radioactive material (P-32, S-35, I-125, H-3 etc.,) used for labeling studies, in vitro and in vivo studies, metabolic studies etc.,

2. Sealed radioactive materials used in equipment like thickness gauge, level gauge, static eliminator, fluorescence analyser, gamma irradiator etc., (Note: the irradiating apparatus may need a separate license. Please refer to Section 4.2 for further details.)

The different licenses that are required for using radioactive materials are -

L4 license- To ***keep or possess*** radioactive materials for use (other than sale).

This license authorizes the building or a group of buildings listed on the application to possess radioactive materials that are listed on the application. Each Faculty/Research Institute holds one radioactive material possession license (L4 license).

L6 license - To ***use, handle and transport*** radioactive materials (other than sale).

This licenseauthorizes the PI to use the radioactive materials and machines that contain radioactive materials listed on the L6 application. This L6 license needs to list the L4 license information. Each PI is required to apply for radioactive material use license (L6 license)

R1 license- To ***register*** as a radiation worker.

This license authorizes a worker to perform radiation work under a PI with a valid L6 license. Each worker performing experiments using the radioactive material under a PI should possess an R1 license. The license should list the L6 license information.

The licensing of radioactive material at NUS follows the structure showed in Figure 1.

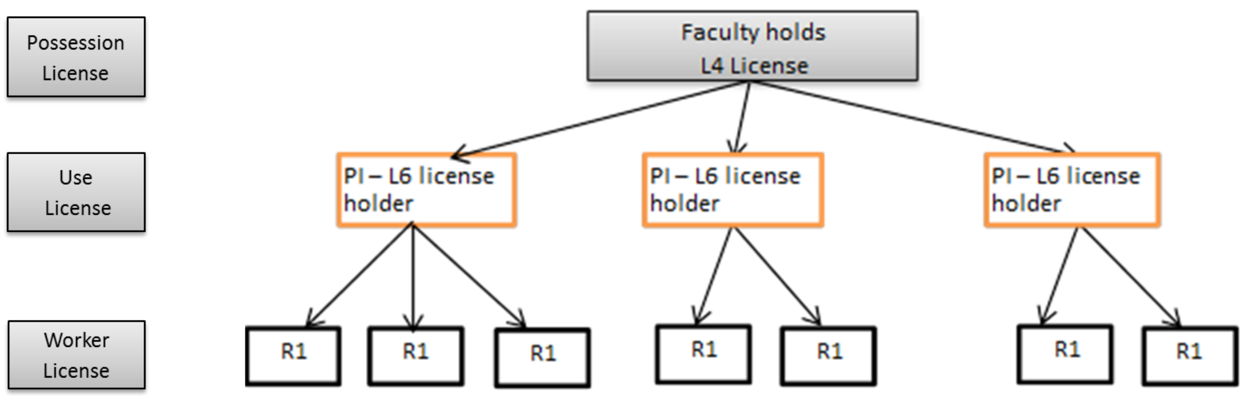


Figure 1: Radioactive Material Licensing Guide

For more information or questions on radiation licensing contact the Radiation Safety Officer

4.2 IRRADIATING APPARATUS LICENSE

This section applies to all radiation licenses required for using

1. *Irradiating apparatus with sealed sources* (Industrial radiography, *industrial fluoroscopy*, gamma irradiator and any *other equipment with sealed sources*)

2. Irradiating apparatus emitting X-Rays (medical, dental and veterinary diagnostic and therapeutic apparatus or any equipment emitting X-rays)

3. Particle accelerators (Van De Graaff accelerators, electrostatic generators, neutron generators, linear accelerators, cyclotrons, betatrons, synchro-cyclotrons, synchrotrons etc.,)

<u>L3 license</u>- To ***keep or possess*** an irradiating apparatus (other than sale).

. This license authorizes the lab or building to possess this irradiating apparatus. Each irradiating apparatus should have its own L3 license.The Faculty or the Department holds this license.

<u>L5 license</u>- To ***use*** an irradiating apparatus (other than sale).

The license authorizes an individual to use a radiation producing equipment. The owner of the machine or the person in charge who has responsibility to ensure safe operation of the apparatus needs to apply for the L5 license. There is no need to obtain separate L5 license to use different radiation producing equipment by the same user. All equipment (and its associated L3 license number) used by a particular user must be listed on his/her L5 license application.

<u>R1 license</u>- To ***register*** as a radiation worker.

The license authorizes an individual to work with a radiation producing equipment. Each worker performing experiments using the irradiating apparatus should possess an R1 license. There is no need to obtain separate R1 license to work with different radiation producing equipment by the same worker. All equipment (and its associated L5 license number) used by a particular worker must be listed on his/her R1 license application. The licensing of radioactive material at NUS follows the structure showed in Figure 2.

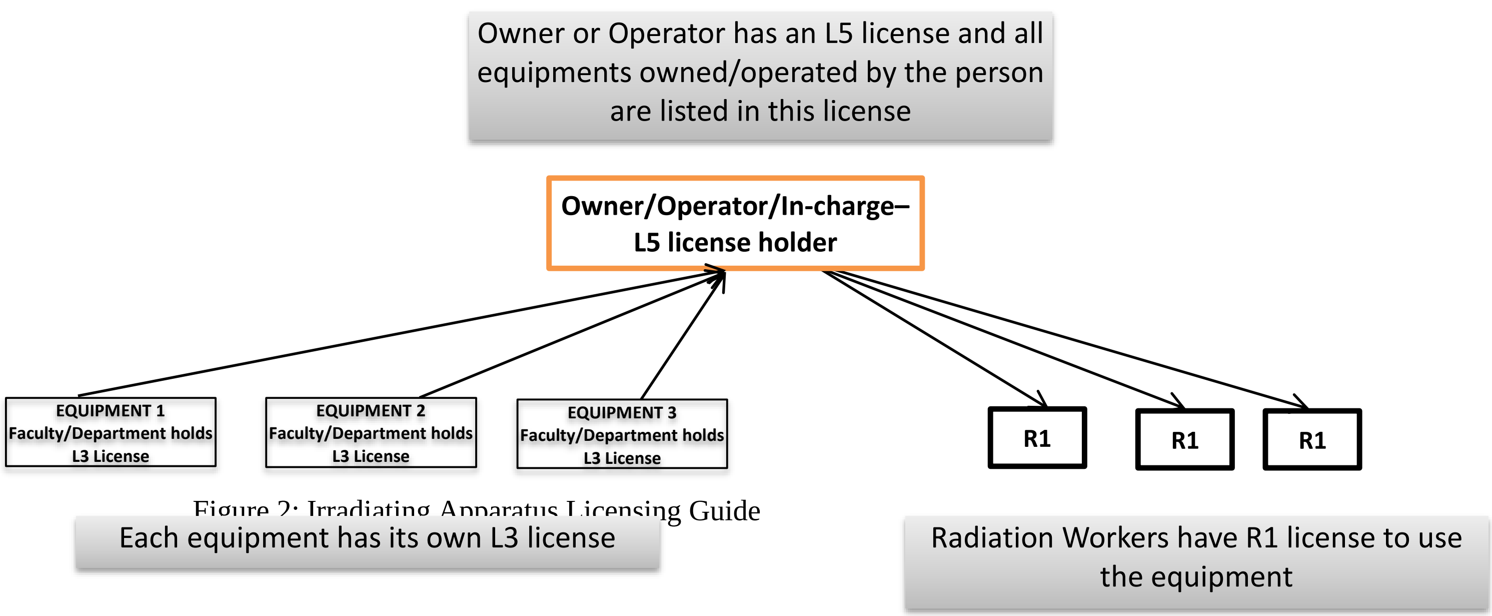


Figure 2: Irradiating Apparatus Licensing Guide

For more information or questions on radiation licensing contact the Radiation Safety Officer

4.3 LICENSE EXEMPTIONS:

For students - Any student who in course of his studies performs any experiment using radiation is exempted from R1 license under the condition that the radiation work is performed under continuous supervision of a registered L6 or R1 license holder.

For unsealed radioactive materials – any research work involving radioactive materials in quantities that fall below the activity or activity concentration prescribed in **Appendix B** does not require a L6 or R1 license from RPNSD. However, the use, storage and disposal of such exempted quantities should follow the guidelines provided in this manual.

For sealed radioactive materials – any research work involving sealed radioactive material in quantities that fall below 100 times the activity or activity concentration prescribed in **Appendix B** does not require a L6 or R1 license from RPNSD. However, the researchers purchasing such sources are required to ensure vendors/suppliers will take back the sources after their intended use at NUS.

For radiation producing machines - any electrical equipment which is not primarily intended to produce ionizing radiation (such as Electron µscopes, cathode ray tubes, transmitting valves, rectifying valves, image converters and television tubes) and which does not produce a radiation level of more than 5 µSv/h at a distance of 5 cm from any accessible surface

5 MEDICAL SURVEILLANCE

5.1 PRE-PLACEMENT EXAMINATION

All L5/ L6/ R1 radiation license applicants are required to attach a report of medical examination performed within the past 12 months along with their license application. The physical medical examination can be conducted at the Occupational Health Clinic in OSHE. The funding for the medical examination should be approved prior to approaching the clinic for the medical exam. The Request for Funding for Occupational Health Related Medical Services form is provided in A**ppendix E** should be completed and submitted to the FSHO for approval. The form should be mailed to the clinic to either

Nurse Kim @ nursekim@nus.edu.sg , 6516 7333; Goh Sha Wee @ oshgsw@nus.edu.sg , 6601 1781.

The clinic will then schedule an appointment for performing the medical examination.

5.2 PERIODIC MEDICAL EXAMINATION

The PI shall arrange medical examination once a year for every radiation worker who is receiving a sum of radiation doses which is greater than three-tenths of the appropriate dose limit permitted under Part I of the Second Schedule of the Radiation Protection (Ionising Radiation) Regulations 2001 (see **Appendix A**) in any calendar year. Medical examination may be required if there is change in irradiating equipment used or change in health status of the radiation worker. E.g. immuno-compromise or pregnancy. This can be performed at the Occupational Health Clinic in OSHE

6 TRAINING

6.1 INITIAL TRAINING

All individuals applying for radiation license from RPNSD for use or working with sources of radiation must undergo Radiation Safety Training relevant to their respective use of radiation. More information on all the trainings provided by OSHE and the training registration details can be found at https://inetapps.nus.edu.sg/osh/portal/shmgt/ssts.html

6.2 LAB SPECIFIC TRAINING

In addition to the mandatory training mentioned above, PIs may conduct safety training on topics specifically related to the job being performed by the radiation workers.

6.3 REFRESHER TRAINING

Within two years of completing the OSHE Radiation Safety Training, all radiation workers are required to retake the OSHE Radiation Safety Training to refresh the safety and health knowledge. The training is updated and revised annually by OSHE.

6.4 RADIATION AWARENESS TRAINING

All individuals who are interested in increasing the awareness of safe use of radiation can undergo the OSHE's Radiation Awareness Training. The completion of the awareness training does not satisfy the OSHE training requirement to handle radioactive material or radiation producing machines

7 REGULATORY DOSE LIMITS

Annual dose limit for radiation workers and members of public are specified in the Second Schedule of the Radiation Protection (Ionising Radiation) Regulations (see Appendix A). Occupational external and internal exposure from ionizing radiation should be controlled such that no individual shall receive a radiation dose in excess of these limits. It should be noted that the dose limits for a radiation worker and an individual member of the public are different.

The Radiation Protection (Ionizing Radiation) Regulations specifies the Annual Limit on Intake (ALI) of a radionuclide for radiation workers. ALI is defined as the activity of a radionuclide which on intakeinto the human body, would provide an exposure equal to the dose limit specified in Part I of the Second Schedule. Different radio-nuclides have different values of ALI (see Appendix C on ALI for Radiation Workers). Some radio-nuclides may concentrate in certain organs, causing these organs to receive particularly high doses. Once taken up by the body, the retention and the exposure will be subjected to excretion rate of the radionuclide from the body.

7.1 PRENATAL MONITORING

The dose limits for a pregnant worker is substantially lower than a normal radiation worker. All radiation workers should be aware and understand the special precautions concerning exposure during pregnancy, especially that the dose equivalent to the embryo or fetus from occupational exposure of the expectant mother should not exceed 2 mSv for the entire gestation period. If possible, laboratory workers who are pregnant or breast-feeding should not use volatile radioactive materials and have extra precaution to prevent intake of radioactive materials. As a radiation worker, if you are pregnant, planning to become pregnant or simply would like more information, please contact the Radiation Safety Officer who will arrange a meeting with you to discuss any particular concerns and review any special precautions in radiation uses. The RSO will inform RPNSD and obtain special/extra radiation monitoring badges to monitor the dose to the abdomen.

7.2 ALARA PRINCIPLE

ALARA is the acronym for “As Low As Reasonably Achievable”. National University of Singapore is committed to adoption of the principles of maintaining radiation doses to all individuals ALARA (As Low As Reasonably Achievable) when working with sources of radiation. ALARA principle forms the foundation of NUS Radiation Safety Program and ensures that every reasonable effort is made to maintain exposures to ionizing radiation as far below the regulatory dose limits as practical. As a result NUS has setup three investigation levels to ensure regulatory limits are not exceeded at any time.

Table 1: Singapore Regulatory and NUS ALARA Radiation Dose Investigation Levels

Exposure Location	Regulatory Limit	ALARA Level 1	ALARA Level 2	ALARA Level 3
	Dose limit per year (mSv)	Dose received in any month (mSv)	Dose received in any month (mSv)	Dose received in any month (mSv)
Effective dose (whole body)	50*	1	2	3
Equivalent dose in				
the lens of the eye	150	3.125	6.25	9.375
the skin, hands and feet	500	10.4	20.83	31.23
Bioassay (Intake)	1 ALI	0.02 ALI	0.10 ALI	0.50 ALI

* Provided users do not receive 100 mSv over a period of 5 years.

ALARA level 1: A monthly exposure of ALARA level 1, will result in the worker exceeding one-fourths of the annual legal exposure limits or exceed 5% of Annual Limit for Intake of radionuclides. If any individual receives a radiation dose in excess of ALARA level 1, a written notification is sent to the user and PI. RSO will conduct an interview with the user to determine if dose levels can be reduced. ILSC will be informed at next regularly scheduled meeting.

ALARA level 2: A monthly exposure of ALARA level 2, will result in the worker exceeding one-half of the annual legal exposure limits or exceed 10% of Annual Limit for Intake of radionuclides. If any individual receives a radiation dose in excess of ALARA level 2, a written notification is sent to the user and PI. The PI must sign to acknowledge receipt of the report. RSO will conduct an interview with the user to determine if dose levels can be reduced. ILSC will be informed will be notified after the report is completed.

ALARA level 3: A monthly exposure of ALARA level 3, will result in the worker exceeding three-fourths of the annual legal exposure limits or exceed 50% of Annual Limit for Intake of radionuclides. If any individual receives a radiation dose in excess of ALARA level 3, the user must suspend radiation work pending an investigation by RSO. A written report of the investigation is sent to user, PI and ILSC. The PI must sign to acknowledge receipt of the report. The ILSC may authorize continuing radiation work after review of the report.

8 DOSE CONTROL / RADIATION PROTECTION

The following principles should be followed to ensure the exposure and dose is maintained ALARA

8.1 TIME, DISTANCE AND SHIELDING PRINCIPLE

Time: Radiation dose is proportional to the time spent in the radiation field. One can reduce the amount of time handling radiation sources, to reduce the radiation dose received. Performing dry runs, having implements or instruments close at hand, cleaning up contamination as is occurs, limiting the presence in rooms with irradiating apparatus are examples of different methods of limiting exposure time to radiation,.

Distance: The maximum practical distance should be maintained between any part of the person's body and the radiation source. The dose received is inversely proportional to the square of the distance from the radiation source. Doubling the distance between a radiation source and an individual will reduce the dose by four times. Moving your storage container to the back of the refrigerator/freezer or moving your waste container to the furthest location in the lab or workbench, using tweezers, forceps and niptongs to handle vials, increasing the distance between control panels and the radiation producing machines are some methods of increasing distance between an individual and radiation source to reduce exposure.

Shielding: A shield in the radiation path will cause the radiation to be attenuated and scattered in various directions so that the dose to the work will be reduced. The type of shielding used will depend on the type and energy of the radiation. Perspex and plastic are ideal for shielding beta emitters like C-14, S-35, P-32 etc., and lead shields should be used for gamma emitting nuclides like Cs-137, I-125, Cr-51 etc., Lead shields should never be used for shielding beta radiation, as it will result in generation of Bremsstrahlung X-rays from the lead shield. Bench top shields and shielded waste containers and shielded storage containers are used while using radioactive materials in benches. Lead curtains, lead bricks and concrete blocks are sometimes used to shield radiation producing machines. Lead aprons may be used if it does not significantly reduce the mobility and increase the radiation work time.

Practical radiation protection involves juggling the three factors to identify the most cost effective solution.

8.2 ENGINEERING CONTROLS

The use of engineering controls is the most preferred method for reducing worker exposure to radiation. Engineering controls are external accessories designed to protect the worker, or are built in aspart of the design of the equipment or work area. The engineering controls should be designed and built in to implement the time, distance and shielding principle. All engineering controls should involve a plan for periodic inspection to determine the effectiveness of the protection provided.

Radiation Producing Machines – Shielded enclosures and safety interlocks, are commonly used as engineering controls for radiation producing machines. The radiation source is enclosed within a lead lined radiation chamber, cabinet or in a concrete walled construction. Safety Interlocks are designed to prevent access to the radiation hazard while it exists. Mechanical interlocks will prevent the opening of a door accessing the source. For X-ray producing machines, electric or magnetic Interlocks will trip to cut the power to the X- Ray source if a door is opened. The machines should be designed to permit any lock out / tag out to prevent unauthorized use / accidents during servicing or repair. Other design features include beam filtration or collimation and active devices such as audible and visible warning signals. All these engineering controls of the machine should be respected and should not be defeated.

Radioactive Materials - Fume hoods dedicated for using radioactive materials are most commonly used as engineering controls. Any chemical or physical form which readily volatilizes or evaporates into the air must be considered a potential airborne radioactivity risk. Use of volatile forms of radionuclides, such as I-125 for iodination or H-3-Sodium Borohydride may generate airborne radioactivity and should be used in a fume hood. Chemical reactions like labeling reaction for S-35 Methionine, generate $S\text{-}35O_2$ gas and hence such reactions should be performed in a fume hood. Use of radioactive materials in the millicurie amounts should always be used in a fumehood irrespective of the volatility of the compound. Airborne radioactivity has resulted in unnecessary intakes and area contamination in laboratories where the users were unaware of this risk and have not taken necessary precautions.

Work areas should be designed in a way to facilitate easy removal of contamination without extensive damage to the existing facility and surfaces. Epoxy coatings, laminates, floor coverings and protective coatings shall be provided on bench surfaces and floors. Sinks shall be either plastic composite, or coated with epoxy of the equivalent or manufactured of stainless steel, to aid in the decontamination of surfaces. The area shall have readily available washing facilities suitable for decontamination purposes.

8.3 ADMINISTRATIVE CONTROLS:

Administrative controls supplement the engineering controls and are put in place by the ILSC and OSHE to limit external exposures as needed. OSHE’s efforts to maintain all radiation doses ALARA form the foundation for all the administrative controls. These controls include compliance with Radiation Safety Manual, procedures and directives. Licensing, Training, procurement control, routine contamination monitoring, postings and warning signs, worker exposure monitoring, and medical surveillance form a part of the administrative controls.

8.4 PERSONAL PROTECTIVE EQUIPMENT

Personal protective equipment (PPE) should be worn whenever radiation work is performed at a laboratory bench. The minimum personal protective equipment required is lab coat, safety glasses and disposable gloves. PPE prevents or reduces the possibility of radioactive materials entering the body via inhalation, ingestion or absorption through skin. All PPE should be routinely monitored for contamination and contaminated PPE should be promptly disposed as radioactive waste. All PPE should be routinely inspected to determine their integrity and any damaged PPE should be immediately replaced.

Laboratory coats and gloves shall be worn at all times when working with radioactive materials. Double gloves shall be worn during radiosynthesis and iodination procedures and are strongly recommended for all radioactive material handling. This will permit the changing of a contaminated outer glove while still receiving protection from the inner glove. Individuals performing iodinations, radio synthesis and labeling, may require additional protective coverings, such as plastic-lined disposable coveralls and booties.

Protective Eye Wear is required in accordance with standard NUS requirements. This includes the use of safety glasses with side shields or full-face shields as applicable. Protective Eye wear is strongly recommended for individuals working with P-32 due to the large range of the 1.72 MeV beta. The plastic lenses in safety glasses absorb one hundred percent (100%) of all alpha and beta particles emitted by radioisotopes. This is important because live tissue on the exterior of the body (like eyes etc.,) is most susceptible to radiation exposure Wearing safety glasses reduces alpha and beta particle exposure to the eyes to zero.

Respiratory Protection may be necessary for certain radioisotope uses. However, respiratory protection should only be used when engineering and other administrative controls and containment do not provide enough protection. Respirators must be chosen carefully to ensure the proper fit and type of cartridge, and the use must be monitored carefully. For this reason, use of respirators for radioactive materials use must be pre-approved by the OSHE, documented and monitored. Prior to using respirators for any reason, fit testing and medical monitoring are required. Only medically qualified and trained personnel will be allowed to use respirators. Respirator training will be conducted in accordance with Safety Department procedures.

9 RADIATION LABORATORY SAFETY

9.1 GENERAL SAFETY GUIDELINES

When handling unsealed sources, adherence to the general laboratory safety rules as spelt out in the General Laboratory Safety Manual, is required. In addition, the general radiation safety guidelines as described below should be followed while working with sources of radiation.

- Always read the safety data sheet of the radiochemical compound to determine the hazards and implement sufficient controls to minimize hazards. Refer to Appendix F for generic safety guidelines for working with commonly used radionuclides.
- Always read the standard operating procedures or user manual of radiation producing equipment and be aware of the controls to prevent any accidental exposure.
- Do not eat, drink, smoke, chew gum, apply cosmetics or store such items in areas where radioactive materials or radiation sources are used or stored. Food and beverage containers may not be stored in the laboratory and refrigerators used for such purposes should be located outside the laboratory
- Always respect the safety interlocks and warning signs on radiation producing machines.
- Tears/breaks in skin should be covered with waterproof tape to prevent accidental absorption of radioactive material.
- Open-toe footwear, sandals and flip-flops, and loose clothing or clothing that exposes body areas are not allowed to be worn at any time in any laboratory.
- Avoid contaminating objects such as telephones, light switches, water tap handles, doorknobs, etc. Segregate items used with radioactive materials with those used with non-radioactive materials to prevent cross contamination.
- Hands should be washed thoroughly after using radioactive material, before going on breaks, and at the end of the workday. Hands and legs should be thoroughly checked for contamination after completion of radiation work.
- Never pipette radioactive material by mouth.
- Always wear radiation monitoring badges.

9.2 DESIGN AND SETUP OF RADIATION USE AREA

Requirements for work areas with unsealed sources are as follows:

- Procedures involving radioactive material should be confined to smallest area possible. The area should be as far as possible from any office locations. The work area should be adequately ventilated and also be as far away as possible from sinks and drains to prevent any accidental spill entering the public sewers.

- The work area should have clear warning signs indicating the use of radioactive materials. It is advisable to use radiation in a room dedicated for such purpose. If radiation use is in a common area, usage and storage area should have sufficient shielding to ensure that the dose rates are below 0.5 μSv/hr at locations accessible by non radiation workers.
- Work areas should be designed in a way to facilitate easy removal of contamination without extensive damage to the existing facility and surfaces. Epoxy coatings, laminates, floor coverings and protective coatings shall be provided on bench surfaces and floors. Sinks shall be either plastic composite, or coated with epoxy of the equivalent or manufactured of stainless steel, to aid in the decontamination of surfaces. The area shall have readily available washing facilities suitable for decontamination purposes. Decontamination instructions and supplies shall be readily available near the work area
- All work involving unsealed radioactive material should be conducted on surfaces which have been covered with polythene sheets that can be easily cleaned or with absorbent pads that can be easily discarded as radioactive waste.
- Suitable provisions should be provided for secured storage of radioactive materials in freezers, cabinets etc.,
- Adequate supply of shielding materials appropriate to the type of radiation being used should be available.
- Secondary containers must be used to prevent spillage and spread of contamination in the event that the primary container fails to contain the radioactive material. Using drip trays lined with absorbent material whenever possible.
- A glove box or fume cupboard shall be provided for working with volatile or dry unsealed sources. Significant activities of potential volatile radioactive material, e.g., unbound I-125, unbound I-131, sodium iodide, sodium borohydride, tritiated water, etc., must be used in a fume hood. (Refer to Chemical Safety Manual for the safe operation of fume hood)
- Radioactive waste storage area should be located as close to the work area as possible to prevent unnecessary transportation and related incidents. The disposable paper towels and foot operated waste bins lined with removable red NUS radioactive waste bags should be readily available.
- Radiation monitors pertaining to the type of radiation should be readily available near the work areas.

10 PROCUREMENT AND RECEIPT OF RADIOACTIVE MATERIALS

10.1 RADIOACTIVE MATERIAL PROCUREMENT

Purchase of radioactive materials should be done ONLY by individuals who possess valid radiation licenses. The license holder should order and use ONLY the radioactive materials that have been listed in the license application. If the license holder wishes to order isotopes not listed in the license, a license amendment (for inclusion of the isotope) should be submitted to regulators through FSHO.

10.2 RECEIPT OF RADIOACTIVE MATERIALS

The packages received at NUS typically fall under two categories

Excepted packages (Limited Quantity Packages) - packages with radioactivity amount less than one thousandth of limits listed in Second Schedule Table 1 of Radiation Protection (Transport of Radioactive Material) Regulations.

Type A packages - packages with radioactivity amount more than that of excepted packages but less than the amount listed in Second Schedule Table 1 of Radiation Protection (Transport of Radioactive Material) Regulations.

All radioactive material packages should be inspected to determine if

- the material received is what was ordered. Verify that the label on each container agrees with the description of the material specified in the packing slip and that the identity and activity of the material are consistent with what was ordered.

- the package appears to be undamaged. Check the integrity of the final source container looking for a broken seal or a cracked vial or for evidence of loss of liquid, e.g., discoloration of the packaging material.

- the levels of contamination and external exposure rate on the external packaging material are within acceptable limits The exposure levels should be below 5 μSv/hr for Excepted packages and 2 mSv/hr for Type A packages. The removable contamination levels as checked using a liquid scintillation counter should be less than 200 dpm per wipe area of 100 cm^2 (dpm- decays per minute) If contaminated, dispose the outer packaging as radioactive waste. If not contaminated, obliterate all radiation labels before discarding in the regular trash.

Appropriate PPE and radiation monitoring badges should be worn during package inspection. The exposure levels should be determined by exposure rate meter and contamination levels should be determined by a wipe test. Please refer to Section 17 on Contamination Monitoring and Section 18 on External Exposure Monitoring for further details. All necessary precautions should be taken to prevent spread of contamination and minimize exposure to all individuals including public during the receipt and inspection of the package.

11 PROCUREMENT AND COMMISSIONING RADIATION PRODUCING MACHINES

Purchase of radiation producing machines should be done ONLY by individuals who possess radiation licenses. The license holder should order and use ONLY the radiation producing machines that has been listed in the license application. If the license holder wishes to use a radiation producing machine not listed on the license, a license amendment (for inclusion of the new machine) should be submitted to regulators through FSHO.

Before commissioning a radiation producing machines, an initial exposure rate survey should be performed and documented on the Radiation Machine Inspection and Survey Form as shown in **Appendix H**. The surveys should be performed when it is on and operating at full power. The form should include a description and serial number of the equipment surveyed, a sketch or description of the equipment surveyed, and an indication of the survey results. A record of the results shall be kept for a period of three years. The exposure rates should be less than the values listed in rows six through eleven in the Table 5 provided in Section 18.1.3.

12 INVENTORY OF RADIOACTIVE MATERIALS

All PI who has in his/her possession any radioactive material shall keep a record of the following particulars in respect of the radioactive material.

a. Name and activity of the radioactive material at the date specified by the manufacturer;
b. Date of receipt;
c. Location of the radioactive material
d. For sealed sources:
    i. The distinguishing number or other identifying mark; and
e. For unsealed sources:
    i. Quantity used each time and the date and purpose of use; and
    ii. Date and the manner of disposal

The Laboratory Inventory form shown in A**ppendix I** should be used to record the above information for unsealed radioactive materials .If any radioactive material has been lost or mislaid, it shall be the duty of the radiation worker to notify the PI and the FSHO of the loss or missing radioactive materials immediately.

If the radioactive material is not accounted for within 24 hours, the PI shall notify RSO who will in turn inform RPNSD, NEA.

13 TRANSFER OF RADIATION SOURCES

13.1 TRANSFER OF RADIOACTIVE MATERIALS

Radioactive materials can be transferred from one PI to another only after visual verification of the receiver's license to ensure that the receiver has permission to possess and use the particular radioisotope. After the transfer, the laboratory inventory form should be updated accordingly with the amount of radioactive material transferred, date of transfer and radiation license number of the receiver. The transfer should be performed only by a licensed radiation worker with the permission of the PI. There are different regulatory requirements based on whether or not motorized vehicles (cars, trains, buses, scooters, bikes etc) are used to transfer the radioactive materials to the destination location.

13.1.1 WITHOUT USING MOTORIZED VEHICLES

The material should be sufficiently shielded to ensure that the exposure rate outside the shielded container is less than 40 μSv/hr at 5 cm. The container should have a label with the name and activity of the radionuclide. While transporting the shielded container, the radiation worker should use the path that is shortest and has least human traffic. The radiation worker should never leave the radioactive material unattended in public area.

13.1.2 USING MOTORIZED VEHICLES (PERSONAL AND PUBLIC VEHICLES)

Please contact Radiation Safety Officer for help with transfer of radioactive materials using motorized vehicles. In this case, the packaging, labeling, and activity amounts in the package should comply with the Radiation Protection (Transport of Radiation Materials) Regulations. It will be a serious violation of NEA rules if radioactive materials are transferred in motorized vehicles without following the appropriate precautions. Please provide advance notice of such transfers to allow time to verify the recipient's license information and preparation of necessary shipping documents.

13.2 TRANSFER OF RADIATION PRODUCING MACHINES

PI/equipment owner should notify the FSHO before any radiation producing machine is transferred to another individual within NUS or sold to another individual outside NUS. If the machine is being transferred or sold, the equipment owner should verify that the new owner possess the valid radiation license prior to transferring/selling the equipment. The new PI/Equipment owner must obtain necessary licenses and complete trainings prior to use of the equipment. The FSHO will notify the RPNSD of the removal of the equipment and will cancel all licenses if necessary.

14 STORAGE OF RADIATION SOURCES

All sources of radiation (radioactive material and radiation producing machines) should be secured to prevent unauthorized removal or access. Hall freezers, freezers in common rooms, etc., containing radioactive material stock must be kept locked at all times to ensure that radioactive material is secured against theft. It is advisable to lock the radioactive waste containers to ensure unauthorized access. The exposure rates in radioactive material storage area should be less than the values listed in rows one through four in the Table 5 provided in Section 18.1.3. The exposure rates in radiation producing machine storage locations should be less than the values listed in rows six through eleven in the Table 5 provided in Section 18.1.3.

All containers storing liquid radioactive materials should be placed in secondary containers with adequate size to retain the leak of entire contents from the primary container

15 RADIATION POSTINGS AND WARNINGS

The purpose of posting and labeling is to identify and communicate

- the potential or actual presence of radiation levels in excess of specified limits.
- areas, containers, or equipment which require special controls

Labels and signs with radiation symbol shall not be used for any purpose other than radiological control as described below or as specified by the RSO. Labels and notices to be used or displayed shall be as large as practicable. When any radiation hazard ceases to exist, all labels and notices used or displayed in connection with such hazard shall be removed immediately.

For all irradiating apparatus generating X- rays and Particle Accelerators a standard radiation hazard symbol (please refer to **Appendix J**) should be placed on the apparatus. The words "**DANGER – RADIATION. This apparatus produces radiation when energised**" should be placed immediately adjacent to the symbol.

For all irradiating apparatus with sealed radioactive material and containers containing unsealed radioactive material the standard radiation hazard symbol specified in **Appendix J** should be placed on the apparatus/container. **T**he words "**DANGER – RADIOACTIVE**" and the name and activity (with reference date) of radionuclide should be immediately adjacent to the symbol. Small containers like eppendorf tubes containing less than 1 µcurie of activity need not be individually labeled as long as they are stored in a labeled secondary container or rack. Labeling laboratory containers is not required as long as -

the containers hold materials during transient procedures lasting only a few hours AND

that are disposed of immediately upon the completion of an experiment AND

under the control of or in the presence of a licensed user

All equipment such as incubators, freezers, gel dryers, glassware, etc., that will handle radioactive material should have standard radiation hazard symbol **(please refer to Appendix J)** posted on the equipment.

All entrances to rooms and labs containing radioactive material or irradiating apparatus should have standard radiation hazard symbol **(please refer to Appendix J)** posted on the doors.

The radiation work area should have standard radiation hazard symbol posted at the work area to clearly warn individuals about the use of radioactive materials

16 RADIATION INSTRUMENTATION

All users of different sources of radiation must have a survey meter which is sensitive to (i.e., is able to detect) the type and energy of radiation being used.

There are two factors that decide the type of radiation detector that a user should choose

- Type of radiation to be monitored – alpha, beta, gamma orlow energy x rays
- Purpose – Contamination monitoring (with units of counts per minutes - CPM) or Exposure monitoring (with units of Roentgen/hr or Sievert/hr).

For contamination monitoring, Pancake Geiger Mueller, End Window Geiger Mueller, Solid Sodium Iodide Scintillation detector are the most commonly used detectors in research laboratories.

For exposure monitoring, Energy compensated Geiger Mueller or Ionization chamber should be used. It may be possible to use the contamination monitoring detectors for exposure monitoring if calibrated appropriately. However, Energy compensated Geiger Mueller and Ionization chamber detectors are the ideal choice for exposure monitoring due to several advantages.

Table 2 can be used as a guide to select the correct type of radiation detector. Please note that the following table only shows the commonly used purpose of each detector and also the type of radiation that is detected ***most efficiently*** by each detector.

Table 2: Summary of Use Characteristics of Various Meters

Type of Detector	**Sub type**	**Type of radiation**	**Purpose**
GM			
	pancake	beta	contamination
	end window	beta	contamination
	energy compensated	beta and gamma	exposure rate
Scintillation			
	Solid	gamma, low energy x rays	contamination
	Plastic	beta	contamination
	liquid scintillation	beta	contamination
Ionization chamber	NA	gamma	exposure rate

17 CONTAMINATION MONITORING

Periodic contamination checks are required in areas where unsealed sources are used to prevent spread of contamination.

Removable contamination can be readily removed using proper decontamination procedures. Removable contamination in any amount may present both an external and internal hazard because it can picked up on skin and possibly ingested.

Fixed contamination cannot be readily decontaminated. Fixed contamination generally does not present a significant hazard unless the material comes loose or is present in such large amounts that it presents an external radiation hazard.

Total Contamination is the term used to refer to the presence of both removable and fixed contamination.

17.1 CONTAMINATION SURVEYS

Routine Surveys – Routine contamination checks should be performed for personnel contamination and suspected laboratory contamination before, during or after use of radioactive materials. Monitor work area, hands, shoes, and clothing for contamination after each procedure and before leaving area. This survey need not be documented and the contaminated areas should be cleaned immediately. Please refer to Section 17.4 for decontamination procedures.

Periodic Surveys – Contamination checks of labs should be performed and documented at scheduled intervals and frequency determined by laboratory classification as shown below

Area of Use	Documented Survey Frequency
Routine laboratory (open containers)	Monthly
Equipment use room (no open containers)	Quarterly
Waste storage room	Monthly
Iodination rooms	After each use

If no radiation work was performed in labs and PI possesses no radioactive materials, then surveys are not required. However, the survey documentation should indicate that surveys were not performed for the time period. The PIs sharing the common areas should identify radiation worker and assign the responsibility of performing the surveys.

Table 3 summarizes the commonly used means of contamination monitoring for radionuclides commonly used in research laboratories. Information on the purchase of radiation detectors can be obtained from the radiation safety officer x 66961

Table 3: Summary of Efficiencies of Various Detectors to Commonly Used Radionuclides

Radionuclide	**Pancake GM Efficiency**	**End Window GM Efficiency**	**LSC Efficiency**	**NaI detector Efficiency Thin Crystal - (2mm x 1 in)**
3H	Not Detectable	Not Detectable	40%	NA
14C	10%	5%	85%	NA
35S	10%	5%	85%	NA
32P	50%	30%	95%	NA
33P	15%	7%	85%	NA
I-125	<1%	<1%	80%	30% (thin)

Cr-51	<1%	<1%	30%	2% (thick)
I-131	18%	9%	90%	15% (thick)
Co-57	<1%	<1%	80%	8% (thick)

Liquid scintillation detectors are used to check removable contamination from any surface by the means of wipe tests. All other detectors can be used to determine removable, fixed or total contamination on a surface depending on how the survey is performed and also on the energy and type of radiation emitted by the radionuclide. All the detectors except the liquid scintillation detector are small and portable.

17.1.1 PANCAKE AND END WINDOW GM DETECTORS

These detectors are small and portable and used for evaluating total contamination of beta emitting radionuclide. GM detectors are not recommended for measuring gamma contamination in the laboratory. Please note that H-3 is not detected by this detector since they do not have enough energy to penetrate the window. The detection efficiencies for various beta emitting nuclides are given below. Pancake detectors have about twice the counting efficiency for beta emitters than end-window detectors.

17.1.2 SCINTILLATION DETECTORS

A scintillator is a material which gives off a photon (flash) of light when struck by radiation. Sodium Iodide (NaI) solid crystal, plastic and liquid scintillation detectors are the common types of scintillation detectors used for contamination monitoring in research laboratories. While NaI solid crystal and plastic scintillators are used for measuring both fixed and removable contamination, the liquid scintillation counters are used only for measuring removable contamination.

17.1.2.1SODIUM IODIDE SOLID CRYSTAL

NaI scintillator is the most commonly used solid crystal scintillation detector. Thin crystal (1 inch x 2 mm) NaI detectors are used for low energy gamma of energy range 10 keV to 60 keV. This detector is commonly used for nuclides like I-125.Thick crystal (1 inch x 1 inch) NaI detectors are used for higher energy gamma emitting nuclides like Cr-51, I-131, Co-57 etc.,

17.1.2.2PLASTIC

They are not very commonly used. They are ideally used for beta contamination monitoring. GM detectors are cheaper and provide comparable performance for beta detection.

17.1.2.3 LIQUID SCINTILLATION

Liquid scintillation counting is a method of counting a radioactive sample by dissolving it in a mixture of chemicals called scintillation fluid or cocktail. The cocktail emits light when beta particles lose energy. The light flashes directly relate to the amount of contamination in the sample. They are ideal for counting radionuclides that decay by alpha and beta particle emission (H-3, C-14, P-32, S-35) and are also used to measure some low energy gamma emitters (I-125) which emit auger electrons as part of their decay. The efficiency of the detection is reduced by several factors that interfere during the process of generation and transfer of light photons. (This reduction in efficiency is termed as quenching). The detection efficiencies of commonly used radioisotopes are given below in Table 4 (Assuming 50% quenching)

Table 4: LSC Detection Efficiencies of Commonly Used Radionuclides

Radionuclide	**LSC Efficiency**
3H	40%
14C	85%
35S	85%
32P	95%
33P	85%
I-125	80%

17.2 HOW TO PERFORM A CONTAMINATION SURVEY

For guidelines on how to use a portable radiation detector for measuring contamination refer to A**ppendix K**. Guidelines on how to use a liquid scintillation counter for removable contamination monitoring, please refer to the A**ppendix L**

Prior to performing any survey, radiation monitoring badges and appropriate PPE should be worn. Care should be given to prevent the possibility of personal contamination or cross-contamination during surveys.

Monitoring and periodic checks shall be conducted on the most common sites for contamination, such as survey meter handle, soap/towel dispensers, drawer handles, refrigerator/freezer handles, chair edges, writing utensils, survey record books, floors, radio dials, telephone receiver/keypad, µwave oven touch pads/handles, doorknobs, light switches, non-radioactive trash containers etc., All designated "break rooms" and “wash sinks” must be surveyed. All areas where radioisotopes are used, stored or disposed, and the floors adjacent to those areas must be surveyed. This includes centrifuges, incubators, cold rooms, sealing equipment, pipettes and any other equipment which has been used for radioisotope work. Areas of the lab that would not be expected to become contaminated, such as desks, telephones, door knobs, light switches, etc, should also be randomly surveyed to assure that contamination has not occurred. It is a good practice to rotate the non-radioactive areas tested so the whole laboratory will be monitored over time and problem areas can be identified and decontaminated.

The surveys should be documented in the Laboratory Contamination Survey Form shown in **Appendix M**. The form should include a sketch or description of the areas surveyed, and an indication of the results.. If a liquid scintillation counter is used for contamination checks the LSC print out may be attached to the Laboratory Contamination survey form. A record of the results shall be kept for a period of three years. All contaminated items shall be either decontaminated or discarded as radioactive waste if decontamination is not feasible.

17.3 CONTAMINATION ACTION LEVELS

Following guideline should be used to judge whether an area is contaminated and if needs decontamination.

For portable contamination monitors reading in CPM (end window GM, Pancake GM and solid scintillation detectors) the surface is considered contaminated if the reading on the meter in CPM is two times greater than the background count rate.

For liquid scintillation counter, the surface is considered contaminated if the reading on the printout from the LSC is greater than 200 DPM/wipe assuming a wipe area of 100 cm^2. Alternatively, the permissible limits as specified under Fifth Schedule of the Radiation Protection (Ionising Radiation) Regulations (see **Appendix D**), can also be used.

If contamination is found, record the result and indicate the action taken on the Laboratory Contamination Survey Form. Such locations should be immediately decontaminated and a record of the survey taken after decontamination should also be documented. Please refer to the Section 17.4 on decontamination procedures on how to remove contamination. A repeat survey of the location must then be made after decontamination and should be recorded to verify that the removable contamination level is less than the limits mentioned above. All contamination should be reduced to a level as close to background as is reasonably achievable. Please contact Radiation Safety Officer if you are unable to reduce your contamination to the levels listed here.

17.4 DECONTAMINATION PROCEDURES

Decontamination shall be conducted to remove loose or fixed surface radioactivity when surveys revealed the presence of radioactive contamination. At the end of the experiment, it is the responsibility of all users to decontaminate the work area prior to leaving the work area. General methods of decontamination are given in the following sub-sections.

17.4.1 DECONTAMINATION OF SKIN

Use proper contamination survey meter for the isotope used and determine readings and area of contamination. Wash affected area with lukewarm water. Cold water will constrict pores making it difficult to remove contamination. Hot water may expand pores causing further penetration through the skin surface. Re-survey after wash and note readings. Continue to wash and survey until no more contamination is detected or if skin starts to become irritated. Do not scrub with anything rough or harsh.

17.4.2 DECONTAMINATION OF CLOTHING

Remove contaminated items immediately. Decontaminate skin if affected. Place all clothing items in a bag and label as required for radioactive waste.

17.4.3 DECONTAMINATION OF EYES

Immediately flush eye with water.

17.4.4 DECONTAMINATION OF LAB FLOOR AND BENCHES

Restrict access. Monitor and define boundaries. Clean up contaminant using absorbent paper wiping from outer edge inwards. Repeat the process several times and use a monitor to check the progress of the work until background levels are detected. Place all absorbent paper in a bag and label as required for radioactive waste.

18 EXTERNAL EXPOSURE MONITORING

External exposure monitoring can be performed by using appropriate portable radiation detectors or by using radiation monitoring badges. The portable radiation detectors provided a live reading of the surrounding exposure levels. Radiation monitoring badges provide cumulated data of an individuals exposure over a period of time while working with radiation.

18.1 AREA EXPOSURE MONITORING

Exposure rate is usually measured in units of Roentgen/hour (R/hr) that represents the amount of ionization created in air by X rays or gamma rays. The dose rate to a human is usually measured in units of Sieverts/hour (Sv/hr) and it represents the amount of radiation dose an individual has received. The exposure rate and dose rate are interchangeably used in the industry, with the following conversion factor. 1 Sv/hr $\simeq$ 0.01 R/hr.

Exposure monitoring can be performed by using either an energy compensated GM probe or by using an Ionization chamber. Although pancake GM and scintillation detectors can be calibrated to measure exposure, it is not advisable to use them for exposure monitoring because of over estimation of exposure rates in the 20 keV to 160 keV range as they are usually calibrated at a higher energy using Cs-137 (662 keV gamma ray)

18.1.1 ENERGY COMPENSATED GM DETECTORS

These are special type of GM detectors that are designed to compensate for overestimation of exposure rates at low energy. These detectors usually have a window that can be opened to detect beta radiation. This detector cannot be used for measuring exposure from very low energy X rays (<50 keV).

18.1.2 IONIZATION CHAMBERS

Ionization chambers are commonly used in areas where large exposure rates are anticipated (nuclear plants, radiopharmacy, teletherapy machines etc.,) They can also be designed to detect both beta and gamma radiation.

18.1.3 EXPOSURE RATE SURVEYS

Periodic exposure rate checks are required in areas where sealed and unsealed sources are stored and also where radiation producing equipments are used. Routine exposure rate checks should be performed to ensure the limits shown in Table 5 are not exceeded.

Table 5: Regulatory Exposure Rate Limits for Various Radiation Use Conditions

Number	Area	Dose Rate	Location

1	Radioactive material storage area/room	0.5 μSv/hr	Public/non radiation worker access locations
2	Radioactive material storage area/room	4 μSv/hr	radiation worker access locations @ 1 m from the storage location
3	Radioactive material storage area/room	40 μSv/hr	radiation worker access locations @ 5 cm from the storage location
4	Radioactive material waste storage area	0.5 μSv/hr	Public/non radiation worker access locations
5	Radioactive material waste bag	1 μSv/hr	Outside the bag
6	Equipment with sealed source while not in use	1.5 μSv/hr	outside the equipment @ public/non radiation worker access locations
7	Equipment with sealed source while in use	10 μSv/hr	outside the equipment @ public/non radiation worker access locations
8	Veterinary diagnostic equipment, while in use at maximum current	10 μSv/hr	Public/non radiation worker access locations
9	Veterinary diagnostic equipment, while in use at maximum current	1 milliSv/hr	one meter from the machine
10	X-Ray machines and Accelerators while in use	10 μSv/hr	radiation worker access locations
11	X- Ray machines and Accelerators while in use	1.5 μSv/hr	Public/non radiation worker access locations

Exposure rate surveys should be conducted prior to commissioning of radiation producing equipment and should be documented. Also, annual exposure rate surveys should be performed and documented for radiation producing equipment.

18.1.4 HOW TO PERFORM A SURVEY

For guidelines on how to use a portable radiation detector for monitoring radiation exposure please refer to Appendix K. Radiation monitoring badges also should be worn while performing surveys. Exposure rate monitoring should be performed at locations specified in the Table 5 in Section 18.1.3 using either an energy compensated GM probe or an ionization chamber. For radiation producing equipments, the surveys should be performed when it is on and operating at full power. The initial surveys performed prior to commissioning of radiation equipments and subsequent annual surveys should be documented in the Radiation Machine Inspection and Survey Form shown in **Appendix H**. The form should include a description and serial number of the equipment surveyed, a sketch or description of the equipment surveyed, and an indication of the survey results. A record of the results shall be kept for a period of three years.

18.2 PERSONNEL EXPOSURE MONITORING

The purpose of personal dosimeters is to record the radiation dose received by the radiation worker in the course of his work. Personal dosimeters also known as Thermo luminescent Dosimeters (TLDs) are later analyzed to determine the recorded dose. In research labs, personal exposure monitoring consists of using a whole body badge to record the whole body dose and using a ring badge to record the dose to fingers. The dosimeters are usually provided by RPNSD upon approval of the L5, L6 and R1 license applications. The badges will be shipped to the FSHO, who will then forward it to the individual workers. The badges are exchanged on a monthly basis. The new badges are sent to the FSHO, who will co-ordinate the badge exchange and shipping to RPNSD for analysis. It is necessary the users follow the prescribed badge exchange frequency for accurate record of the radiation dose they received. The dose analysis reports are sent to the FSHO who will notify the user.

If you are a radiation worker and have been issued a TLD to monitor your radiation exposure, you should follow a few simple practices to ensure that the dosimeter accurately records your radiation exposure.

- TLD badges will not be able to record dose from use of H-3 as the beta radiation emitted by H-3 does not have sufficient energy to penetrate the badge.
- Wear only your own TLD, never wear another person's badge.
- Wear whole body badges between the collar and waist with the shiny surface facing outside
- To avoid contamination, wear ring badges underneath gloves with the chip on the palm side of the hand that handles radiation sources.
- Do not store your badge near radiation or high-heat sources.
- Do not leave your badge attached to your lab coat (when not wearing your lab coat).

- Care must be taken not to cross-contaminate a badge or ring dosimeter. A contaminated dosimeter will give a false-positive dose reading since it continues to be irradiated even after work is completed. If you suspect contamination on your badge, notify the Radiation safety officer immediately.
- Lost badges should be immediately notified to the Radiation Safety Officer
- Never intentionally expose your badge to any radiation.
- Do not wear your badge when receiving medical radiation exposure (e.g., x-rays, nuclear medicine, etc.).
- Return your badge to your FSHO for processing at the end of the wearing period.

Where any individual ceases to be employed as a radiation worker, OSHE shall provide a record of radiation dose received while working at NUS. **FSHO/RSO** should complete the Transfer Record Form show in **Appendix N** and send a copy to the radiation worker and also to the Chief Executive.

19 INTERNAL EXPOSURE MONITORING

Certain individuals who handle unsealed radioactive materials in relatively large quantities are monitored by OSHE for internal contamination by perfroming bioassays. The bioassays are of two distinct types –

19.1 THYROID MONITORING

The thyroid gland accumulates 20 - 30% of the soluble radioiodine taken in by the body and hence routine thyroid monitoring for individuals using radioiodine is necessary. Following individuals should notify the Radiation Safety Officer before performing single experiment involving use of

- more than 1 mCi of free, unbound radioactive isotopes of Iodine (I-125, I-131 etc.,) and Sodium Iodide and Potassium Iodide.
- more than 10 mci of radioactive isotopes of Iodine (I-125, I-131 etc.,) bound to molecules.

Such individuals will be subjected to a baseline Thyroid monitoring test to determine the baseline thyroid burden. Later, thyroid monitoring should be performed after 24 hours but within one week of actual use of radioiodine. The radioiodine activity in the thyroid will be measured and compared to the baseline value to determine if the body burden is within ALARA levels shown in Table 1 provided in Section 7.2.

19.2 URINE ANALYSIS

Individuals working with more than 10 mCi of tritium at any one time should contact Radiation Safety Officer within 24 hours. The urine samples will be collected and analyzed using liquid scintillation counter to determine if the body burden is within the ALARA levels shown in Table 1 provided in Section 7.2.

20 DISPOSAL OF RADIOACTIVE WASTE

Radioactive waste refers to wastes containing radio isotopes, and may be potentially detrimental to human health and/or the environment, and which requires special treatment and disposal. Radioactive wastes generated in the laboratories in NUS must be tested and disposed in a safe and environmentally sound manner. RSO will co-ordinate with the users, RPNSD and waste disposal site disposal 3 to 4 times per year for collection and disposal of radioactive waste from labs.

20.1 GENERAL REQUIREMENTS

All radioactive waste should be in the dry form for regulators to accept the waste for disposal. So all liquid (solvent and aqueous) waste generation should be minimized and should be absorbed in a chemically compatible absorbent before waste pick up.

For liquids generated during rinsing of containers containing radioactive material, the first (1^{st}) and second (2^{nd}) rinsing should be collected in containers and absorbed in chemically compatible absorbent before waste pick up. Rinse water from third (3^{rd}) and subsequent rinsing of apparatus may be discharged into the sewer directly at point of use.

Aqueous and solvent type radioactive wastes should not be mixed in the same container. Whenever possible each container should contain waste only contaminated with a single radionuclide.

Glassware and sharps such as vials and syringes are to be packed separately in bins or multiple layers of bags suitably padded before they are placed in radioactive waste bags.

For Animal carcasses, the means of disposal will depend s on the activity of the nuclide per gram of the carcass. Please refer to Section 20.3 for more information on disposal requirements of animal carcasses.

Sealed radioactive materials cannot be disposed in Singapore. All sealed radioactive materials should be either returned back to the vendor or should be stored in a secluded storage area permanently. Inform FSHO of any sealed source that you wish to discard.

For radiation producing machines, no disposal of any irradiating apparatus is allowed, without the prior approval in writing to OSHE and RPNSD.

No compaction of radioactive waste is permitted.

20.2 STORAGE AND HANDLING REQUIREMENTS

Proper gloves are to be worn by all while handling the radioactive wastes to prevent spread of contamination.

The PIs shall ensure that all radioactive wastes are segregated and stored at a designated storage area, marked clearly with warning signs. The waste storage locations are to be confirmed with the assistance of FSHO. General waste and recyclable materials shall not be stored in this radioactive designated storage area.

Radioactive waste materials must be secured at all times. This may be accomplished either by maintaining materials in a designated locked freezer or cabinet or by restricting access to the room in which the materials are stored.

Radioactive waste should be stored in shielded containers to ensure that the dose rates outside the container are less than 0.5 µSv/hour. The selection of shielded containers should be based on the type of radiation emitted by the radionuclide. (plastic containers for beta emitter and leaded containers for gamma emitters)

All dry solid radioactive wastes must be deposited into red plastic waste disposal bags with NUS logo and radioactivity hazard symbol. (These bags are available from OSHE.)

Each bag when full shall be closed and securely sealed with red masking tape.

The activity, content and isotope shall be entered on both the i) "*Request for Disposal of Radioactive Waste Form"* (OSHE/F/RS/01, Please refer to **Appendix O**) which is available on the website http://www.nus.edu.sg/osh/forms.htm and ii) on the radioactive waste container label (see **Appendix P**). The radioactive waste container label is supplied by OSHE upon request and it is to be adhered onto the waste disposal bag. They are to be checked by the OSHE and/or the Faculty Safety & Health Officers before they are certified safe for disposal.

Competent person shall ensure good housekeeping for all waste stored in the common area under their jurisdiction.

20.3 WASTE DISPOSAL REQUIREMENTS

OSHE shall coordinate with users, RPNSD, and waste disposal site for the safe disposal of radioactive wastes.

For dry waste, the amount of radioactivity in each waste bag should be less than the radionuclide's corresponding exemption limit for that nuclide as listed in **Appendix B**. Each disposal bag should contain waste only contaminated with a single radionuclide. The exposure rate on the surface of each bag must *NOT* be greater than 0.1 mrem/hr or 1 µSv/hr. OSHE shall measure the levels of each radioactive waste bag as a second level of inspection and audit.

For Animal carcasses, if the activity per gram of the carcass is below the radionuclide's corresponding exemption limit for that nuclide as listed in **Appendix B,** it can be sent for incineration. The exposure rate on the surface of each bag must *NOT* be greater than 0.1mRem/hr or 1 µSv/hr before sending for incineration. For Animal carcasses, if the activity per gram of the carcass is above the radionuclide's corresponding exemption limit for that nuclide as listed in **Appendix B,** the user should store in a dedicated freezer and

a. decay until activity is below the exemption levels (for short lived nuclides eg., P-32, P-33, I-125, S-35)or
b. contact OSHE for disposal (for long lived nuclides eg., C-14, H-3

21 ACCIDENT / INCIDENT REPORTING AND INVESTIGATION

21.1 RADIATION ACCIDENTS

Under the Radiation Protection (Ionising Radiation) Regulations 2001, a radiation accident shall be considered to have occurred if:

a) An unexpected, uncontrolled high level of ionising radiation occurs as in the case of loss, by damage of the radiation shielding, of a sealed radioactive source or of irradiating apparatus;

b) An individual enters a high radiation field by accident;

c) There is loss of control of unsealed radioactive material causing a spillage or leakage of the radioactive material;

d) The skin or clothing of an individual becomes contaminated; or

e) Radioactive material is accidentally released into the environment in excess of the discharge level permitted by the Regulations;

such that:-

i. Any individual has, or could have, received an effective dose which is equal to or in excess of one fifth of the dose limit as specified in the Second Schedule (see **Appendix A**);

ii. The skin or personal clothing of any radiation worker is contaminated in excess of 50 times (2.5 times for any other individual) the appropriate permitted contamination limits for skin or personal clothing as specified in the Fifth Schedule (see **Appendix D**);

iii. Any area in the premises where work with ionising radiation or radioactive material is conducted is contaminated in excess of 50 times the permitted contamination limit for surfaces in such an area as specified in the Fifth Schedule (see **Appendix D**); or

iv. Any other area is contaminated in excess of 10 times the permitted contamination limit for surfaces in low level laboratories as specified in the Fifth Schedule (see **Appendix D**).

In addition to the above, if any radioactive material has been lost or mislaid, it shall be the duty of the radiation worker to notify the PI/ Licencee of the loss or missing radioactive materials immediately. If the radioactive material is not accounted for within 24 hours, the licensee shall notify OSHE who shall in turn inform RPNSD.

21.2 ACCIDENT RESPONSE PROCEDURES

All accidents, known exposures and near misses (which does not result in injury) MUST be reported to OSHE via the online Accident/ Incident Reporting System (AIRS) http://nus.edu.sg/osh/services/airs.htm. All injuries requiring first aid treatment shall be recorded in the First Aid Log Book.

Reporting must be done within twenty-four (24) hours. It can be submitted by the informant, injured staff/ student, PI, Laboratory Supervisor or other representative if the staff/ student are unfit or unable to do the initial report.

All accidents and incidents must be investigated by NUS in order to identify the root cause(s) and contributing factor(s). The investigation team will be headed by Radiation Safety Officer and may comprise of representatives from OSHE, the Departmental Safety and Health Committee, the Faculty Safety & Health Officer, PI, Laboratory Supervisor or other members if required.

Pending the investigation results to confirm whether an excessive exposure has indeed occurred, the RSO shall:

i. Immediately suspend the radiation worker from work in which he will be exposed to radiation.

ii. Arrange for medical examination for the radiation worker and affected personnel

iii. Obtain the contact details of the affected personnel (which may be a visitor, contractor, or a member of public).

Where the investigation confirms that there is indeed an excessive exposure, OSHE shall be responsible to notify the Chief Executive of RPNSD.

For more information, refer to the SOP '*Accident / Incident Reporting and Investigation'* (OSHE/SOP/GL/02) available in the website http://www.nus.edu.sg/osh/sop.htm.

22 RADIATION EMERGENCIES

An incident which involves serious injury or death, fire, explosion, or significant release of a health or life threatening material, coupled with a radiological accident as defined in Section 21 of this manual, treatment of injured individuals takes precendece over confining release of radioactivity. Emergency phone numbers and safety personnel contacts are provided in Section 27 of this manual

23 RADIOACTIVE MATERIAL SPILL RESPONSE

For laboratories using unsealed sources, the PI/ Lab Supervisor shall ensure that the following equipments are provided:

a. Spill packs containing a plastic bag containing gloves, overshoes, absorbent material (paper towels, vermiculite, etc), trays, thongs, etc.
b. Suitable radiation counters to monitor contamination levels.

Spills involving radioactive material can be classified as Minor or Major. Spills in the microCurie amounts in a single lab are considered minor spills. Spills in the milliCurie amounts in a single lab or spill in microCurie amounts over a large area including corridors and stairs are considered major spills.

23.1 MINOR SPILLS

Notify all persons in the room about the spill immediately. Monitor personnel before they leave and then change clothes or laboratory coats, as necessary.

Using an appropriate contamination monitor (GM or Scintillation counters) survey all suspected laboratory personnel (including yourself) who might be contaminated. Follow decontamination procedures (see Section 17.4) before they leave the room. Survey the spill area and mark or cordon off the spill area.

Confine the spill immediately by dropping absorbent paper on the liquid spill; if the spilled material is dry, dampen it to prevent the radioactive particles from dispersing.

Wear double gloves, laboratory coats, shoe covers, appropriate dosimetry, and other protective equipment as needed.

Clean up all spills using absorbent paper. Use a liquid cleaner spray and clean the spill area. Repeat the process several times and use a monitor to check the progress of the work. Repeat a contamination survey to ensure the contamination levels are three times below background. All radioactive materials (including absorbents, etc) should be disposed as radioactive wastes.

Notify the PI and FSHO of the spill. Report the spill to OSHE via the online Accident/ Incident Reporting System (AIRS) http://nus.edu.sg/osh/services/airs.htm

23.2 MAJOR SPILLS

Take note of the nature of the spilled material in order to advise emergency personnel on the possible hazards of the spill.

Notify all persons not involved in the spill cleanup to vacate the room at once and prohibit entrance except to emergency personnel. Declare area off limits. Post warning signs at all its entrances. All windows should be closed; fans and air conditioners should be switched off.

Contact the PI, FSHO and RSO immediately. The RSO will decide if clean up can be performed in house or outside help needs to be called in.

Any person who has accidentally inhaled, ingested or absorbed radioactive materials from the spill or the spill cleanup process should immediately seek medical attention. Use a contamination monitor to check and decontaminate affected personnel. Please refer to Section 17.4 for details on decontamination procedures. If the spill has contaminated the clothing, discard the clothing at once. Discarded clothing is to be disposed as radioactive waste.

Monitor the contamination levels of all persons involved in the spill clean-up by using the GM/ scintillation counters. .

All radioactive materials (including absorbents, etc) should be disposed as radioactive wastes.

Report the spill to OSHE via the online Accident/ Incident Reporting System (AIRS) http://nus.edu.sg/osh/services/airs.htm

24 CHECKING OF LEAKAGE/ BREAKAGE OF SEALED SOURCE

All sealed sources should be checked for leakage by the owner of the sealed source at least once every 12 months. A register of the wipe tests conducted should be maintained. The procedure for performing leak test is provided in A**ppendix Q.** The source is considered leaking if the count rates from the wipe test are above three times background count rate.

Where any radioactive substance is leaking, or is likely to leak:

a. RSO shall be informed immediately and OSHE will in turn notify RPNSD
b. immediate vacation of all appropriate areas to safeguard every individual present in the vicinity of the sealed source
c. a leak-proof container shall be used to contain the leak until completely repaired.
d. decontamination carried out by properly equipped individuals supervised by the licensee or qualified individual.

25 DECOMMISSIONING

25.1 DECOMMISSIONING OF LABS USING RADIOACTIVE MATERIAL

A radiation use location is said to be "decommissioned" only after

- All radioactive material inventory balance are accounted for
- Radioactive sources and irradiating equipment have been disposed off or transferred to another laboratory
- Wipe, survey tests have been conducted

Upon completion of these steps, the FSHO completes the Laboratory Decommissioning Checklist and files the confirmation documentation. FSHO will co-ordinate all license cancellations

25.2 DECOMMISSIONING OF RADIATION PRODUCING MACHINES

A radiation producing machine is said to be "decommissioned" only after

- Source of the radiation is removed from the equipment using sealed radioactive materials

OR

- Source of the radiation is completely impaired from the equipment using X ray tubes. The tubes should be impaired in a manner that it will be impossible to use the tube again in the future. Contact Radiation Safety Officer for further questions.

OR

- The equipment is sent back to the manufacturer or supplying vendor for reuse or recycling.

OR

- The equipment is sold to an individual outside NUS campus. (The equipment owner should verify that the new owner possess any required license prior to selling the equipment)

The FSHO should be notified prior to the decommissioning of the equipment. FSHO will co-ordinate all license cancellations

25.3 DECOMMISSIONING OF EQUIPMENT USING RADIOACTIVE MATERIAL

This applies to all equipment, instruments, refrigerators, freezers, lab ware or other apparatus where radioactive material was used or stored. Before such equipment are given over for disposal, transferred to another location,

- they should be checked for contamination using the appropriate contamination monitor. If radiation levels are found more than three times background levels, they should be cleaned/decontaminated.
- radiation labels found on the equipment is removed and/or defaced

The surveys should be recorded on the Contamination Survey Form found in **Appendix L**. The details of the equipment including name and serial number should be recorded on this form. All equipment decommissioning records should be maintained by the PI. The FSHO should be notified prior to the decommissioning of the equipment.

26 RADIATION LABORATORY INSPECTIONS:

Inspections of laboratories using radioactive materials and radiation producing machines will be done the Radiation Safety Officer once every six months to verify compliance with Radiation protection regulations. The Inspection will be performed against the Radiation Laboratory Inspection Checklist provided in the **Appendix S.** The inspection will also include random measurements of exposure levels and contamination levels in radiation use laboratories.

The inspection report along with the results of the inspection will be forwarded to the principal investigator, and a recheck may be conducted in the event problems have been detected that need corrective action.

27 EMERGENCY PHONE NUMBERS AND SAFETY PERSONNEL CONTACTS

27.1 EMERGENCY PHONE NUMBERS

SCDF - Ambulance/Fire	995
Police	999
Campus Security (24hrs)	x 1616 (6874 1616)
General Maintenance/ Breakdown of Services (24 hrs)	x 1515 (6516 1515)

In the event of emergency, please call Campus Security and SCDF or Police

27.2 UNIVERSITY HEALTH CENTRE (UHC)

(http://www.nus.edu.sg/uhc/)

Main Clinic

Satellite Clinic

Kent Ridge Campus	**Bukit Timah Campus**
20 Lower Kent Ridge Road University Health Centre, Level 1	469G Bukit Timah Road Block B, #02-01, Multipurpose Auditorium
Operating Hours Mon – Thurs 8.30am – 6pm Fri 8.30am – 5.30pm Closed on Sat, Sun & Public Holidays	*Operating Hours* Mon/ Wed/ Fri 8.30 – 10.30am (during term only) Closed on Tue, Thu, Sat, Sun & Public Holidays
Closed for lunch from 12.30pm – 1.30pm	
Last registrations are 15 mins before closing time	**Last registrations are 15 mins before closing time**
General Enquiries: 6601 5035 uhc_health@nus.edu.sg	General Enquiries: 6467 5492 uhc_health@nus.edu.sg

27.3 NEAREST HOSPITAL

In the event of critical injury/ illness after office hours, proceed to the Accident & Emergency Unit of a nearby hospital. The nearest hospital in the vicinity of the University is:

National University Hospital (NUH)
Lower Kent Ridge Road
Singapore 119074
Main Line (24hr general enquiries) Tel: (65) 6779 5555
Emergency Tel: (65) 6772 5000
www.nuh.com.sg

27.4 OFFICE OF SAFETY, HEALTH AND ENVIRONMENT (OSHE)

A. OSHE

Office of Safety, Health and Environment
University Health Centre, Basement
20 Lower Kent Ridge Road
Singapore 119077
General Enquiries: 6516 1084
Fax: 6774 6979
Email: safety@nus.edu.sg

www.nus.edu.sg/osh/

B. Faculty/ Department Safety and Health Officers/ Coordinators

Contacts for Safety & Health Officers/ Coordinators on safety and health issues pertaining to your faculty are accessible at:

http://www.nus.edu.sg/osh/aboutus/staff.htm#staff_fac.

28 LIST OF APPENDICES

Appendix A	Ionizing Radiation Occupational Dose Limits
Appendix B	Radionuclide Exemption Quantity Limits
Appendix C	Annual Limits on Intake (ALI) for Radiation Workers
Appendix D	Limits for Contamination of Surfaces
Appendix E	Request for Funding for Occupational Health Related Medical Services (OSHE/51/D01)
Appendix F	Fact Sheets of Commonly Used Isotopes

Appendix G **Radioactive Package Receipt and Inspection Form (To be included soon)**

Appendix H Radiation Machine Inspection and Survey Form

Appendix I Radioactive Material Inventory Form

Appendix J Standard Symbol For Designating Any Ionising Radiation Hazard

Appendix K Portable Radiation Survey Meter Operation Procedure

Appendix L Liquid Scintillation Counter Operation/Wipe Test Procedure

Appendix M Radioactive Material User Monthly Survey Form

Appendix N **Radiation Dose Record Transfer Form (to be included soon)**

Appendix O Request for Disposal of Radioactive Waste Form (OSHE/F/RS/01)

Appendix P Radioactive waste container label

Appendix Q Sealed Source Leak Test Procedure

Appendix S **Radiation Laboratory Inspection Checklist (To be included soon)**

Appendix T RPNSD Service Request Form

Appendix A: Ionizing Radiation Occupational Dose Limits

(Source: Second Schedule, Radiation Protection (Ionising Radiation) Regulations 2001)

SECOND SCHEDULE

Regulations 2, 14 (1), (4) and (5), 15 (4), 16 (1), (2) and (3), 18 and 49 (1)

PART I

DOSE LIMITS FOR RADIATION WORKERS

(*a*) Except as provided in paragraph (*d*) of this Part, the dose limits for radiation workers shall be those given in the following table. The dose from any medical or dental exposure as a patient, from the exposure to natural background radiation or from other exposures received by the radiation worker as a member of the public shall not be taken into account.

Application	Dose limit per year (mSv)
Effective dose (whole body)	20[1]
Equivalent dose in	
the lens of the eye	150
the skin[2]	500
the hands and feet	500

(*b*) Where only a part or parts of the body are irradiated by external radiation, the effective dose received from external radiation shall be determined by calculating the sum of $w_T H_T$ over all the organs and tissues irradiated, where —

(i) H_T is the equivalent dose received by any particular tissue or organ T; and

(ii) W_T is the weighting factor for that tissue or organ.

[1] The limit on effective dose (whole body) is 20 mSv per year, averaged over defined periods of 5 years and with the further provision that the effective dose shall not exceed 50 mSv in any single year. The limit shall apply to the sum of the relevant doses from external exposure in the specified period and the committed effective dose.

[2] The limit of 500 mSv for skin is averaged over areas of no more than 1 cm^2 regardless of the area exposed.

The values of the tissue weighting factors to be used for determining the weighted equivalent dose $w_T H_T$, shall be those given in the following table:

Tissue or organ	Tissue weighting factor W_T
Gonads	0.20
Bone marrow (red)	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Oesophagus	0.05
Thyroid	0.05
Skin	0.01
Bone surface	0.01
Remainder	0.05[1]

(*c*) The occupational dose limit for women who are not pregnant shall be the same as that of men.

(*d*) Once pregnancy has been declared, the equivalent dose limit to the surface of the woman's abdomen (lower trunk) shall be 2 mSv for the remainder of the pregnancy and the intake of radionuclides shall be limited to one-twentieth of the ALI specified in the Third Schedule.

[1] The equivalent dose in the remainder is the estimated mean equivalent dose over the whole body excluding the specified tissues and organs.

PART II

DOSE LIMITS FOR INDIVIDUAL MEMBERS OF THE PUBLIC

The annual dose limits for individual members of the public shall be those listed in the following table. The dose from any medical or dental exposure as a patient or from the exposure to natural background radiation shall not be taken into account.

Application	Dose limit per year (mSv)
Effective dose (whole body)	1[1]
Equivalent dose in	
the lens of the eye	15
the skin[2]	50

[1] In special circumstances, a higher value of effective dose for the whole body could be allowed in a single year, provided that the average over 5 years does not exceed 1 mSv per year. The limit shall apply to the sum of the relevant doses from external exposure in the specified period and the committed effective dose.

[2] The limit of 50 mSv for skin is averaged over areas of no more than 1 cm^2 regardless of the area exposed.

PART III

VALUES OF RADIATION WEIGHTING FACTOR FOR DIFFERENT TYPES OF IONISING RADIATION

The values of radiation weighting factor to be used in determining the equivalent dose in a tissue or organ shall be those given in the following table. All values relate to the radiation incident on the body or, for internal sources, emitted from the source.

Type of ionising radiation and energy range	Radiation weighting factor
Photons, all energies	1
Electrons and muons, all energies	1
Neutrons, energy < 10 keV	5
10 keV to 100 keV	10
>100 keV to 2 MeV	20
>2 MeV to 20 MeV	10
>20 MeV	5
Protons, other than recoil protons, energy >2 MeV	5
Alpha particles, fission fragments, heavy nuclei	20

Appendix B: Radionuclide Exemption Quantitiy Limits
(Source: First Schedule, Radiation Protection (Ionising Radiation) Regulations 2001)

p. 54 2001 Ed.] *Radiation Protection (Ionising Radiation) Regulations* [CAP. 262, Rg 2

FIRST SCHEDULE

Regulation 3 (1) and (2)

MAXIMUM ACTIVITIES AND ACTIVITY CONCENTRATIONS OF RADIONUCLIDES EXEMPTED FROM THE PROVISIONS OF THE ACT

Nuclide	Activity concentration (Bq/gm)	Activity (Bq)	Nuclide	Activity concentration (Bq/g)	Activity (Bq)
H-3	1×10^{6}	1×10^{9}	Fe-52	1×10^{1}	1×10^{6}
Be-7	1×10^{3}	1×10^{7}	Fe-55	1×10^{4}	1×10^{6}
C-14	1×10^{4}	1×10^{7}	Fe-59	1×10^{1}	1×10^{6}
O-15	1×10^{2}	1×10^{9}	Co-55	1×10^{1}	1×10^{6}
F-18	1×10^{1}	1×10^{6}	Co-56	1×10^{1}	1×10^{5}
Na-22	1×10^{1}	1×10^{6}	Co-57	1×10^{2}	1×10^{6}
Na-24	1×10^{1}	1×10^{5}	Co-58	1×10^{1}	1×10^{6}
Si-31	1×10^{3}	1×10^{6}	Co-58m	1×10^{4}	1×10^{7}
P-32	1×10^{3}	1×10^{5}	Co-60	1×10^{1}	1×10^{5}
P-33	1×10^{5}	1×10^{8}	Co-60m	1×10^{3}	1×10^{6}
S-35	1×10^{5}	1×10^{8}	Co-61	1×10^{2}	1×10^{6}
Cl-36	1×10^{4}	1×10^{6}	Co-62m	1×10^{1}	1×10^{5}
Cl-38	1×10^{1}	1×10^{5}	Ni-59	1×10^{4}	1×10^{8}
Ar-37	1×10^{6}	1×10^{8}	Ni-63	1×10^{5}	1×10^{8}
Ar-41	1×10^{2}	1×10^{9}	Ni-65	1×10^{1}	1×10^{6}
K-40	1×10^{2}	1×10^{6}	Cu-64	1×10^{2}	1×10^{6}
K-42	1×10^{2}	1×10^{6}	Zn-65	1×10^{1}	1×10^{6}
K-43	1×10^{1}	1×10^{6}	Zn-69	1×10^{4}	1×10^{6}
Ca-45	1×10^{4}	1×10^{7}	Zn-69m	1×10^{2}	1×10^{6}
Ca-47	1×10^{1}	1×10^{6}	Ga-72	1×10^{1}	1×10^{5}
Sc-46	1×10^{1}	1×10^{6}	Ge-71	1×10^{4}	1×10^{8}
Sc-47	1×10^{2}	1×10^{6}	As-73	1×10^{3}	1×10^{7}
Sc-48	1×10^{1}	1×10^{5}	As-74	1×10^{1}	1×10^{6}
V-48	1×10^{1}	1×10^{5}	As-76	1×10^{2}	1×10^{5}
Cr-51	1×10^{3}	1×10^{7}	As-77	1×10^{3}	1×10^{6}
Mn-51	1×10^{1}	1×10^{5}	Se-75	1×10^{2}	1×10^{6}
Mn-52	1×10^{1}	1×10^{5}	Br-82	1×10^{1}	1×10^{6}
Mn-52m	1×10^{1}	1×10^{5}	Kr-74	1×10^{2}	1×10^{9}
Mn-53	1×10^{4}	1×10^{9}	Kr-76	1×10^{2}	1×10^{9}
Mn-54	1×10^{1}	1×10^{6}	Kr-77	1×10^{2}	1×10^{9}
Mn-56	1×10^{1}	1×10^{5}	Kr-79	1×10^{3}	1×10^{5}

FIRST SCHEDULE — *continued*

Nuclide	Activity concentration (Bq/gm)	Activity (Bq)	Nuclide	Activity concentration (Bq/g)	Activity (Bq)
Kr-81	1×10^4	1×10^7	Tc-97	1×10^3	1×10^8
Kr-83m	1×10^5	1×10^{12}	Tc-97m	1×10^3	1×10^7
Kr-85	1×10^5	1×10^4	Tc-99	1×10^4	1×10^7
Kr-85m	1×10^3	1×10^{10}	Tc-99m	1×10^2	1×10^7
Kr-87	1×10^2	1×10^9	Ru-97	1×10^2	1×10^7
Kr-88	1×10^2	1×10^9	Ru-103	1×10^2	1×10^6
Rb-86	1×10^2	1×10^5	Ru-105	1×10^1	1×10^6
Sr-85	1×10^2	1×10^6	Ru-106	1×10^2	1×10^5
Sr-85m	1×10^2	1×10^7	Rh-103m	1×10^4	1×10^8
Sr-87m	1×10^2	1×10^6	Rh-105	1×10^2	1×10^7
Sr-89	1×10^3	1×10^6	Pd-103	1×10^3	1×10^8
Sr-90	1×10^2	1×10^4	Pd-109	1×10^3	1×10^6
Sr-91	1×10^1	1×10^5	Ag-105	1×10^2	1×10^6
Sr-92	1×10^1	1×10^6	Ag-110m	1×10^1	1×10^6
Y-90	1×10^3	1×10^5	Ag-111	1×10^3	1×10^6
Y-91	1×10^3	1×10^6	Cd-109	1×10^4	1×10^6
Y-91m	1×10^2	1×10^6	Cd-115	1×10^2	1×10^6
Y-92	1×10^2	1×10^5	Cd-115m	1×10^3	1×10^6
Y-93	1×10^2	1×10^5	In-111	1×10^2	1×10^6
Zr-93	1×10^3	1×10^7	In-113m	1×10^2	1×10^6
Zr-95	1×10^1	1×10^6	In-114m	1×10^2	1×10^6
Zr-97	1×10^1	1×10^5	In-115m	1×10^2	1×10^6
Nb-93m	1×10^4	1×10^7	Sn-113	1×10^3	1×10^7
Nb-94	1×10^1	1×10^6	Sn-125	1×10^2	1×10^5
Nb-95	1×10^1	1×10^6	Sb-122	1×10^2	1×10^4
Nb-97	1×10^1	1×10^6	Sb-124	1×10^1	1×10^6
Nb-98	1×10^1	1×10^5	Sb-125	1×10^2	1×10^6
Mo-90	1×10^1	1×10^6	Te-123m	1×10^2	1×10^7
Mo-93	1×10^3	1×10^8	Te-125m	1×10^3	1×10^7
Mo-99	1×10^2	1×10^6	Te-127	1×10^3	1×10^6
Mo-101	1×10^1	1×10^6	Te-127m	1×10^3	1×10^7
Tc-96	1×10^1	1×10^6	Te-129	1×10^2	1×10^6
Tc-96m	1×10^3	1×10^7	Te-129m	1×10^3	1×10^6
Te-131	1×10^2	1×10^5	Ce-143	1×10^2	1×10^6
Te-131m	1×10^1	1×10^6	Ce-144	1×10^2	1×10^5
Te-132	1×10^2	1×10^7	Pr-142	1×10^2	1×10^5

FIRST SCHEDULE — *continued*

Nuclide	Activity concentration (Bq/gm)	Activity (Bq)	Nuclide	Activity concentration (Bq/g)	Activity (Bq)
Te-133	1×10^{1}	1×10^{5}	Pr-143	1×10^{4}	1×10^{6}
Te-133m	1×10^{1}	1×10^{5}	Nd-147	1×10^{2}	1×10^{6}
Te-134	1×10^{1}	1×10^{6}	Nd-149	1×10^{2}	1×10^{6}
I-123	1×10^{2}	1×10^{7}	Pm-147	1×10^{4}	1×10^{7}
I-125	1×10^{3}	1×10^{6}	Pm-149	1×10^{3}	1×10^{6}
I-126	1×10^{2}	1×10^{6}	Sm-151	1×10^{4}	1×10^{8}
I-129	1×10^{2}	1×10^{5}	Sm-153	1×10^{2}	1×10^{6}
I-130	1×10^{1}	1×10^{6}	Eu-152	1×10^{1}	1×10^{6}
I-131	1×10^{2}	1×10^{6}	Eu-152m	1×10^{2}	1×10^{6}
I-132	1×10^{1}	1×10^{5}	Eu-154	1×10^{1}	1×10^{6}
I-133	1×10^{1}	1×10^{6}	Eu-155	1×10^{2}	1×10^{7}
I-134	1×10^{1}	1×10^{5}	Gd-153	1×10^{2}	1×10^{7}
I-135	1×10^{1}	1×10^{6}	Gd-159	1×10^{3}	1×10^{6}
Xe-131m	1×10^{4}	1×10^{4}	Tb-160	1×10^{1}	1×10^{6}
Xe-133	1×10^{3}	1×10^{4}	Dy-165	1×10^{3}	1×10^{6}
Xe-135	1×10^{3}	1×10^{10}	Dy-166	1×10^{3}	1×10^{6}
Cs-129	1×10^{2}	1×10^{5}	Ho-166	1×10^{3}	1×10^{5}
Cs-131	1×10^{3}	1×10^{6}	Er-169	1×10^{4}	1×10^{7}
Cs-132	1×10^{1}	1×10^{5}	Er-171	1×10^{2}	1×10^{6}
Cs-134m	1×10^{3}	1×10^{5}	Tm-170	1×10^{3}	1×10^{6}
Cs-134	1×10^{1}	1×10^{4}	Tm-171	1×10^{4}	1×10^{8}
Cs-135	1×10^{4}	1×10^{7}	Yb-175	1×10^{3}	1×10^{7}
Cs-136	1×10^{1}	1×10^{5}	Lu-177	1×10^{3}	1×10^{7}
Cs-137	1×10^{1}	1×10^{4}	Hf-181	1×10^{1}	1×10^{6}
Cs-138	1×10^{1}	1×10^{4}	Ta-182	1×10^{1}	1×10^{4}
Ba-131	1×10^{2}	1×10^{6}	W-181	1×10^{3}	1×10^{7}
Ba-140	1×10^{1}	1×10^{5}	W-185	1×10^{4}	1×10^{7}
La-140	1×10^{1}	1×10^{5}	W-187	1×10^{2}	1×10^{6}
Ce-139	1×10^{2}	1×10^{6}	Re-186	1×10^{3}	1×10^{6}
Ce-141	1×10^{2}	1×10^{7}	Re-188	1×10^{2}	1×10^{5}
Os-185	1×10^{1}	1×10^{6}	Rn-222	1×10^{1}	1×10^{8}
Os-191	1×10^{2}	1×10^{7}	Ra-223	1×10^{2}	1×10^{5}
Os-191m	1×10^{3}	1×10^{7}	Ra-224	1×10^{1}	1×10^{5}
Os-193	1×10^{2}	1×10^{6}	Ra-225	1×10^{2}	1×10^{5}

FIRST SCHEDULE — *continued*

Nuclide	Activity concentration (Bq/gm)	Activity (Bq)	Nuclide	Activity concentration (Bq/g)	Activity (Bq)
Ir-190	1×10^{1}	1×10^{6}	Ra-226	1×10^{1}	1×10^{4}
Ir-192	1×10^{1}	1×10^{4}	Ra-227	1×10^{2}	1×10^{6}
Ir-194	1×10^{2}	1×10^{5}	Ra-228	1×10^{1}	1×10^{5}
Pt-191	1×10^{2}	1×10^{6}	Ac-228	1×10^{1}	1×10^{6}
Pt-193m	1×10^{3}	1×10^{7}	Th-226	1×10^{3}	1×10^{7}
Pt-197	1×10^{3}	1×10^{6}	Th-227	1×10^{1}	1×10^{4}
Pt-197m	1×10^{2}	1×10^{6}	Th-228	1×10^{0}	1×10^{4}
Au-198	1×10^{2}	1×10^{6}	Th-229	1×10^{0}	1×10^{3}
Au-199	1×10^{2}	1×10^{6}	Th-230	1×10^{0}	1×10^{4}
Hg-197	1×10^{2}	1×10^{7}	Th-231	1×10^{3}	1×10^{7}
Hg-197m	1×10^{2}	1×10^{6}	Th-nat	1×10^{0}	1×10^{3}
Hg-203	1×10^{2}	1×10^{5}	(incl. Th-232)		
T1-200	1×10^{1}	1×10^{6}	Th-234	1×10^{3}	1×10^{5}
T1-201	1×10^{2}	1×10^{6}	Pa-230	1×10^{1}	1×10^{6}
T1-202	1×10^{2}	1×10^{6}	Pa-231	1×10^{0}	1×10^{3}
T1-204	1×10^{4}	1×10^{4}	Pa-233	1×10^{2}	1×10^{7}
Pb-203	1×10^{2}	1×10^{6}	U-230	1×10^{1}	1×10^{5}
Pb-210	1×10^{1}	1×10^{4}	U-231	1×10^{2}	1×10^{7}
Pb-212	1×10^{1}	1×10^{5}	U-232	1×10^{0}	1×10^{3}
Bi-206	1×10^{1}	1×10^{5}	U-233	1×10^{1}	1×10^{4}
Bi-207	1×10^{1}	1×10^{6}	U-234	1×10^{1}	1×10^{4}
Bi-210	1×10^{3}	1×10^{6}	U-235	1×10^{1}	1×10^{4}
Bi-212	1×10^{1}	1×10^{5}	U-236	1×10^{1}	1×10^{4}
Po-203	1×10^{1}	1×10^{6}	U-237	1×10^{2}	1×10^{6}
Po-205	1×10^{1}	1×10^{6}	U-238	1×10^{1}	1×10^{4}
Po-207	1×10^{1}	1×10^{6}	U-nat	1×10^{0}	1×10^{3}
Po-210	1×10^{1}	1×10^{4}	U-239	1×10^{2}	1×10^{6}
At-211	1×10^{3}	1×10^{7}	U-240	1×10^{3}	1×10^{7}
Rn-220	1×10^{4}	1×10^{7}	U-240	1×10^{1}	1×10^{6}
Np-237	1×10^{0}	1×10^{3}	Cm-244	1×10^{1}	1×10^{4}
Np-239	1×10^{2}	1×10^{7}	Cm-245	1×10^{0}	1×10^{3}
Np-240	1×10^{1}	1×10^{6}	Cm-246	1×10^{0}	1×10^{3}

FIRST SCHEDULE — *continued*

Nuclide	Activity concentration (Bq/gm)	Activity (Bq)	Nuclide	Activity concentration (Bq/g)	Activity (Bq)
Pu-234	1×10^{2}	1×10^{7}	Cm-247	1×10^{0}	1×10^{4}
Pu-235	1×10^{2}	1×10^{7}	Cm-248	1×10^{0}	1×10^{3}
Pu-236	1×10^{1}	1×10^{4}	Bk-249	1×10^{3}	1×10^{6}
Pu-237	1×10^{3}	1×10^{7}	Cf-246	1×10^{3}	1×10^{6}
Pu-238	1×10^{0}	1×10^{4}	Cf-248	1×10^{1}	1×10^{4}
Pu-239	1×10^{0}	1×10^{4}	Cf-249	1×10^{0}	1×10^{3}
Pu-240	1×10^{0}	1×10^{3}	Cf-250	1×10^{1}	1×10^{4}
Pu-241	1×10^{2}	1×10^{5}	Cf-251	1×10^{0}	1×10^{3}
Pu-242	1×10^{0}	1×10^{4}	Cf-252	1×10^{1}	1×10^{4}
Pu-243	1×10^{3}	1×10^{7}	Cf-253	1×10^{2}	1×10^{5}
Pu-244	1×10^{0}	1×10^{4}	Cf-254	1×10^{0}	1×10^{3}
Am-241	1×10^{0}	1×10^{4}	Es-253	1×10^{2}	1×10^{5}
Am-242	1×10^{3}	1×10^{6}	Es-254	1×10^{1}	1×10^{4}
Am-242m	1×10^{0}	1×10^{4}	Es-254m	1×10^{2}	1×10^{6}
Am-243	1×10^{0}	1×10^{3}	Fm-254	1×10^{4}	1×10^{7}
Cm-242	1×10^{2}	1×10^{5}	Fm-255	1×10^{3}	1×10^{6}
Cm-243	1×10^{0}	1×10^{4}			

(*a*) Exemption is given for radioactive substances for which either the total activity or the activity concentration of the radionuclide does not exceed the levels given in the above table.

(*b*) In the case of more than one radionuclide, the appropriate sum of the ratios of the activity or activity concentration of each radionuclide and the corresponding exempt activity or activity concentration shall be taken into account.

(*c*) Bulk amounts of materials with activity concentrations lower than the levels in the above table shall be individually considered by the Chief Executive.

Appendix C: Annual Limits on Intake (ALI) for Radiation Workers
(Source: Third Schedule, Radiation Protection (Ionising Radiation) Regulations 2001)

THIRD SCHEDULE

Regulation 24 (2) and
Second Schedule (Part I)

ANNUAL LIMITS ON INTAKE (ALI)
FOR RADIATION WORKERS

[Abbreviation: Metastable excited state (m)]

Column 1		Column 2	Column 3
Element (Atomic Number)	Isotope	Most restrictive inhalation ALI (Bq)	Most restrictive ingestion ALI (Bq)
Hydrogen (1)	H 3	1×10^9	1×10^9
Beryllium (4)	Be 7	2×10^8	6×10^8
Carbon (6)	C 14	4×10^7	4×10^7
Fluorine (9)	F 18	9×10^8	4×10^8
Sodium (11)	Na 22	1×10^7	7×10^6
	Na 24	6×10^7	5×10^7
Silicon (14)	Si 31	4×10^8	2×10^8
Phosphorus (15)	P 32	5×10^6	8×10^6
Sulphur (16)	S 35	3×10^7	7×10^7
Chlorine (17)	Cl 36	3×10^6	2×10^7
	Cl 38	5×10^8	2×10^8
Potassium (19)	K 42	5×10^7	5×10^7
Calcium (20)	Ca 45	1×10^7	2×10^7
	Ca 47	1×10^7	1×10^7
Scandium (21)	Sc 46	3×10^6	1×10^7
	Sc 47	3×10^7	3×10^7
	Sc 48	2×10^7	1×10^7
Vanadium (23)	V 48	7×10^6	8×10^6
Chromium (24)	Cr 51	2×10^8	4×10^8

THIRD SCHEDULE — *continued*

Column 1		Column 2	Column 3
Element (Atomic Number)	Isotope	Most restrictive inhalation ALI (Bq)	Most restrictive ingestion ALI (Bq)
Manganese (25)	Mn 52	1×10^7	1×10^7
	Mn 54	1×10^7	3×10^7
	Mn 56	2×10^8	9×10^7
Iron (26)	Fe 55	3×10^7	1×10^8
	Fe 59	5×10^6	1×10^7
Cobalt (27)	Co 57	8×10^6	6×10^7
	Co 58	7×10^6	2×10^7
	Co 58m	8×10^8	9×10^8
	Co 60	4×10^5	3×10^6
Nickel (28)	Ni 59	3×10^7	3×10^8
	Ni 63	1×10^7	1×10^8
	Ni 65	2×10^8	1×10^8
Copper (29)	Cu 64	3×10^8	2×10^8
Zinc (30)	Zn 65	4×10^6	5×10^6
	Zn 69	2×10^9	7×10^8
	Zn 69m	9×10^7	5×10^7
Gallium (31)	Ga 72	4×10^7	2×10^7
Germanium (32)	Ge 71	6×10^8	8×10^9
Arsenic (33)	As 73	2×10^7	8×10^7
	As 74	9×10^6	2×10^7
	As 76	2×10^7	1×10^7
	As 77	6×10^7	5×10^7
Selenium (34)	Se 75	1×10^7	9×10^6
Bromine (35)	Br 82	5×10^7	4×10^7
Rubidium (37)	Rb 86	1×10^7	8×10^6
	Rb 87	2×10^7	2×10^7

THIRD SCHEDULE — *continued*

Column 1		Column 2	Column 3
Element (Atomic Number)	Isotope	Most restrictive inhalation ALI (Bq)	Most restrictive ingestion ALI (Bq)
Strontium (38)	Sr 85	4×10^7	4×10^7
	Sr 85m	9×10^9	4×10^9
	Sr 89	2×10^6	6×10^6
	Sr 90	6×10^4	5×10^6
	Sr 91	5×10^7	3×10^7
	Sr 92	1×10^8	4×10^7
Yttrium (39)	Y 90	7×10^6	5×10^6
	Y 91	1×10^6	5×10^6
	Y 91m	2×10^9	2×10^9
	Y 92	1×10^8	4×10^7
	Y 93	3×10^7	2×10^7
Zirconium (40)	Zr 93	1×10^6	7×10^7
	Zr 95	3×10^6	2×10^7
	Zr 97	2×10^7	8×10^6
Niobium (41)	Nb 93m	3×10^6	1×10^8
	Nb 95	1×10^7	3×10^7
	Nb 97	9×10^8	4×10^8
Molybdenum (42)	Mo 99	2×10^7	1×10^7
Technetium (43)	Tc 96	3×10^7	2×10^7
	Tc 96m	3×10^9	2×10^9
	Tc 97	7×10^7	3×10^8
	Tc 97m	1×10^7	4×10^7
	Tc 99	8×10^6	3×10^7
	Tc 99m	2×10^9	1×10^9
Ruthenium (44)	Ru 97	2×10^8	1×10^8
	Ru 103	8×10^6	2×10^7
	Ru 105	2×10^8	7×10^7
	Ru 106	2×10^5	2×10^6
Rhodium (45)	Rh 103m	1×10^{10}	6×10^9
	Rh 105	7×10^7	4×10^7

THIRD SCHEDULE — *continued*

Column 1		Column 2	Column 3
Element (Atomic Number)	Isotope	Most restrictive inhalation ALI (Bq)	Most restrictive ingestion ALI (Bq)
Palladium (46)	Pd 103	4×10^7	7×10^7
	Pd 109	7×10^7	3×10^7
Silver (47)	Ag 105	2×10^7	4×10^7
	Ag 110m	1×10^6	7×10^6
	Ag 111	1×10^7	1×10^7
Cadmium (48)	Cd 109	1×10^6	9×10^6
	Cd 115	2×10^7	1×10^7
	Cd 115m	2×10^6	5×10^6
Indium (49)	In 113m	2×10^9	9×10^8
	In 114m	1×10^6	3×10^6
	In 115	3×10^4	6×10^5
	In 115m	6×10^8	2×10^8
Tin (50)	Sn 113	7×10^6	2×10^7
	Sn 125	4×10^6	4×10^6
Antimony (51)	Sb 122	1×10^7	8×10^6
	Sb 124	3×10^6	6×10^6
	Sb 125	6×10^6	2×10^7
Tellurium (52)	Te 125m	1×10^7	2×10^7
	Te 127	2×10^8	1×10^8
	Te 127m	4×10^6	9×10^6
	Te 129	8×10^8	4×10^8
	Te 129m	3×10^6	5×10^6
	Te 131m	8×10^6	6×10^6
	Te 132	5×10^6	5×10^6
Iodine (53)	I 125	2×10^6	1×10^6
	I 126	1×10^6	6×10^5
	I 129	3×10^5	2×10^5
	I 131	1×10^6	8×10^5
	I 132	1×10^8	7×10^7
	I 133	8×10^6	4×10^6
	I 134	5×10^8	2×10^8
	I 135	4×10^7	2×10^7

Column 1		Column 2	Column 3
Element (Atomic Number)	Isotope	Most restrictive inhalation ALI (Bq)	Most restrictive ingestion ALI (Bq)
Cesium (55)	Cs 131	5×10^8	3×10^8
	Cs 134	2×10^6	1×10^6
	Cs 134m	2×10^9	1×10^9
	Cs 135	2×10^7	1×10^7
	Cs 136	1×10^7	7×10^6
	Cs 137	2×10^6	1×10^6
Barium (56)	Ba 131	1×10^8	4×10^7
	Ba 140	2×10^7	6×10^6
Lanthanum (57)	La 140	1×10^7	8×10^6
Cerium (58)	Ce 141	8×10^6	2×10^7
	Ce 143	2×10^7	1×10^7
	Ce 144	2×10^5	2×10^6
Praseodymium (59)	Pr 142	2×10^7	1×10^7
	Pr 143	8×10^6	1×10^7
Neodymium (60)	Nd 147	1×10^7	1×10^7
	Nd 149	3×10^8	1×10^8
Promethium (61)	Pm 147	2×10^6	5×10^7
	Pm 149	2×10^7	1×10^7
Samarium (62)	Sm 147	2000	6×10^5
	Sm 151	4×10^6	1×10^8
	Sm 153	3×10^7	2×10^7
Europium (63)	Eu 152	4×10^5	1×10^7
	Eu 152m	9×10^7	4×10^7
	Eu 154	3×10^5	7×10^6
	Eu 155	3×10^6	4×10^7
Gadolinium (64)	Gd 152	500	8×10^5
	Gd 153	5×10^6	5×10^7
	Gd 159	7×10^7	3×10^7
Terbium (65)	Tb 160	3×10^6	9×10^6

Column 1		Column 2	Column 3
Element (Atomic Number)	Isotope	Most restrictive inhalation ALI (Bq)	Most restrictive ingestion ALI (Bq)
Dysprosium (66)	Dy 165	6×10^8	2×10^8
	Dy 166	8×10^6	7×10^6
Holmium (67)	Ho 166	2×10^7	1×10^7
Erbium (68)	Er 169	3×10^7	3×10^7
	Er 171	1×10^8	5×10^7
Thulium (69)	Tm 170	3×10^6	1×10^7
	Tm 171	1×10^7	1×10^8
Ytterbium (70)	Yb 175	4×10^7	3×10^7
Lutetium (71)	Lu 177	3×10^7	2×10^7
Hafnium (72)	Hf 181	6×10^6	1×10^7
Tantalum (73)	Ta 182	2×10^6	9×10^6
Tungsten (74)	W 181	6×10^8	2×10^8
	W 185	1×10^8	3×10^7
	W 187	1×10^8	2×10^7
Rhenium (75)	Re 183	2×10^7	2×10^7
	Re 186	2×10^7	2×10^7
	Re 187	1×10^9	5×10^9
	Re 188	3×10^7	2×10^7
Osmium (76)	Os 185	8×10^6	3×10^7
	Os 191	2×10^7	2×10^7
	Os 191m	2×10^8	2×10^8
	Os 193	3×10^7	2×10^7
Iridium (77)	Ir 190	1×10^7	1×10^7
	Ir 192	3×10^6	1×10^7
	Ir 194	2×10^7	1×10^7

THIRD SCHEDULE — *continued*

Column 1		Column 2	Column 3
Element (Atomic Number)	Isotope	Most restrictive inhalation ALI (Bq)	Most restrictive ingestion ALI (Bq)
Platinum (78)	Pt 191	1×10^8	5×10^7
	Pt 193	5×10^8	4×10^8
	Pt 193m	9×10^7	3×10^7
	Pt 197	1×10^8	4×10^7
	Pt 197m	6×10^8	2×10^8
Gold (79)	Au 198	2×10^7	1×10^7
	Au 199	4×10^7	3×10^7
Mercury (80)	Hg 197	1×10^8	6×10^7
	Hg 197m	6×10^7	3×10^7
	Hg 203	1×10^7	1×10^7
Thallium (81)	TI 200	2×10^8	1×10^8
	TI 201	4×10^8	3×10^8
	TI 202	8×10^7	5×10^7
	TI 204	4×10^7	3×10^7
Lead (82)	Pb 203	2×10^8	6×10^7
	Pb 210	1×10^4	2×10^4
	Pb 212	5×10^5	2×10^6
Bismuth (83)	Bi 206	1×10^7	9×10^6
	Bi 207	4×10^6	1×10^7
	Bi 210	4×10^5	1×10^7
	Bi 212	4×10^6	9×10^7
Polonium (84)	Po 210	1×10^4	9×10^4
Astatine (85)	At 211	7×10^5	2×10^6
Radium (88)	Ra 223	1×10^4	2×10^5
	Ra 224	2×10^4	3×10^5
	Ra 226	9000	9×10^4
	Ra 228	2×10^4	7×10^4
Actinium (89)	AC 227	20	9000
	AC 228	4×10^5	4×10^7

THIRD SCHEDULE — *continued*

Column 1		Column 2	Column 3
Element (Atomic Number)	Isotope	Most restrictive inhalation ALI (Bq)	Most restrictive ingestion ALI (Bq)
Thorium (90)	Th 227	5000	2×10^6
	Th 228	200	3×10^5
	Th 230	400	3×10^5
	Th 231	8×10^7	5×10^7
	Th 232	90	5×10^4
	Th 234	2×10^6	4×10^6
Protactinium (91)	Pa 230	5×10^4	1×10^7
	Pa 231	100	1×10^4
	Pa 233	7×10^6	2×10^7
Uranium (92)	U 230	4000	2×10^5
	U 232	100	2×10^5
	U 233	500	7×10^5
	U 234	600	7×10^5
	U 235	600	7×10^5
	U 236	600	7×10^5
	U 238	600	8×10^5
	U 240	3×10^7	2×10^7
Neptunium (93)	Np 237	300	3×10^4
	Np 239	3×10^7	2×10^7
Plutonium (94)	Pu 238	300	4×10^4
	Pu 239	300	4×10^4
	Pu 240	300	4×10^4
	Pu 241	2×10^4	2×10^6
	Pu 242	300	4×10^4
	Pu 243	5×10^8	2×10^8
	Pu 244	300	4×10^4
Americium (95)	Am 241	300	3×10^4
	Am 242m	300	4×10^4
	Am 242	2×10^6	5×10^7
	Am 243	300	3×10^4
	Am 244	7×10^6	4×10^7

THIRD SCHEDULE — *continued*

Column 1		Column 2	Column 3
Element (Atomic Number)	Isotope	Most restrictive inhalation ALI (Bq)	Most restrictive ingestion ALI (Bq)
Curium (96)	Cm 242	6000	9×10^5
	Cm 243	400	5×10^4
	Cm 244	500	6×10^4
	Cm 245	300	3×10^4
	Cm 246	300	3×10^4
	Cm 247	300	4×10^4
	Cm 248	80	9000
	Cm 249	6×10^8	8×10^8
Berkelium (97)	Bk 249	1×10^5	1×10^7
	Bk 250	2×10^7	2×10^8
Californium (98)	Cf 249	200	3×10^4
	Cf 250	400	6×10^4
	Cf 251	200	3×10^4
	Cf 252	500	1×10^5
	Cf 253	2×10^4	7×10^6
	Cf 254	300	3×10^4
Einsteinium (99)	Es 253	2×10^4	2×10^6
	Es 254m	2×10^5	3×10^6
	Es 254	3000	4×10^5
Fermium (100)	Fm 254	1×10^6	5×10^7
	Fm 255	3×10^5	6×10^6

Appendix D: Limits for Contamination of Surfaces
(Source: Fifth Schedule, Radiation Protection (Ionising Radiation) Regulations 2001)

FIFTH SCHEDULE

Regulations 47 (2), (3) and (4) and 49 (1)

PART I

LIMITS FOR CONTAMINATION OF SURFACES

Nuclide	Limit (Bq/cm^2)	Nuclide	Limit (Bq/cm^2)
Th-230	10^{-1}	Se-75	10^{2}
Th-232	10^{-1}	Rb-86	10^{2}
Pa-231	10^{-1}	Sr-89	10^{2}
U-232	10^{-1}	Y-90	10^{2}
Pu-238	10^{-1}	Ru-106	10^{2}
Pu-239	10^{-1}	Ag-110m	10^{2}
Am-241	10^{-1}	Cd-109	10^{2}
Cm-244	10^{-1}	Cd-115m	10^{2}
Sm-147	10^{-0}	In-113m	10^{2}
Sm-153	10^{-0}	Sb-124	10^{2}
Pb-210	10^{-0}	I-125	10^{2}
Po-210	10^{-0}	I-131	10^{2}
Ra-226	10^{-0}	Cs-134	10^{2}
Th-227	10^{-0}	Cs-137	10^{2}
Th-228	10^{-0}	La-140	10^{2}
U-234	10^{-0}	Pm-147	10^{2}
U-235	10^{-0}	Eu-152	10^{2}
U-236	10^{-0}	Eu-154	10^{2}
U-238	10^{-0}	Bi-210	10^{2}
Sr-90	10^{-1}	H-3	10^{3}
Ra-223	10^{-1}	C-14	10^{3}
Ra-224	10^{-1}	S-35	10^{3}
Na-24	10^{-2}	Cl-36	10^{3}
P-32	10^{-2}	Ca-45	10^{3}
Co-56	10^{-2}	Ca-47	10^{3}
Co-60	10^{-2}	Sc-46	10^{3}
Cu-64	10^{-2}	Sc-47	10^{3}

Nuclide	Limit (Bq/cm^2)	Nuclide	Limit (Bq/cm^2)
Cu-65	10^{-2}	Cr-51	10^{3}
Zn-65	10^{-2}	Mn-54	10^{3}
Ga-68	10^{-2}	Fe-55	10^{3}
Fe-59	10^{-3}	Cs-129	10^{3}
Co-57	10^{-3}	Cs-131	10^{3}
Co-58	10^{-3}	Ba-133	10^{3}
Ni-63	10^{-3}	Ce-139	10^{3}
Ga-67	10^{-3}	Ce-141	10^{3}
Ge-68	10^{-3}	Nd-147	10^{3}
Br-77	10^{-3}	Gd-153	10^{3}
Rb-81	10^{-3}	Tb-160	10^{3}
Sr-85	10^{-3}	Eb-169	10^{3}
Sr-87	10^{-3}	Tm-170	10^{3}
Y-87	10^{-3}	Yb-169	10^{3}
Y-88	10^{-3}	Lu-177	10^{3}
Mo-99	10^{-3}	Hf-181	10^{3}
Tc-99m	10^{-3}	W-185	10^{3}
Tc-99	10^{-3}	Re-186	10^{3}
Ru-103	10^{-3}	Ir-192	10^{3}
Ag-111	10^{-3}	Au-196	10^{3}
In-111	10^{-3}	Hg-197	10^{3}
Sn-113	10^{-3}	Hg-203	10^{3}
Sb-125	10^{-3}	Tl-201	10^{3}
I-123	10^{-3}	Tl-204	10^{3}
All other alpha emitters with a half life > 3 months	10^{1}	All other non-alpha emitters	10^{2}

FIFTH SCHEDULE — *continued*

PART II

MODIFYING FACTORS FOR VARIOUS SURFACES

Surface contamination levels shall at all times be kept as low as reasonably achievable and shall not exceed those designated. The contamination limits in Part I are those for surfaces in low level laboratories. Modifying factors for other surfaces are given below.

Surface	Modifying Factor
Low level laboratories	1
Medium level laboratories	5
High level laboratories	10
Glove box interiors	10
Fume cupboard interiors	5
Skin (radiation workers)	1
Protective clothing	1
Personal clothing	0.05
Non-radioactive areas	0.05

Appendix E: Request for Funding for Occupational Health Related Medical Services (OSHE/51/D01)

Office of Safety, Health & Environment

OSHE/51/D01.01

NUS National University of Singapore

REQUEST FOR FUNDING FOR OCCUPATIONAL HEALTH RELATED MEDICAL SERVICES

General Instructions

1. Each staff or student to submit this form to their PI or Head of Department for approval (one form per staff or student).
2. The completed form is to be submitted to Dr. Gregory Chan, Senior Occupational Health Physician at Office of Safety, Health & Environment for approval. Please liase with Nurse Kim, who is contactable @ **6516 7333** or e-mail: oshlkg@nus.edu.sg
3. Please bring along relevant forms, MSDS, respirator or any other necessary tools during the medical appointment.

University Health Centre is located at 20 Lower Kent Ridge Road

Telephone No: 67761631 Fax No: 6778 3173

Occupational Health services is available between: 9 am to 11.30 am and 2 pm to 4.30 pm from Monday to Friday

The Occupational Health Clinic is available on Tuesday mornings and Thursday afternoons by appointment basis. Please make your appointment with our OSHE Occupational Health Nurse.

On-site chest x-ray: 8.30 am to 11.30 am and 1.30 pm to 5pm (Tuesday, Wednesday & Thursday only, unless advised otherwise)

The centre is closed on Saturday, Sunday and Public Holiday.

Section A: To be Completed by Authorized Personnel (Principal Investigator/Laboratory Supervisor or Head of Department)

Authorized Personnel Name:	**Department/Program:**	
Contact No.	**Staff No.:**	**Email Address:**

Please tick one of the following:

☐ Teaching Activities ☐ Research Activities

Brief Description of Research ***(Please attach Material Safety Data Sheet of the Agent Used)***

☐ Staff or student working in BSL 2 laboratory ☐ Research Diving ☐ Others:

☐ Staff or student working in BSL 2+ / 3 laboratory ☐ Animal Care & Husbandry

Please list hazardous agents which the staff or students will potentially exposed to:

☐ Chemical: ☐ Biological: ☐ Others:

☐ Radiation: ☐ Noise

Medical assessment or treatment required:

☐ Hepatitis B screening, vaccinations, post screening

☐ Tetanus Vaccination

☐ Medical examination for Ionizing radiation, R1 license application. Please download the relevant form from the website: http://www.nea.gov.sg/cms/nst/doc/R1.doc

☐ Medical examination for laser / non-Ionizing radiation, N3 license application. Please download the relevant form from the website: http://www.nea.gov.sg/cms/nst/doc/N3.doc

☐ Other vaccination or immunizations required (please specify): ____________________

☐ Respirator Fit Test

☐ Respirator Fitness examination

☐ Diving medical examination

☐ Audiometric testing

☐ Medical tests to confirm occupational related infection/illness/disease (please specify): ____________________

☐ Others (please specify): ____________________

PI Declaration

I declare that the attached departmental staff or students require the above assessment and / or treatment for teaching / research activities.

____________________ ____________________

Signature of PI or Laboratory Supervisor **Date**

Section B: To Be Completed by Staff and Student Undergoing Medical Assessment or Treatment			
Name of staff or student	**Staff No./Student Matric No.**	**Contact email**	**Contact Number**

Section C: Approval by OSHE and/or Faculty/Institute/School Safety and Health Officer

The request for the above medical assessment/treatment is

☐ Approved (Reference Number: OSHE/51/05-)

☐ Not Approved

Subject to the following conditions:

_______________________________	____________________	______________
Name of OSHE staff or Faculty/School Safety and Health Officer	Signature	Date

Section D: To Be Completed by UHC Staff

To: OSHE staff

☐ Cost of medical examination : $

☐ The cost of the medical examination includes additional investigation, the total cost is : $

_______________________________	____________________	______________
Name of UHC staff	Signature	Date

Appendix F: Fact Sheets of Commonly Used Isotopes

Tritium H-3:

Radiological half-life, T1/2	12.3 years
Principle emission	18.6 keV beta (maximum)
Dose rate (1cm from a beta point source)	300 mrad/h per mCi
Biological monitoring method	Urine samples
Range in air	4.7mm
Range in water	6x10"^{J}mm
Shielding required	None
Monitoring method for contamination	Wipe survey

Special Considerations:

- Tritium compounds can be absorbed through the skin therefore labcoats and gloves must always be worn. Consider wearing two pair of gloves and change them frequently.

- Practice procedures without radioactivity prior to performing the procedure with H-3. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- Work involving volatile forms of H-3 (e.g., gas, tritiated water) shall be performed in a fume hood. Place previously opened containers of tritiated water into a fume hood, not a refrigerator.
- Monitor storage areas where large quantities of H-3 are kept, as certain forms tend to "creep". Due to its low beta energy, tritium cannot be monitored directly, and therefore regular wipe surveys of the work are recommended.

Carbon -14 C-14:

Radiological half-life, Ti,2	5730 years
Principle emission	156eV beta (maximum)
Dose rate {1cm from a beta point source)	300 mrad/h per mCi
Biological monitoring method	Breath or urine samples
Range in air	21.8cm
Range in water	0.28mm
Shielding required	1cm plexiglass
Monitoring method for contamination	GM counter

Special Considerations:

- Urinalysis: Not Required; however, prudent after a 14C radioactive spill or suspected intake.
- Inherent volatility (at STP): Not Significant.
- Possibility of organic 14C compounds being absorbed through gloves.
- Care should be taken NOT to generate CO2 gas which could be inhaled.
- Internal Dose is the concern: Skin contamination, ingestion, inhalation, and puncture.
- Always wear a lab coat and disposable gloves when working with 14C.
- The concentration of carbon in adipose tissue, including the yellow marrow, is about 3 times the average whole body concentration. No other organ or tissue of the body concentrates stable carbon to any significant extent.
- The fractional absorption of dietary carbon (uptake to blood) is usually in excess of 0.90.
- Three main classes of carbon compounds may be inhaled: organic compounds, gases (CO or CO2), and aerosols of carbon containing compounds such as carbonates and carbides.

Organic Compounds - most organic compounds are NOT very volatile under normal circumstances; the probability of these being inhaled as vapors is therefore small. In circumstances where such substances are inhaled, it would be prudent to assume that once they enter the respiratory system they are instantaneously and completely translocated to the systemic circulation without changing their chemical form.
Gases - the inhalation of CO and its retention in body tissues has been studied extensively. Since gas has a relatively low solubility in tissue water, doses due to absorbed gas in tissues are insignificant in comparison with doses due to the retention of CO bound to hemoglobin. CO2 in the blood exists mainly as a bicarbonate.
Carbonates & Carbides - It is assumed that inhaled or ingested 14C labeled compounds are instantaneously and uniformly distributed throughout all organs & tissues of the body where they are retained with a biological half-life of 12-40 days.

Phosphorus-32 P-32:

Radiological half-life, J_{V2}	14.3 days
Principle emission	1.71 MeVbeta (maximum)
Dose rate (1cm from a beta point source)	300 mrad/h per mCi
Biological monitoring method	Urine samples
Range in air	6.1m
Range in water	0.8cm
Shielding required	1cm plexiglass
Monitoring method for contamination	GM counter

Special Considerations:

- Avoid direct eye contact with the P-32 beta. Never look directly upon an unshielded container of P-32. Eye protection (safety glasses or goggles) should be worn when handling P-32 vials.
- Plastic or other low Z material shielding and storage containers should be used to minimize exposure from P-32. Do not use lead shielding, as it generates bremsstrahlung X ray radiation.
- Tweezers and Forceps and other remote handling tools should be used when handling P-32.
- Because of the high energy beta, the possibility of skin contamination or direct handling of P-32 needs to be minimized. If skin contamination is detected decontamination needs to be initiated immediately. Even low activities of P-32 skin contamination for a short period of time can result in a significant dose to the skin.

Sulphur-35 S-35:

Radiological half-life, T1/2	87.4 days
Principle emission	167 keV beta (maximum)
Dose rate {1cm from a beta point source)	300 mrad/h per mCi
Biological monitoring method	Urine samples
Range in air	26cm
Range in water	0.32mm
Shielding required	1cm plexiglass
Monitoring method for contamination	GM counter

Special Considerations:

- Plastic or other low Z material shielding and storage containers should be used to minimize exposure from P-32. . Do not use lead shielding, as it generates bremsstrahlung X Ray. Tweezers and Forceps and other remote handling tools should be used when handling S-35 vials
- Radiolysis may occur with S-35 amino acids (e.g., methionine) during storage, with a resulting volatile impurity. New vials and closed vials that have been stored for a period of time should be opened in a fume hood or through an activated charcoal filter. Volatile impurities are generally small (0.05%).
- If practical procedures involving the use of S-35 compounds should be in enclosed containers because of the potential for production of volatile S-35 compounds. Routinely check water baths and the inside of incubators for contamination during and after procedures involving S-35.
- Metabolic behavior of common S-35 labeled organic compounds may be considerably different from common S-35 labeled inorganic compounds. This difference must be considered if uptake occurs.

Chromium-51 Cr-51:

Radiological half-life, *Ty₂*	27.7 days
Principle emission	0.32 MeV gamma (9.8%), 5keV X-ray (22%)
Dose rate (1cm from a beta point source)	18R/h
Biological monitoring method	Whole body count
Half-value layer	3mm lead
Monitoring method for contamination	Nal or other scintillation detector

- Use lead for shielding and storage materials.
- Indirect viewing aids should be used to minimize exposure from Cr-51.
- Tweezers and Forceps and other remote handling tools should be used when handling Cr-51 Vials.

Iodine-125 I-125:

Radiological half-life, *Ty₂*	60 days
Principle emission	35keVgamma(7%), 27-32keV X-ray (140%)
Dose rate (1cm from a point source)	1.4R/h
Biological monitoring method	Thyroid scan
Half-value layer	0.02mm lead
Monitoring method for contamination	Nal or other scintillation detector

- Use lead for shielding and storage materials.
- Indirect viewing aids should be used to minimize exposure from I-125.
- Tweezers and Forceps and other remote handling tools should be used when handling I-125 Vials.
- Unbound I-125 is inherently volatile. Work with unbound I-125 shall be performed in a fume hood or well ventilated area. Iodinations shall be performed in a hood, approved by the Radiation Safety Office and equipped with charcoal filter and sampling apparatus.
- Acidic and frozen solutions enhance radioiodine volatility. Keeps pH of solutions containing I-125 at 7 or higher. Do not freeze solutions containing I-125.

Appendix H: Radiation Machine Inspection and Survey Form

Radiation Machine Inspection and Survey Form

Surveyor: ________________________________ Date:________ Room(s):____________

Radiation Producing Equipment

Name __________________________________ Serial Number ________________

Attach map of area(s) or equipment surveyed or describe in comments section below

Survey Instrument Information

Manufacturer	Model	Serial #	Meter Type
			☐ Pancake GM ☐ NaI scintillation ☐ Energy Compensated GM ☐ Ionization Chamber

Meter in calibration? Yes___ No___
Batteries good? Yes___ No___

Meter Background: ___________ mR/hr or μ Sv/hr
Exposure Rate at full power: ___________ mR/hr or μ Sv/hr at public access location
Exposure Rate at full power: ___________ mR/hr or μ Sv/hr at radiation worker location

Survey results (Check one)

- ☐ Interlocks tested and functioning properly
- ☐ Warning lights tested and functioning properly
- ☐ Shutter tested and functioning properly
- ☐ Exposure Rate at public access location < 1.5 μ Sv/hr or 0.15 mR/hr
- ☐ Shutter tested and functioning properly < 10 μ Sv/hr or 1 mR/hr

Comments

____

____

____

____

____

Appendix I: Radioactive Material Inventory Form

RADIOACTIVE MATERIAL INVENTORY FORM

SOURCE INFORMATION

RADIONUCLIDE – ______________.

ACTIVITY (µCi / mCi / kBq / MBq) – ____________ AS OF DATE –______________.

ORIGINAL VOLUME (µl) – ____________________.

RECEIVED DATE –___________________

ROOM NUMBER – ___________________.

Date Used	Amount Used (µCi / mCi / kBq / MBq)	Amount Remaining (µCi / mCi / kBq / MBq)	Purpose of Use	Used By	Initials

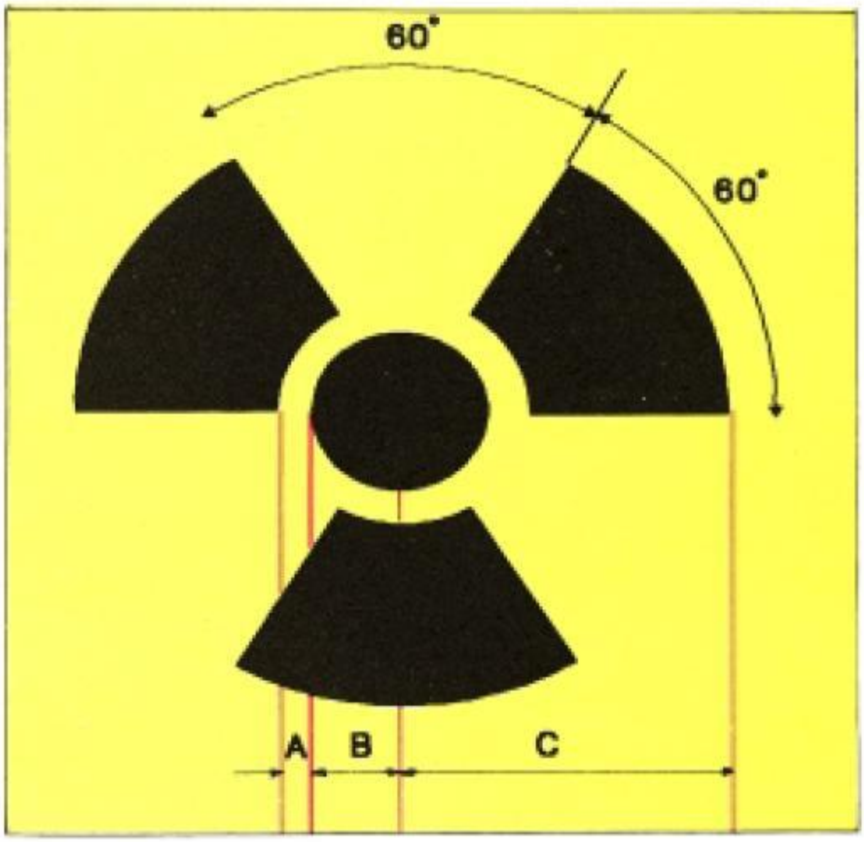
Date Disposed: ___________________________

Disposed By (Name): ____

Signature: ____

Appendix J: Standard Symbol For Designating Any Ionising Radiation Hazard

STANDARD SYMBOL FOR DESIGNATING
ANY IONISING RADIATION HAZARD



A : B : C = 1 : 2 : 10

Trefoil symbol shall be black in colour and background shall be yellow.

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Appendix K: Portable Radiation Survey Meter Operation Procedure

This section provides guidance on how to use portable survey meters for contamination monitoring (using pancake GM, end window GM and NaI scintillation detectors) and exposure monitoring (using Energy compensated GM and Ionization chamber detectors)

Scintillation radiation detectors are very shock sensitive and fragile. GM detectors have very thin windows that can be easily punctured by sharp objects. So handle the detectors with care. Do not keep survey meters in fume hoods or cabinets in which you use or store corrosives; the fumes can quickly render the instrument useless. If the instrument will not be used for an extended period of time, remove the batteries and attach a tag stating that batteries have been removed. Many instruments work best if the humidity is low. High humidity may cause the meter to read much higher than background even when no radiation source is present. A small container or porous bag of silica gel desiccant placed inside the instrument's case may prevent problems. Inspect color-indicating silica gel frequently for color change.

Prior to using any radiation detector, read the operating manual to become familiar with the controls and operating characteristics. Before using the meter, ensure you are wearing appropriate PPE (gloves, lab coat, goggles etc.,)

Check the meter to determine if the calibration sticker is current. Meters must be calibrated annually (at least once per year) and records should be kept for the past three years. Meters cannot be calibrated by the Office of Safety Health and Environment and must be sent to an approved calibration service.

RPNSD provides calibration service and the meter can be taken to RPNSD office located at Level 3, Annexe Bldg 40 Scotts Road. The RPNSD Service Request Form found in Appendix T should be completed and submitted to RPNSD along with a cheque for SGD 141.75 service charge per meter.

Inspect the physical condition and make sure there are no cracks or dents on the probe. Use a known sample radiation source and observe the response of the probe.

Ensure the instrument has sufficient battery life. Corrosion from batteries or corrosive atmospheres can destroy an instrument quickly. Replace low batteries promptly and perform a visual check occasionally.

Determine the background count-rate/exposure rate so you can compare your survey results with a "background" measurement. The background measurement should be performed preferably outside the lab or areas where no radiation sources are present.

For contamination monitoring:

The background rate for a pancake or end window GM meter should be less than 100 counts per minute while the background reading for a NaI meter should be less than 400 counts per minute. If background readings exceed these levels, investigate the area for unknown sources of radiation or detector contamination. Do not use the survey meter if it does not register a background count. With speaker on, point the probe window at the area or equipment you wish to monitor for radiation or radioactive contamination. Do not cover the probe surface with parafilm or other protective coating. Parafilm and similar materials will shield the low energy betas from C-14, P-33 and S-35 and may prevent the meter from detecting contamination.

For exposure monitoring:

The background exposure rate is typically in the range of 20-30 µR/hr. All areas accessed by non radiation workers should be always less than 50 µR/hr.

Since the response time for pancake GM, End Window GM and Energy Compensated GM detectors are slow, they may take 10 seconds or more to reach 90% of final value. Scintillation detectors do not suffer from slow response. All surveys are conducted by slowly passing the probe over the area or equipment to be surveyed. Be certain to survey at a constant speed - approximately 2 cm/sec. The distance from the surface or object should also be constant. A distance of 1 cm is suggested. Be careful not to contaminate the probe itself. Observe the reading on the detector.

(Note: **If your detector has scale multipliers** (e.g., x 0.1, x 1, x 10, etc.)**,** the background and actual measurement should be multiplied by this multiplier to obtain the correct reading. , if the needle is on 300 and the multiplier is on the "X 0.1" scale, the rate is 300 x 0.1 = 30. The units depends on whether you are using a contamination monitor or exposure rate monitor. Contamination monitors have units of Counts per minute (CPM) and exposure rate monitors usually have rates of (mR/hr). Usually, start with the lowest scale multiplier and move to the higher scale. if the needle “pegs” the scale.)

At very high counting rates, pancake GM, End Window GM and energy compensated GM detectors may become "saturated" and the meter reading will fall to zero, potentially causing a false sense of security. When performing surveys where high levels of contamination or high radiation levels are expected, always approach the area cautiously with the survey meter turned on. A rapid increase in the meter reading followed by a drop to zero indicates a high radiation field. Saturation may occur when measuring radiation fields resulting from a few µcuries of P-32. Scintillation detectors do not suffer from “saturation” effect.

Appendix L: Liquid Scintillation Counter Operation/Wipe Test Procedure

Removable contamination is best identified by a wipe survey.

Wear appropriate PPE including gloves and lab coat before performing the survey. You should change the gloves during the survey if you suspect the gloves might have become contaminated while performing the survey. This ensures that you will not cross-contaminate any wipe samples.

Perform a wipe survey by rubbing a filter paper (approximately 45mm in diameter) or cotton swab over the survey area with moderate pressure. The paper or swab may be wetted with ethanol or water to increase the collection efficiency.

Usually an area of 100 cm^2 is surveyed. To monitor a larger area, take additional wipes. ALWAYS assign a number to each wipe AND make a sketch or use some other type of record to indicate where each individual wipe sample was taken.

Deposit wipe sample into a clean scintillation vial. Fill the vial at least 2/3-full with scintillation cocktail. Tightly cap the vial. Mix the contents of the vial thoroughly. Count the sample for at least 1 minute in a liquid scintillation counter. ALWAYS INCLUDE A "BACKGROUND" VIAL. Examine the counting results.

The net sample count rate is determined by subtracting the background count rate from the gross count rate.

Sample activity is determined by dividing the net sample count rate by the instrument's efficiency for the isotope in question.

Appendix M: Radioactive Material User Monthly Survey Form

Radioactive Material User Monthly Survey Form

Radiation User is required to conduct a meter or swipe survey depending on the radioisotope usage, if they use radioisotope during this month

Surveyor:______________________________ Date: __________________________

Room(s):______________________________ Which Radioisotope Used _______________

Attach map of area(s) or equipment surveyed or describe in comments section below

Survey Instrument Information

Manufacturer	Model	Serial #

Meter Type

- ☐ Pancake GM (Beta)
- ☐ NaI detector (Gamma)
- ☐ Liquid Scintillation
- ☐ Others _______________

Meter in calibration? Yes___ No___
Batteries good? Yes___ No___

Meter Background:______________________ CPM

Survey types (Check all that apply)

- ☐ Meter survey performed
- ☐ Swipe survey performed (Attach Liquid Scintillation Counter printout and indicate which vial is background)

Survey results (Check one)

- ☐ No readings greater than two times background were detected
- ☐ Readings greater than two times background were detected
  If readings greater than two times background were detected, then document the findings and perform decontamination survey

Comments

____

____

____

____

____

Note: C-14 or H-3 users must perform a swipe survey and use liquid scintillation counter.

Appendix O: Request for Disposal of Radioactive Waste Form (OSHE/F/RS/01)

NUS National University of Singapore

Office of Safety, Health & Environment
OSHE/F/RS/01Rev.02

Request for Disposal of Radioactive Waste On: ______________________

Part I: To be Completed by Requestor		
A: Requestor's Details		
Name (Prof/Dr/Mr/Ms/Miss):	**Signature:**	**Contact Nos:**
Department:	**Email:**	**Waste Location:**

B: Radioactive Waste Details

Container Serial Number	Container Type (E.g. Plastic Bag, Carton, Bin etc)	Waste Contents (E.g. Paper, Vermiculite etc)	Radioactive Substances in the Wastes (E.g. Methionine, Thymidine)	Radionuclide	Exposure Rate on Surface (mrem/hr)	Qty (µCi)

C: Authorization	
Checked By OSHE:	**Certified by CRPNS, NEA:**
Remarks:	**Remarks:**

Appendix P: Radioactive waste container label

(Radioactive Waste Container Label)

NUS
National University
of Singapore

Container Serial No:	Disposal Date:
Department / Institute:	
Radioactive waste generated by:	Laboratory / Room No:
Name of Radionuclide / Quantity (µCi)	Exposure Rate (mRem / hr)
Checked By: Date:	Inspected By: Date:

Appendix Q: Sealed Source Leak Test Procedure

Sealed Source Leak Testing

It is required under the Radiation Protection (Ionizing Radiation) Regulations that all sealed radioactive sources used in gauges etc be leak tested once in 12 months.

The sample for such test (known as **Leak Test Sample**) may be from the following as spelt out in the Radiation Protection (Ionizing Radiation) Regulations 29(1a) :

1) Every immediate container or bonding which forms part of the sealed source; OR

2) Every container in which such a sealed source is permanently installed but which does not form part of the sealed source.

As most sealed radioactive sources are used in gauges for level monitoring etc, the sample for the leak test will most likely be categorised under 2) above.

Items needed for collection of Leak Test Samples.

1) A list of all sealed radioactive sources used in gauges must be maintained and kept updated to show exact number of such sources.

2) Calibrated & working radiation survey meter

3) Tongs / Forceps / Tweezers etc.

4) Regular cotton wool

5) Laboratory grade ethanol (Alcohol)

6) Sealable plastic bags (recommended size : 8cm x 11cm)

7) Labels for the sealable plastic bags ; permanent marker can also be used to mark the bags.

8) Disposable Gloves

Procedures for collection of Leak Test Samples from Sealed Sources

1) Approach the sealed radioactive source with a calibrated & working survey meter to ensure that radiation levels are within limits.

   Levels are considered within limits(Radiation Protection (Ionizing Radiation) Regulations 24(3a,3b)) if they are :

Location	**Levels Measured (□Sv/h)**
Up to 1 metre from source housing	4 - 20
5cm from surfaces of source housing	40 - 200

Important : When measuring, do not place hand across path of radiation beam.

2) After the levels are ascertained, check the isotope & serial number of the source against the list you have. If number & isotope tallies, record the radiation level measured against it.

3) Tear off some cotton and make up a ball of about 2 - 3cm diameter and use a tong, tweezer or forcep to hold it.

4) Moisten the cotton ball lightly with alcohol.

5) The moistened cotton ball is then used to wipe the external surfaces of the gauge particularly the joints between the source housing and the structure holding it.

6) After wiping, the cotton ball is put into a sealable plastic bag which had been properly labelled with the isotope name, serial number and activity of the radioactive source.

   (DO NOT TOUCH THE COTTON BALL AFTER WIPING)

7) The samples can either be tested yourself using a liquid scintillation counter or can be sent to RPNSD for testing.

   a) For self analysis, please refer to Appendix L for liquid scintillation counter operation and wipe test procedure. The leak test results must be recorded in the Sealed source leak test form provided in Appendix R.

   b) For RPNSD testing, the samples in the sealable plastic bags are then sent to the Radiation Protection & Nuclear Science Department (RPNSD), The National Environment Agency for analysis. RPNSD is located at Level 3, Annexe Bldg 40 Scotts Road. The cost of the wipe test analysis is SGD 57.75

Appendix R: Sealed Source Leak Test Report

SEALED SOURCE LEAK TEST REPORT

SOURCE INFORMATION

SERIAL NUMBER – __________ RADIONUCLIDE – ______ ACTIVITY – __________ AS OF DATE – __________.

TEST DATE – ______________________ ROOM NUMBER – ___________.

TEST METHOD

____ - Wipe(s) taken directly on source
____ -Wipe(s) taken on surface near source to measure transferred contamination
____ - Wipe(s) taken inside exhaust vent
____ - Source in storage, wipe(s) taken in storage area
____ - Other:

COUNTING INSTRUMENT USED

Model –_________________

Serial Number –_________________

Location –_________________

COUNTING INFORMATION

Counting Time (Minutes) –________________.

Number of Samples –________________.

Background Counts Per Minute (CPM) –________________.

	Sample Counts Per Minute CPM)	Net Counts (CPM) = Background - Sample	Net Counts >200 YES / NO
Sample 1			
Sample 2			
Sample 3			

NOTIFY RADIATION SAFETY OFFICER IF NET COUNTS >200

Name: ____

Signature: ______________________________ Date: ______________________________

Appendix T: RPNSD Service Request Form

National Environment Agency

Our Environment - Sustain and Enjoy

National Environment Agency
Centre for Radiation Protection
And Nuclear Science
Environment Building
40 Scotts Road #03-00
Annex Block
Singapore 228231

FOR OFFICIAL USE	
Received & Checked by:	Counterchecked by: (CRPNS Officer-in-charge)
Date:	Date:

Service Request Form

IMPORTANT
Please complete and submit individual form for each report / certificate required.

(A) Customer Particulars (Existing Customer)	
Company Name:	
Requestor Name:	
Billing Organisation Name:	
Addressee Name (on report):	
Department (*if applicable*)	
Payment By: (Please circle whichever applicable) – Nets / Visa / Cheque / GIRO / Cash Card	

(Note : GIRO payment is only applicable to company that has signed up for a GIRO account with CRPNS)
For each service fee please refer to http://app2.nea.gov.sg/regulatory_info.aspx#miscellaneous

(B) New Customer		
UEN No.:		
Company Name:		
Department (*if applicable*):		
Company Address:		
Contact Person:	Name:	
	NRIC/FIN/PP:	
	Tel No :(O)	(HP)
	Email:	
If mailing or billing address is different from the company address, please provide details below:		
(i) Mailing Address:		
Contact Person:		Tel No. :(O) (H/P)
(ii) Billing Address:		
Contact Person:		Tel No.:(O) (H/P)

(C) [i]Type of Service Request
Please tick (✓) the appropriate box where applicable

IMPORTANT
For multiple samples, please ensure the following information is indicated clearly in the letter from your company.

☐ **Gamma-ray Analysis (Food / Non-Food Sample)**

▪ Sample Description:	
▪ Product Code/Seal No./Lot No:	
▪ Brand:	
▪ Quantity:	
▪ If additional copies of reports are needed, please specify the quantity:	

☐ **Survey Meter / QFE Calibration**

▪ Brand:	
▪ Model:	
▪ Survey Meter/QFE S/N	

☐ **Sealed Source Leakage Test**

▪ Name of Isotope:	
▪ Source S/N:	

☐ [ii]**Consultancy Service**

▪ Radiation Type:	**Ionising / Non-ionising ****
▪ Type of Consultancy:	
▪ Type of Inspection:	**Industrial / Medical / Dental / Vet ****
▪ Preferred Date:	
▪ Site Address:	

**** Delete where applicable**

☐ **Other Remarks:**

____

____
Authorised Signature/Date

The National Environment Agency collects personal information to facilitate the implementation of environmental and public health policies in Singapore. To allow us to serve you better, and to process any application you have made, NEA may share data submitted by you with other government agencies, or non-governmental agencies authorised to carry out specific government services, unless prohibited by legislation.

[i] NEA reserves the right to reject any application if insufficient information is provided
[ii] No upfront payment required but late payment interest will apply as specified on the tax invoice.