Radiation Safety Manual

University of Illinois at Urbana - Champaign

Contents

1. Introduction

The University of Illinois at Urbana-Champaign (U of I) holds a Type A Broad Scope Radioactive Materials License issued by the Illinois Emergency Management Agency (IEMA) in accordance with the Illinois Radiation Protection Act. All ionizing radiation sources must be used in a manner that is consistent with state and federal laws and regulations and with the requirements of the campus Radioactive Materials License. All radiation-producing machines must be registered with IEMA through the Division of Research Safety (DRS) and must be operated in compliance with state regulations.

U of I is also committed to protecting the health and safety of its faculty, staff, students, visitors, and environment by appropriately identifying and managing radiological hazards. Additionally, U of I is committed to minimizing radiation exposures to faculty, staff, students, and visitors that result from the use of ionizing radiation sources in research and teaching to levels that are as low as reasonably achievable.

This manual is designed to help staff members perform research, teaching, and public service with radiation sources in a safe, legal, and efficient manner. It is a general resource on rules, procedures, and responsibilities for working with radiation. The manual is not all-inclusive. Because of the wide variety of radiation sources, facilities, research methods, and situations, it is impossible to anticipate and address all eventualities within the scope of this manual. Communication between users of radiation sources, DRS, and the Radiation and Laser Safety Committee (RLSC) is essential to the responsible and beneficial use of radiation sources. The manual is written primarily for personnel working with beta/gamma-emitting radioactive materials. Additional requirements may be necessary for work with radioisotopes that decay by alpha emission or by spontaneous fission.

2. Responsibilities for Radiation Safety

The U of I strives to maintain a safe and healthy working and learning environment for faculty, staff, students, and visitors. The cooperation of the entire campus community is needed to realize this goal. This is particularly true of research and teaching that involves radiation sources, where the campus Radiation and Laser Safety Committee, DRS and radiation safety officer (RSO), principal investigators (PIs) and department heads, and laboratory workers share the responsibility for creating and maintaining a safe workplace.

2.1 Radiation and Laser Safety Committee Responsibilities

The Radiation and Laser Safety Committee advises the Chancellor through the Vice Chancellor for Research and Innovation and DRS on matters related to the campus radiation safety program. The RLSC is composed of academic staff and faculty members representing various areas of research and teaching, and members who represent the campus administration including the campus RSO.

The Chancellor delegates authority to the RLSC to oversee the use of radiation sources throughout the campus. The RLSC has the authority to allow, deny, or revoke authorization for individuals to obtain and use radiation sources at the U of I.

The responsibilities of the Radiation and Laser Safety Committee include the following:

1. Review proposals for unusually hazardous uses of radiation sources as deemed by the RSO and establish criteria for equipment and procedures to ensure employee, student, and public safety.

2. Review cases that involve repeated infractions of the rules and regulations for protection against radiation, including lasers.
3. Review accidents that may involve exposure or serious economic loss and other cases for which reports to outside regulatory authorities are required.
4. Review public relation problems that involve radiation sources, including lasers.
5. Review appeals from radiation users and modify rules or the decisions of DRS personnel where necessary, regarding matters and business under the authority delegated to the RLSC in Article II.
6. Meet formally as often as necessary, but at least four times per year, to review the campus radiation safety program with DRS personnel.
7. Recommend the establishment or modification of campus radiation and laser safety policies.
8. Review communications between DRS and government agencies that affect the campus radiation safety program and the campus radioactive materials license.

2.2 Division of Research Safety Responsibilities

1. Provide advice and assistance to everyone concerned on all aspects of radiation safety.
2. Approve proposals for procurement, use, and transfer of radiation sources, except proposals involving unfamiliar or extreme hazards that DRS judges as requiring review by the RLSC.
3. Receive and monitor all shipments of radioactive materials, deliver acceptable incoming shipments to the end user, and ensure that outgoing shipments conform to shipping regulations.
4. Maintain permanent records of receipt, use, transfer, and disposal of radioactive materials.
5. Supervise and assist in disposal of radioactive wastes.
6. Assign personnel monitoring devices (e.g., film badges and dosimeters) when necessary, give instructions in their use, and maintain personnel monitoring records.
7. Check radiation monitoring and survey instruments for proper operation and calibrate as often as necessary.
8. Assist in designing and selecting equipment, shielding, and facilities and in formulating or modifying operating procedures for new or existing installations or buildings.
9. Calculate the levels of radiation intensity, time limits of personnel exposure, and minimum working distance around accelerators, reactors, X-ray machines, and other intense radiation sources.
10. Perform and keep records of leak tests on sealed sources.
11. Make and keep records of systematic surveys in areas where the presence of radiation or contamination of surfaces, air, or water is suspected, and notify the area supervisor of the results. In some cases this may require detailed monitoring of an operation from beginning to end by a DRS staff member.
12. Report hazardous radiological conditions promptly to the responsible individual and, when necessary, to the immediate supervisor and the RLSC.
13. Supervise and assist in decontamination of all but minor spills.

14. Schedule routine medical examinations in accordance with established policy; help to establish criteria and make arrangements for such examinations as may be required in emergency situations.
15. Enforce all written directives of the RLSC.
16. Stop any operation or deny access of any individual to radiation sources in the interest of safety. Such action must be reported verbally and in writing to the RLSC as soon as possible.
17. Grant exemptions to the rules (or impose more stringent restrictions) in emergency situations when, in the judgment of DRS, such action is necessary to reduce risk of serious injury or economic loss. Such actions must be reported verbally and in writing to the RLSC as soon as possible.
18. Maintain files of federal, state, and local licenses and registrations concerned with radiation sources, and initiate applications for renewals and/or amendments of same.
19. Determine whether a radiation incident requires a report to any governing body and prepare such reports for the approval of the RLSC. **Exception:** If an immediate report is required, then the campus radiation safety officer will (with knowledge and approval of the RLSC Chair if possible) file such a report with the appropriate authorities and will provide copies to the RLSC.
20. Be familiar with the federal, state, and local laws relating to radiation and be aware of changes in such laws as they occur. Inform the RLSC when such changes suggest modifications of policy, and institute necessary changes in the radiation safety program.

2.3 Permit Holder and Unit Head Responsibilities

In addition to assuming all the responsibilities of an individual radiation user, the Permit Holder will:

1. Be responsible for ensuring that all personnel, particularly new personnel, who have access to radiation sources under their jurisdiction are properly instructed and that they have the necessary skills and disposition to manage radiation safely. The minimum training requirements are outlined in Section 4.
2. Determine the types of radiation sources, equipment, facilities, and procedures needed for their work and work under their supervision.
3. Comply with all radiation permit requirements.
4. Ensure that the procedures for purchase, acquisition, use, and transfer of radioactive materials under their supervision are followed. This includes keeping accurate inventory and disposal records.
5. Routinely check protective equipment and instruments to ensure they are working properly and adequately performing their intended functions.
6. Work with DRS to solve radiation safety problems unique to their situation and to correct violations of federal, state, or local rules and regulations.
7. Assist DRS in complying with existing laws and license requirements (e.g., maintenance of records, preparation of reports) by providing necessary information and assistance.
8. Obtain prior approval of the campus RSO before any individual under age 18 is allowed to work in a radiation laboratory.

9. Report lost, stolen, or missing sources of radiation to DRS. DRS is required to notify state regulators within 24 hours after when the absence becomes known.
10. Inform DRS of an intention to cease using radioactive material, when an extended departure from campus is planned, or if there is any reason the obligations in the Radiation Safety Manual cannot be met.
11. When away from campus for an extended period, ensure that radioactive materials and work involving radiation sources receive adequate supervision. A Permit Holder that will be absent from their laboratory for a period of three months or longer must designate a temporary supervisor and inform DRS in writing of this designation. The education, training, and administrative authority of the person designated as temporary supervisor must be sufficient to ensure that all safety requirements will be met and must be acceptable to DRS.
12. Unit heads must inform DRS whenever any Permit Holder in their unit will be absent from campus for more than three months or whenever there are circumstances with regard to the Permit Holder that might require additional assistance from DRS (e.g., temporary disability).

2.4 Worker Responsibilities

Users have the final responsibility for the safe use of the radiation sources to which they have access. Users must:

1. Keep their exposure as low as practical.
2. Wear assigned personnel monitoring devices in an approved manner.
3. Be familiar with and comply with all sections of the Radiation Safety Manual that apply to their work.
4. Be familiar with the nature of their work area's radiation sources, the extent of their potential risk, and the proper means of safely managing those risks.
5. Monitor their work area frequently for radioactive materials contamination.
6. Clean up minor spills immediately.
7. Dispose of radioactive waste in an approved manner.
8. Ensure that radioactive sources and containers are properly labeled and the work area is properly posted.
9. Assist in maintaining required records and inventories.
10. Prevent unauthorized persons from having access to radiation sources in their area.
11. Protect service personnel, and allow no maintenance or repairs of area facilities or equipment unless approved by the area supervisor and/or DRS.
12. Notify their supervisor and DRS of unexpected difficulties.
13. Be prepared to handle accidents or injuries.
14. Notify and seek the assistance of their Permit Holder and DRS as soon as possible in emergencies.
15. Take no action that would interfere with the responsibilities of their supervisor.
16. Notify their supervisor immediately of any lost, stolen, or missing radiation source.

3. Authorization of Ionizing Radiation Sources

The procurement, possession, or use of radioactive materials is allowed only pursuant to a Radiation Permit issued by DRS. A permit is also required for technologically “enhancing” naturally occurring radioactive materials. This section discusses the application process, responsibilities for maintaining a permit, steps to amend or terminate a permit, and the policy on abandoned radioactive materials.

3.1 Radiation Permit Application Process

Complete a Radiation Permit Application and submit it to DRS.

DRS reviews the application and may inspect the work area and ask questions to ensure that the space, applicant’s experience, and procedures are adequate for the intended work. When satisfactory, DRS prepares the permit specifying quantities, locations, and conditions for use of radioactive materials, and obtains approval of the campus RSO and the RLSC Chair. By agreeing to the permit conditions, the applicant acknowledges their acceptance of the responsibilities associated with the permitted activities. The approved permit must be made available to all persons using radiation sources under its provisions.

Once the permit is in effect, procurement of radioactive materials may commence (see Section 5).

3.2 Radiation Permit Validity

A permit is valid as long as the conditions in the permit are fulfilled and there is a need for radioactive materials. In some cases, a Permit Holder may need a radiation permit only for a specified period of time. At the end of that time, the permit should be deactivated in accordance with Section 3.4. When no radioactive materials usage is planned for several months or more, the Permit Holder should request that the permit be deactivated.

3.3 Amendments

Permit holders can request amendments to their permit at any time by notifying DRS of the desired change in writing. DRS evaluates the change, and if the amendment is approved by the RSO and RLSC Chair, then amended permit is made available to the Permit Holder.

3.4 Deactivating/Reactivating a Permit

A space must be free of any radioactive materials (e.g., in the form of contamination, source vials, waste, or stored samples) before a permit can be deactivated. Radioactive materials must be properly disposed of or transferred to another authorized permit holder as described in Section 5. Laboratory personnel must perform surveys to ensure that no contamination exists. Once surveys have shown that the space is free of contamination, laboratory personnel must remove or deface radioactive labels and markings. DRS must then be contacted to perform a final survey and remove the radioactive materials postings from the entrances. The permit is deactivated when all areas have received a satisfactory final survey and postings have been removed.

A Permit Holder can simply reactivate a previously deactivated permit by contacting DRS. No additional signatures are required to reactivate a permit.

3.5 Abandoned Radioactive Materials

Campus units are responsible for decontaminating facilities and for identifying and properly disposing radioactive materials abandoned by their personnel.

Situations may arise in which unknown or abandoned radioactive materials and/or contamination are discovered. In such cases, the campus unit is responsible for performing detailed analyses and disposing of such materials and/or reducing contamination to acceptable levels as stipulated by regulatory agencies. If a campus unit is unable to assume these responsibilities or perform these required tasks within a reasonable time frame, then it may enlist the services of a qualified outside vendor or DRS on a cost-reimbursement basis.

When unknown or abandoned radioactive materials or contamination is discovered, DRS will request the responsible campus unit in writing to perform cleanup within 60 days. After 60 days, DRS may assume responsibility and proceed to complete the task unless DRS and the campus unit agree otherwise. The campus unit will reimburse DRS for costs incurred in the process. The RLSC will arbitrate any disputes that may arise.

4. Radiation Safety Training Requirements

4.1 Users of Radioactive Materials

Regulations require that users of radioactive materials be properly trained. All users of radioactive materials are required to complete the DRS online Radioactive Materials Safety Training at intervals not to exceed 12 months. In addition, and Permit Holders are responsible for providing specific training on radioactive sources and procedures used in their laboratories. Risk assessment and Standard Operating Procedures (SOPs) are important tools for developing laboratory-specific training and policies. Training should include:

- Health protection problems associated with the isotopes in use
- Lab-specific precautions and procedures to minimize exposure
- Purposes and functions of protective devices and survey meters
- The permit conditions and requirements
- Employee responsibility to promptly report any condition that may lead to or cause a violation of the regulations or cause an unnecessary exposure
- Actions to take in the event of an emergency
- Radiation exposure reports that workers may request

Particular attention should be given to contamination survey requirements, dosimetry requirements, necessary documentation, safety precautions and equipment, authorized radionuclides, possession limits, precautions during pregnancy, and authorized locations for radioactive materials. Regulations require that this knowledge be reinforced by annual radiation safety training.

Records of this instruction must be maintained by the Permit Holder for audit by DRS personnel or for inspection by state regulatory personnel.

4.2 Radiation Awareness Training

Regulations require annual awareness training for anyone who enters locations where radioactive materials are used or stored. Examples include Building Service Workers (BSWs) and tradespeople such as electricians and plumbers. Such individuals are required to complete the DRS online Radiation Safety Awareness Training annually.

5. Obtaining and Transferring Radioactive Materials

5.1 Ordering Radioactive Materials

Only holders of current radiation permits may order radioactive materials. The permit specifies the conditions, limitations, isotopes, and quantities under which the approved user may possess and use the specific radioisotopes being purchased.

To purchase radioactive materials, the Permit Holder submits a completed university purchase requisition to their business office. The purchase requisition should bear the words “Radioactive Materials.” The Permit Holder’s campus unit must initiate a purchase requisition or standing purchase order for the radioactive materials in the Banner or iBuy System. The **only** iBuy form that can be used to purchase radioactive materials is the university **"Controlled Substance Form.”** The unit must enter the applicable information into the radioactive materials purchasing database for final authorization.

To ensure expeditious handling of the order, the Permit Holder should ensure that the following information is provided on the university purchase requisition:

1. The name and signature of the Permit Holder responsible for the materials.
2. The isotope being ordered.
3. The amount of activity in millicuries (mCi) or microcuries (µCi) being ordered.
4. The chemical form of the isotope being ordered.

Unless previous arrangements have been made, all radioactive materials must be shipped to:

Division of Research Safety

Special Materials Storage Facility, MC-612

ATTN: PI/Permit Number

University of Illinois

2006 South Griffith Drive

Champaign, Illinois 61820

5.2 Receipt of Radioactive Materials

Unless prior arrangements have been made, DRS receives all campus orders of radioactive materials at the Special Materials Storage Facility. DRS monitors all shipments in accordance with regulations established by IEMA. After each shipment of radioactive materials has been checked and found to be in compliance with all applicable rules and regulations, DRS personnel deliver it to the user.

DRS provides a Radioactive Materials Receipt Record for each package delivered. The person accepting the radioactive materials is asked to sign for the package(s).

Laboratory personnel should use a wipe test to check the inner container and determine whether leaking has occurred. Shipments containing materials that may be volatile, gaseous, or readily dispersible should be opened in a fume hood. The user must notify DRS immediately if there is a problem with the shipment.

Upon receipt of a new shipment, laboratory personnel should enter pertinent data in a Radioisotope Use and Waste Log

Laboratory personnel must dispose of the shipping material in an appropriate manner. If contamination is present, then place the material in a radioactive waste container. If the shipping material is free of contamination, then remove or deface any "radioactive materials" labels or markings and dispose of it in the regular trash or recycling bin.

5.3 Transfers of Radioactive Materials from Off-campus

Occasionally, a Permit Holder may receive radioactive materials as a gift from another campus or institution where a purchase order is not involved. In such cases, the Permit Holder must make prior arrangements with DRS for purposes of license verification, radiation permit authorization, and receipt instructions.

5.4 Off-Campus Shipments/Transfers

Radioactive materials are a class 7 Hazardous Material/Dangerous Goods as defined by Department of Transportation (DOT) 49 CFR Part 173 and International Air Transport Association (IATA) 10.0. Shipments of radioactive materials to off-campus locations may be done only by personnel who have received the necessary training. Contact DRS to determine what training is required.

Any researcher preparing, packaging, labeling, or offering radioactive materials for transport must take the DRS online Awareness Training for the Transport of Hazardous Materials. For shipments that qualify as radioactive materials in excepted quantities, function-specific training is available from DRS.

DRS personnel will ensure that the radioactive materials are properly packaged and in compliance with shipping regulations. All such shipments are handled on a case-by-case basis. Contact DRS for assistance.

5.5 On-Campus Transfers

Transfers of radioactive materials within the campus may occur between mutually agreeable Permit Holders after authorization by DRS. These are regarded as “on-campus” transfers. A Permit Holder is not allowed to dispense radioactive materials on a routine basis to other researchers. DRS will approve procedures for recurring transfers of radioactive materials over a period of time on a case-by-case basis. The steps for the transfer of radioactive materials are:

DONOR:

1. Request permission by contacting DRS. Provide the following information:
    - Radiation permit number and name of the individual to receive the materials
    - Location where materials will be used/stored by the recipient
    - Isotopes and amounts (mCi or µCi) to be transferred

2. Ensure that the materials are properly packaged for transport (e.g., secondary containment with appropriate shielding as necessary and labeled with a radioactive symbol).
3. Maintain accurate written records of all transfers including isotopes, quantities, dates, and documentation of contamination surveys of packages.

RECIPIENT:

1. Maintain accurate written records of the receipt, including isotopes, quantities, dates, and from whom those materials were received
2. Ensure that the radioactive materials are stored properly

6. Using Radioactive Materials

6.1 ALARA (As Low As Reasonably Achievable)

The university is committed to minimizing radiation exposures to faculty, staff, students, and the public resulting from the use of radiation sources in research and teaching. The regulations for working safely with radiation require all exposures to be As Low As Reasonably Achievable (ALARA). Principles and practices implemented must control our individual doses from daily work, our collective doses through our career, and minimize amounts of radioactive waste and emissions. The RLSC and DRS advise and assist faculty, staff, and students in all matters regarding radiation safety. Through DRS, the RLSC recommends to the campus administration the policies, and procedures for maintaining ALARA radiation exposures by the safe handling, storage, use, transport, and disposal of radiation sources.

6.2 Exposure Reduction Practices

Exposure control must include reduction of external exposure and prevention of internal contamination.

Reduction of External Exposure

Minimize personal exposure to external radiation by managing these three parameters: time, distance, and shielding. Plan experiments well to spend as little time as possible near the radiation source. For new procedures and new personnel, one or more trial runs beforehand with non-radioactive materials are recommended to test the effectiveness of procedures, training, and equipment.

Keep as much distance as possible, especially to sensitive parts of your body (e.g., eyes, upper body). For strong sources, tongs can often be used to prevent high exposures to the hands. Use adequate shielding for high-energy beta- and gamma-emitters whenever possible. Beta particles are stopped by 1 cm of Plexiglas. Stopping gamma rays requires dense material such as lead. Do *not* use lead shielding for beta-emitting nuclides because it will produce hazardous Bremsstrahlung (X-rays). Shielded syringes are available for manipulation of liquids that contain high-energy radioisotopes.

Prevention of Internal Contamination

Reduce the chance for radioactive materials to enter the body through inhalation, ingestion, or skin contamination. Maintain a high standard of cleanliness and housekeeping and follow good hygiene practices:

- **NO** eating, drinking, or application of cosmetics in radioisotope areas

- **NO** human food and drink in research areas including lab refrigerators, freezers, or microwave ovens
- Wash hands and arms thoroughly before eating, drinking, or applying cosmetics

Engineering Controls

Whenever possible, operations with radioactive materials should be conducted in a fume hood, dry box, or some other type of closed system. Operations with materials susceptible to atmospheric distribution, such as boiling, evaporating, distilling, or burning, must be done in a fume hood with adequate airflow of approximately 60-120 linear feet per minute (lfpm); some newer fume hoods are designed to be in compliance at lower rates of approximately 60-65 lfpm. Fume hoods in radioactive materials laboratories are checked periodically for airflow and the proper sash height is indicated on the fume hood. Work with radionuclides that have half-lives of more than a few hours should be done within containment to prevent the spread of contamination in the event of a spill. Work with radioactive materials in powder form should be done in an enclosed system.

Work Practices

Work with hazardous materials on impervious benchtops, and dedicate an area for work with radioisotopes. Working surfaces should be covered with absorbent paper regardless of the type of surface.

Label all areas (e.g., benchtops, sinks) and equipment (e.g., containers, waste receptacles) that may contact radioactive materials. Use tape or labels marked with the radiation symbol. Remove or permanently deface these symbols when the hazard no longer exists.

When work is completed, each user should clean up their own work area and arrange for disposal of all radioactive materials and equipment.

Vacuum pumps used in systems containing radioisotopes should be used in fume hoods with proper flow rates.

Before submitting repairs on facility infrastructure or equipment used for radioactive materials work such as sink drains and fume hoods, make sure the equipment and surrounding area are free of contamination.

Personal Protective Equipment (PPE)

Always use appropriate Personal Protective Equipment (PPE) when handling radioactive materials. PPE reduces the chance of intake and skin contact. Assess all hazards and select PPE based on your risk assessment. At a minimum, wear:

- A laboratory coat
- Gloves
- Safety glasses
- Closed-toe shoes

Change gloves and wash hands frequently. Remove gloves before touching any clean items that are usually touched without gloves. Do not reuse disposable gloves.

6.3 Exposure Control for Airborne Radioactive Materials

Some compounds may become airborne through volatilization, aerosolization, or metabolization when stored or used. When these compounds contain radioisotopes, the risk of internal exposure through inhalation increases. Use a chemical fume hood for all work with potentially airborne radioactive compounds. Before opening packages or containers (e.g., vials) that have gaseous, volatile, or pressurized (e.g., ampules) radioisotopes, place them in a fume hood. Use activated charcoal, exchange resins, or zeolite catalysts to trap radioisotopes for decay. Open containers, such as cell culture dishes that contain radioisotopes, can be covered with carbon-impregnated paper.

Examples of radioactive isotopes that can become airborne:

- Iodine such as I-123, I-125, and I-131
- Tritiated (Hydrogen-3) compounds in water
- Compounds containing carbon-14
- Radioactive gases such as krypton-85, radon-222, or chlorine-36
- Methionine (and other amino acids) containing sulfur-35

6.4 Storage of Radioactive Materials

Radioactive materials must be secured at all times.

This may be accomplished by *any* of the following:

1. Attending the materials
2. Maintaining materials in a locked freezer or cabinet
3. Locking the room in which the materials are stored

These requirements apply to **ALL** radioactive materials in the laboratory, including waste, contaminated equipment, and sealed sources.

Radioactive materials stored in occupied areas must be shielded in accordance with the ALARA principle.

Unbreakable containers are recommended for storing radioactive liquids. Glass and other fragile containers used for storage must be kept in non-breakable, leak-proof secondary containers or trays capable of containing the entire volume of liquid stored in the primary container.

Radioactive gases and volatile forms of radioisotopes should be stored in a well-ventilated area, such as a fume hood.

Sealed Sources

Sealed sources **must** remain in the same condition as received from the manufacturer.

No modification of sealed sources is permitted without express written consent from DRS.

Sealed sources that have been mutilated and damaged beyond what would reasonably be expected to occur as a result of normal use should be reported to DRS as soon as possible.

Labeling

Clearly label all radioisotopes and calibration sources. Stock solutions of radioisotopes should be clearly labeled with the following information:

Caution: Radioactive Materials

Radionuclide

Activity and assay date

Person responsible for sample or source

This regulatory requirement does not apply to sources with an activity less than listed in the table below. However, for the safety of personnel and to guarantee proper waste disposal, all containers should be labeled with at least the identity of the radioisotope and chemical contents.

Table of quantities requiring labeling:

Nuclide	Quantity (µCi)
H-3	1000
C-14	1000
P-32	10
P-33	100
S-35	100
Tc-99m	1000
I-125	1
I-131	1

Limits for other radionuclides may be found in Appendix C of the Code of Federal Regulations, Title 10, Part 20:

http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-appc.html

6.5 Using Radioisotopes in Animals

Research with vertebrate animals must be approved by the Institutional Animal Care and Use Committee (IACUC). DRS reviews all IACUC protocols that involve the use of radiation sources to ensure that safety requirements have been addressed. This includes the following items:

- Areas in which animals are kept must be posted in accordance with the requirements of IEMA statutes and regulations.
- Cages and pens must bear labels listing the isotope used, the quantity and date administered, measured external radiation levels, and the name of the Permit Holder. These cages and pens should be separated from those housing non-radioactive animals.

- Ventilation should be adequate to handle the possibility of airborne radioactivity. In some instances, this may require the use of a fume hood or other controlled environmental systems.
- Animal carcasses, bedding, and excreta must be disposed of properly. If excreta are mixed with bedding materials, handle in accordance with dry radioactive waste procedures. Carcasses containing hydrogen-3, carbon-14, or iodine-125 at concentrations below 0.05 microcuries per gram may be disposed of without regard to radioactivity, but they may not be introduced into the food chain. DRS must approve disposal methods for animal carcasses before work begins.

Animal caretakers must be instructed and trained by the Permit Holder on handling procedures, dose levels, occupancy time limits, and applicable special conditions. Animal caretaking must be performed by trained research personnel.

Authorization to administer radioisotopes to animals must be approved by DRS. DRS establishes the criteria for releasing the animals to the owners.

6.6 Inventory and Record Keeping

Regulations require tracking of all radioactive materials. Every use and waste disposal must be recorded. A Radioisotope Use and Waste Log is available on the DRS website. The online inventory is updated automatically whenever radioactive materials are delivered or waste picked up by DRS. Sewer disposal must be requested in the online database for the disposed amount to be subtracted. The inventory must be confirmed by the laboratory every six months.

DRS personnel periodically audit radiological laboratories on campus. The following are expected to be readily available for inspection:

- Laboratory survey records
- Radioactive materials inventory and use records

Printouts from automatic counters such as a liquid scintillation counter may be used as a survey record if the survey locations are clearly noted. Records must be maintained by the Permit Holder for as long as the radiation permit remains active.

7. Contamination Surveys

Surveys are important to prevent spreading of contamination. Surveys must be performed by Saturday of the week following the week in which open sources of radioactive materials have been used (unless your permit specifies a different frequency). The surveys should be sufficiently extensive to allow confidence that there is no contamination outside of marked radiation areas. Common places to check for contamination are benchtops, tools and equipment, floors, door handles and drawer pulls, and computer keyboards.

7.1 Types of Contamination

Removable contamination can be readily transferred from one surface to another. Removable contamination presents an internal and external hazard because it can be picked up on the skin and ingested. **Fixed contamination** cannot be readily removed and generally poses a lower hazard unless the material is brittle or the contamination is large enough to present an external hazard.

7.2 Types of Surveys

Two types of survey methods are used: 1) a direct (or meter) survey; and 2) a wipe (or smear) survey.

Direct surveys, using a Geiger-Mueller (GM) meter or scintillation probe, can identify gross contamination (total contamination consisting of both fixed and removable contamination) but can detect only certain radioisotopes.

Wipe surveys, using “wipes” such as cotton swabs or filter papers counted on a liquid scintillation counter or gamma counter, can identify removable contamination only but will detect most radioisotopes used at the university. Wipe surveys are the most versatile and sensitive method of detecting low-level removable contamination in the laboratory.

7.3 Survey Instrumentation

The portable **Geiger-Mueller (GM) survey meter** is best used for P-32, a high-energy beta emitter, and other high-energy beta and gamma emitters such as Co-60, Zn-65, Cs-137, and U-238. A GM meter can also be used to identify areas heavily contaminated with lower-energy beta emitters, such as C-14 or S-35, for which the GM meter has a relatively low efficiency. GM meters should not be used to survey for I-125 contamination because they detect I-125 only when there are very high levels of contamination.

The portable thin crystal **NaI scintillation survey meter** should be used to check for I-125 contamination and to conduct surveys around low-energy X-ray sources such as X-ray diffractometers and electron microscopes.

The **liquid scintillation counter (LSC)**, used for wipe tests, is the most versatile counting instrument because it has a high counting efficiency for a wide range of radionuclides. Most LSCs provide a printout of sample results that may be used as survey record.

Gamma counters are not portable and are used to count swipes of gamma emitters such as Cr-51 or I-125.

7.4 How to Perform a Meter Survey

Prior to performing any survey, clean gloves should be worn. This prevents the possibility of personal contamination or cross-contamination.

Perform an instrument check. To check the operation of a survey instrument, do the following:

1. Calibration check:

Check the calibration label on the instrument and ensure that the instrument is within the calibration period. If the calibration due date has passed, then contact DRS to have the instrument recalibrated and find another instrument to use.

2. Battery check:

Turn the switch on the survey meter to "BATTERY," or flip the battery switch to "ON." The needle on the meter face should move to a position within or beyond the indicated area on the meter face scale. Replace the battery if needed before using the survey meter.

3. Speaker check:

If there is an audio switch on the survey meter, then turn it to "ON." Set the survey meter to a scale of "X1." The survey meter should chirp or click. If the speaker does not function, then the survey meter can still be used, but the surveyor will need to check the reading on the survey meter face.

4. Background check:

Go to an area with an expected low background rate and note the count rate. The background rate for a GM meter should be less than 100 counts per minute; the background reading for a NaI meter should be less than 400 counts per minute. If the background reading exceeds that level, then investigate the area for unknown sources of radiation or detector contamination. Do not use the survey meter if it does not register a background rate.

5. Instrument response check:

Hold the supplied check source (often a thorium lantern mantle) up to the probe window. Note the count rate. The survey meter should respond to the check source, providing positive indication that the instrument is functioning properly.

Do not cover the probe surface with parafilm or other protective coating. Parafilm and similar materials will shield the low-energy beta particles from C-14, P-33, and S-35 and may prevent the meter from detecting contamination.

Hold the probe window approximately 1 cm from the surface to be surveyed and move the probe over the surface at about 1 cm/second. A faster movement rate may result in missing contamination.

Check the most common sites for contamination, such as the survey meter handle, soap/towel dispensers, drawer handles, refrigerator/freezer handles, chair edges, writing utensils, survey record books, floors, radio dials, microwave oven touch pads/handles, doorknobs, light switches, and non-radioactive trash containers.

Record survey results in a survey log. Obtain several background readings and record the highest result. Next, complete the survey. If survey results are equivalent to the background, log the result as '≤ BKG'. A surface may be considered as contaminated if the result is greater than the background count rate. If contamination is found, then record the result and indicate the action taken. Once corrective actions have been taken, perform another survey of the area until the contamination is within the range of the highest background results.

7.5 How to Perform a Wipe Survey

Prior to performing any survey, clean gloves should be worn. This reduces the likelihood of personal contamination or cross-contamination.

Removable contamination is best identified by a wipe survey, which is performed by rubbing a filter paper (approximately 45 mm 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 square centimeters (4 in × 4 in) is surveyed. To monitor a larger area, take additional swipes.

When surveying for low-energy beta-emitters such as H-3, C-14, P-33, and S-35, analyze the wipe using liquid scintillation counting.

When surveying for high-energy beta emitters such as P-32, wipe samples may be counted using either liquid scintillation counting or a GM meter.

When monitoring for low-energy gamma emitters such as I-125, wipe samples should be counted with a thin crystal NaI scintillation meter.

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.

Survey results must be documented on a survey log or similar form. Results may be reported as gross count rate, net count rate, or in units of activity (usually disintegrations per minute). Ensure that the survey log accurately reflects how results are being reported. Similar to a meter survey, if the results are above the highest background sample, then the contamination will need to be removed. Re-survey to confirm effectiveness of the removal. If the contamination cannot be effectively removed, then contact DRS.

8. Radioactive Waste

All radioactive waste must be disposed of in a responsible manner according to applicable regulations. Waste that contains long-lived radioisotopes (half-lives > 120 days) is shipped by DRS for final disposal at an off-site facility. Materials contaminated with short-lived nuclides may be stored on campus until indistinguishable from background radiation levels and then disposed of as non-radioactive waste.

Waste that is picked up by DRS for disposal must be segregated, packaged, and labeled following the instructions in this section. DRS will not handle any package that does not conform to the requirements or that may present a safety hazard to its personnel or members of the public.

The route of disposal depends on the following factors:

- Chemical hazards present in the waste
- Physical phase (liquid or solid)
- Half-life of isotope

8.1 Chemical Hazards Present (Dual Hazard Waste)

When the waste contains more than trace amounts of hazardous chemicals such as regulated metals (As, Ba, Cd, Cr, Pb, Hg, Se, Ag), toxics, or flammables, it is considered a "dual hazard waste" and likely needs to be picked up by DRS. This includes solids (e.g., contaminated lead). Please consult with DRS before submitting a pickup request. When submitting the request in the DRS Waste Management App, find the UI # of the chemicals present. Identify the waste as radioactive by checking the appropriate box on the form. Add the following information in the description:

- Permit #
- Radioisotope
- Activity
- Result of a contamination survey on the outside of the package (see Section 8.7)

Toluene and xylene-based liquid scintillation cocktails and some HPLC fluids fall into this category. The liquids need to be free of all filterable solids. Collect such liquid waste in spill-proof, sturdy plastic containers no larger than 10 L capacity and use a 60-mesh metal screen for filtering.

When collecting liquid waste, pay attention to potential chemical incompatibilities. Incompatible chemicals can generate gases that may cause the container to rupture and potentially may be toxic (e.g., cyanides or azides in acids; tissues digested in nitric acid). The waste generator must ensure that chemical reactions will not occur in liquid waste containers.

Be aware that dual hazard waste can incur high disposal costs and should therefore be minimized as much as possible. If your research will generate large amounts of dual-hazard waste, then please contact DRS for consultation before you begin the experiments.

If the only chemical hazard is an organic solvent and the amount is small (mL range), then the solution may be poured onto absorbent material (pads, cat litter) and dried inside a fume hood. The dried material can then be submitted as radioactive dry debris (see Section 8.3).

8.2 Liquids Without Chemical Hazards (Sewer Disposal)

Aqueous waste containing only water-soluble or dispersible non-hazardous chemical components may be disposed of through the sanitary sewer (sink) if the concentration is below a relevant limit. Most water-soluble scintillation cocktails fall under this category. Use a sink designated for this purpose and adjust the pH to between 6 and 10 before disposal. The concentration limits are shown below:

Radioisotope	Concentration limit (µCi/mL)
H-3	1×10^{-2}
C-14	3×10^{-4}
P-32	9×10^{-5}
P-33	8×10^{-4}
S-35	1×10^{-3}
I-125	2×10^{-5}
I-131	1×10^{-5}

Other radionuclide concentration limits can be found in Title 10, Code of Federal Regulations, Part 20, Appendix B, Table 3.

To request a sewer disposal, enter the activity to be disposed of in the DRS database under “Sewer Disposal” and click “Initiate Disposal”. The inventory will be adjusted accordingly once the request is approved.

Water-insoluble liquids or aqueous solutions in excess of the concentrations specified above must not be released into the sewage system. The liquid should be solidified and submitted as dry debris (see next section). Consult DRS about unusual circumstances.

8.3 Solids Without Chemical Hazards (Dry Debris)

Dry debris consists of items contaminated with radioisotopes, such as gloves, pipette tips, paper, etc. It cannot contain any freestanding liquids, hazardous chemicals including lead, sharps, or animal carcasses or tissue.

Segregate dry waste by radionuclide half-life ($\leq$ 120 days and > 120 days) and keep wastes containing tritium (H-3) and carbon-14 (C-14) segregated from other long-lived isotopes.

Collect dry debris in containers labeled with the radiation hazard symbol, the radioisotope identity, and the words “Caution–Radioactive Materials”. Containers must be lined with plastic bags with a thickness of at least four mils of low-density polyethylene (LDPE), clear or transparent yellow in color, and bearing the radiation hazard symbol. Individual bags should be no greater than 30 gallons in volume. Laboratories are responsible for providing their own disposal containers and bags.

Submit dry debris in the DRS Waste Management App and select UI # 6 for short-lived radioisotopes (half-life $\leq$ 120 days) and UI # 7 for long-lived radioisotopes (half-life > 120 days). Identify the waste as radioactive by checking the appropriate box on the form. Add the following information in the description:

- Permit #
- Radioisotope
- Activity
- Result of a contamination survey on the outside of the package (see Section 8.7)

8.4 Scintillation Vials and Other Glassware

Empty liquid scintillation counting vials or other glassware that contained media with a concentration of C-14 or H-3 less than 0.05 micro-Curies per milliliter (µCi/mL) need not be decontaminated and should be disposed of with the regular, non-radioactive waste. Ensure that vials have been properly emptied and “radioactive materials” labels have been removed or defaced.

Empty vials that contained media with a concentration of C-14 or H-3 above 0.05 microcuries per milliliter (µCi/mL) or any other radioisotopes can be:

- Decontaminated by washing. Count a representative sample of the wash water to determine effectiveness. Decontamination is successful when the average count rate is less than twice the background level. Wash water may be disposed of according to Section 8.2.
- Disposed of in dry debris (see Section 8.3). Make sure the glassware is completely empty and dried.

Most glass items (e.g., test tubes, dishes) can be decontaminated and reused after routine washing or an overnight soaking with an industrial-strength detergent.

8.5 Radioactive Sharps

Sharps require special precautions and handling. When the following items have come into contact with radioisotopes, dispose of them in Sharps Disposal Containers (SDCs) that bear a “**Caution–Radioactive Materials”** label listing isotope and date:

- Needles and syringes
- Pasteur pipettes
- Scalpels and razor blades
- Microscope slides and coverslips
- Broken glassware

Sharps containers are closable, puncture-resistant, leak-proof on the sides and bottoms, and are typically available in 1-quart, 2-gallon, and 8-gallon sizes.

Most glassware, such as liquid scintillation vials and test tubes, is easily decontaminated as described above and should not be routinely discarded as sharps.

When sharps containers are full, request a pick up in the DRS Waste Management App.

8.6 Animal Carcasses

Radioactive materials used in animals must be addressed on a case-by-case basis. Permit Holders who are planning to administer radioactive materials to animals should contact DRS for guidance concerning the disposal of carcasses. DRS will review the administration of radioactive materials to animals during the IACUC review.

Animal tissues containing 0.05 µCi or less of H-3, C-14, or I-125 per gram of animal tissue averaged over the weight of the entire animal may be disposed of as if it were not radioactive. However, animal tissue in which radioactive materials have been introduced must not be disposed in a manner that would permit its use either as food for humans or as animal feed, such as rendering.

8.7 Contamination Surveys for Waste Pickups

For all radioactive waste items picked up by DRS, the outside of the container must be free of contamination. For this reason, a survey of the outside of the container is required and the result must be entered into the pickup request.

To perform the survey, moisten a piece of filter paper or a cotton swab with water or alcohol. Wipe an area of approximately 100 square centimeters per wipe (4 in × 4 in per wipe) along the outside surface of the bag or container. Multiple wipes may be required for larger containers. Count the wipes with a suitable detector (see below) and compare with the background count. Record the container cpm as the net count rate (gross cpm – background cpm). The container cpm should be less than two times the background count rate. If it is not, then either decontaminate the outside of the bag or place the contaminated bag inside a clean bag and re-survey.

Suitable detectors:

- Low-energy beta (e.g., H-3, C-14, or S-35): Liquid Scintillation Counter
- High-energy beta (e.g., P-32): Geiger Counter
- Gamma (e.g., I-125, I-131): NaI Scintillation Counter

See Section 7 for more details on survey procedures.

9. Emergency and Spill Clean-up Procedures

In an emergency situation it is of utmost importance to know how to respond. Read this section carefully and memorize the content. Discuss with your supervisor the specific emergency procedures for the laboratory you are working in BEFORE you start your work.

In any radiation emergency, personnel protection comes first, confinement of radioactivity next. The amounts used on campus are low enough that the safety and health of first responders are NOT at risk.

Call 911 in an emergency that involves:

- **Serious injury**
- **Fire or explosion**
- **A spill of radioactive materials that causes air contamination**

If building evacuation is required, then pull the fire alarm and move to the assembly area as outlined in your Building Emergency Action Plan (BEAP). From the safe location, call 911 to inform the emergency responders about the accident and include information if radioactive materials were spilled or if a victim is contaminated.

After emergency notifications have been initiated, contact DRS at 217-333-2755 during office hours. During after-hours, DRS will be notified by emergency responders.

Identify yourself to the emergency responders and provide information as requested.

After the emergency has passed, DRS will follow up with all personnel involved to investigate the incident.

9.1 Spill and contamination of personnel

In case of a spill of radioactive materials that involves contamination of personnel, take the following steps:

Personnel Protection

1. Remove contaminated clothing
2. Wash the affected skin area thoroughly with water and a mild detergent. Do NOT use any harsh chemicals or scrubbers that could compromise the skin.
3. Notify DRS at 217-333-2755 as soon as possible. DRS will determine and supervise decontamination procedures as necessary.

Spill clean up

Spills of radioactive materials are cleaned up the same way as chemical spills based on the chemical properties. To limit the exposure to radiation, maximize your distance to the spill by using tools such as tongs and disposable mops. Protect your skin from contamination by wearing a lab coat, safety glasses, and gloves with long cuffs. A face shield is recommended for large spills.

1. Localize the spill and place absorbent material along the edges.
2. Chose absorbent material based on the chemical properties, e.g., acid or base neutralizers for caustics, and inert absorbent pads or material such as vermiculite, dry sorb, or cat litter for any other liquids.
3. Work from the outside in and absorb the spilled liquid or powder. Make sure not to step into the spill area.
4. Place all absorbent material into a sturdy bag or container with a lid. Include contaminated clothing and PPE. Seal the bag/container and submit to DRS for waste disposal.
5. Clean the spill area with soap and water.
6. Survey yourself including the bottom of your shoes and any items that may have come in contact with the spill to check for contamination.
7. Survey the spill area and surroundings to check for radiation.
8. If radiation is above background, place a shield over it and mark the area with radiation tape.
9. Contact DRS.

9.2 External Exposure

If someone received or believes to have received an exposure to a high radiation field, e.g. from an x-ray machine or a high-activity source, then turn off the beam or shield the source to limit the exposure. Seek medical attention as necessary. Notify DRS. DRS will evaluate the potential exposure and initiate action as necessary.

10. Exposure Limits and Dosimetry

10.1 Occupational Exposure Limits

The annual limit for employees who work with radiation is the lower of:

a. The total effective dose equivalent = 5,000 millirem (0.05 Sv); or
b. The sum of the deep dose equivalent and the committed dose equivalent to any individual organ or tissue (other than the lens of the eye) = 50,000 millirem (0.5 Sv).

The annual limits to the lens of the eye, to the skin, and to the extremities are:

a. Eye dose equivalent = 15,000 millirem (0.15 Sv)
b. A shallow dose equivalent = 50,000 millirem (0.5 Sv)

10.2 Non-Occupational Exposure Limits (Members of the Public)

Each user of radioactive materials must conduct operations so that:

1. The dose in any unrestricted area from external sources does not exceed 2 millirem (0.02 mSv) per hour.
2. The total effective dose equivalent to individual members of the public from a licensed operation, exclusive of the dose contribution from a licensee's disposal of radioactive materials into the sanitary sewer, does not exceed 100 millirem (1 mSv) in any year.

10.3 Declared Pregnant Workers Exposure Limits

The increased sensitivity of rapidly dividing cells makes the human embryo and fetus particularly susceptible to injury from exposure to ionizing radiation. For this reason, regulations require that exposure to the fetus during the gestation period not exceed 500 millirem (5 mSv). More information on this topic can be found under Recommended reading for pregnant female radiation workers.

Any radiation worker who is pregnant or believes that she may be pregnant should contact DRS and review the recommended reading. All inquiries will be confidential. The individual must complete a Declaration of Pregnancy Form for the lower limits to apply. If a written declaration of pregnancy is not submitted, then the worker's dose continues to be controlled under the normal dose limits for radiation workers. A declaration of pregnancy can be withdrawn at any time.

For the type of radiation work performed at the U of I, it is rarely necessary to recommend reassignment or changes to job duties to reduce exposure.

The dose must be approximately uniform throughout the pregnancy. Care must be taken so that no more than 50 millirem (0.5 mSv) is received during any one month during a declared pregnancy. Efforts must be made to avoid substantial variation above the uniform monthly exposure rate to a declared pregnant woman.

If, by the time the pregnant woman informs DRS of the estimated date of conception, the dose to the embryo/fetus has exceeded 450 millirem (4.5 mSv), then the limit for the remainder of the pregnancy will be 50 millirem (0.5 mSv).

If the pregnant woman has not notified DRS of her estimated date of conception, then the dose to the fetus must not exceed 50 millirem (0.5 mSv) per month during the remainder of the pregnancy.

10.4 Exposure Limits for Minors

The annual occupational dose exposure limits for minors are 10 percent of the annual occupational dose exposure limits specified for adult workers in Section 10.1.

10.5 Personnel Dosimetry

The use and type of personnel dosimetry is determined by the activities and functions that the individual performs. By regulation, any person who receives or is likely to receive more than 10 percent of the maximum permissible dose or who enters a high radiation area must be provided with and must wear personnel monitoring devices.

DRS assigns dosimetry when certain quantities and radionuclides are used. Specifically, the use of >10 mCi of P-32 requires the user to wear both an extremity dosimeter (commonly referred to as a "finger ring") and a whole-body dosimeter. At usage levels ≤10 mCi of P-32, dose assessments will be performed to evaluate the need for dosimetry. Dosimetry is not issued for individuals who are working with weak beta-emitting radionuclides such as H-3, C-14, P-33, and S-35.

DRS evaluates use of dosimetry for other radionuclides and quantities on a case-by-case basis.

To enroll in dosimetry services, complete a Dosimetry Request Form and return it to DRS.

Whole body dosimeters, or badges, monitor exposure to the whole body and should be worn between the neck and the waist, usually on the front of the body.

Finger ring dosimeters monitor radiation exposure to the hands and fingers. These dosimeters may be worn on any finger and should normally face the palm side of the hand. Finger rings must be worn under gloves to prevent them from becoming contaminated.

Every person with assigned dosimeters must wear the badges and/or ring dosimeters when working with sources of ionizing radiation.

The dosimeter reading is the legal record of an individual's occupational radiation exposure. Therefore, a dosimeter must be worn only by the individual to whom it is assigned, must not be tampered with or experimentally irradiated, and must not be used to measure radiation exposure received as a medical patient.

When not being worn, dosimeters must be stored in a location where they will not be exposed to radiation.

Dosimeters are collected monthly or quarterly by DRS personnel and sent to a vendor for processing. Dosimeters must be made available for this exchange to occur.

If a dosimeter is lost, then discontinue radiation-related activities and contact DRS. Individuals who have lost a dosimeter must provide information to DRS personnel so that an assessment of their radiation exposure can be performed. DRS will order a replacement dosimeter.

10.6 Bioassays

Bioassays are used to determine types, concentrations, quantities, or locations of personal uptake of radioactive materials into the body. A baseline (before first use) bioassay and another bioassay within 24 to72 hours following each use of the quantities specified are required for the following isotopes:

- Users of *unbound* radioactive iodine (typically I-125 or I-131) in quantities of ≥1 mCi on a bench top or in quantities ≥10 mCi in a fume hood require thyroid bioassays. They are performed using a hand-held scintillation probe and survey meter.
- Tritium bioassays are required when a person uses >100 mCi of H-3 without using a fume hood. They are performed by condensing water from exhaled air followed by liquid scintillation counting of the activity in the sample.

Additional bioassays may be required for personnel on a case-by-case basis as determined by DRS.

10.7 Personnel Exposure Records

DRS maintains exposure records for all monitored personnel. Annual reports of exposure are always available to the wearer, and a notice is sent advising them to review their exposure report annually in accordance with Section 10.5.

At the request of a worker, DRS must furnish their exposure report. The report is furnished within 30 days from the time the request is made, within 30 days of termination of employment, or within 30 days after the individual's dose has been determined, whichever is later.

11. Isotope Information Sheets

Tritium ^3H

Radiological half-life, $T_{1/2}$……………………………………………………….12.3 years

Principle emission…………………………………………..….18.6 keV beta (maximum)

External dose rate ………….……….minimal, see below

Annual limit on intake (ALI) by ingestion……………………………………...$8x10^4$ µCi*

Biological monitoring method……………………….……………………breathe samples

Range in air………………………………………………………………………….4.7 mm

Range in water………………………………………………………….….$6x10^{-3}$ mm

Shielding required…………………………………………………………………..none

Monitoring method for contamination………….………wipe survey and LSC analysis

Sanitary sewer release concentration limit…..$1x10^{-2}$ µCi/ml

Special considerations

- The primary hazard of tritium compounds comes from internal contamination. Upon contact tritium compounds can be absorbed through the skin. Change gloves every hour when working with 50 mCi or more.

- Tritium can migrate from tritiated compounds to other molecules including water. This "creep" can cause contamination of areas of high humidity (e.g. inside refrigerators) and tritium build-up in ice inside freezers. If possible, place previously opened containers of tritiated compounds into a fume hood. If storage in a refrigerator is required, store inside a second sealed container. Monitor storage areas where large quantities of H-3 are kept.

- Bioassays are required when using >100 mCi on an open bench or >1000 mCi in a fume hood. Contact the Division of Research Safety before performing such work.

- Due to its low beta energy, tritium cannot be monitored directly, and therefore regular wipe surveys of the work areas are required.

* ALIs can vary considerably, e.g., DNA precursors such as tritiated thymidine are regarded as more toxic than tritiated water partly because the activity is concentrated in the cell nuclei.

Carbon ^{14}C

Radiological half-life, $T_{1/2}$……………………………………………………5730 years

Principle emission……………………………………………...156 keV beta (maximum)

External dose rate ……………… minimal skin penetration, see below

Annual limit on intake (ALI) by ingestion……………….………………..……….2x10^3 µCi

Biological monitoring method…………………………….…………breath or urine samples

Range in air………………………………………………………………………..21.8 cm

Range in water…………………………………………………………..…...0.28 mm

Shielding required………………………………1 cm acrylic glass (Plexiglas®; Lucite®)

Monitoring method for contamination…………...…………………………. wipe survey and LSC analysis

Sanitary sewer release concentration limit…………………………………..9x10^{-5} µCi/ml

Special considerations

- Carbon-14 is primarily an internal hazard. In addition, skin contact can result in high local doses.
- Exposure from external millicurie (or less) sources ***without contacting*** those materials is low due to the minimal penetration of the outer dead layer of skin.
- Be alert to the chemical properties (e.g., halogenated compounds) of various C-14 compounds that may allow absorption through the skin.
- Be aware of the chemistry occurring and determine if volatile compounds, such as carbon dioxide are formed that pose an inhalation hazard. Procedures releasing C-14 gases should be performed in a fume hood.

Phosphorus ^{32}P

Radiological half-life, $T_{1/2}$……………………………………………………..14.3 days

Principle emission…………………………………………….…1.71 MeV beta (maximum)

Dose rate (1 cm from a beta point source; isotropic in air, unshielded)…..350 R/h per mCi

Annual limit on intake (ALI) by ingestion……………….……………….………$6x10^2$ µCi

Biological monitoring method………………………………………….....urine samples

Range in air……………………………………………………………………..6.1 m

Range in water………………………………………………………….…….….0.8 cm

Shielding required………………………………1 cm acrylic glass (Plexiglas®; Lucite®)

Monitoring method for contamination………….…………………………..GM counter

Sanitary sewer release concentration limit…………………………….....$9x10^{-5}$ µCi/ml

Special considerations

- P-32 poses an external and internal hazard.
- Users handling > 10 mCi at a time require a ring (extremity) dosimeter and whole body dosimeter.
- Do not work over open containers as the dose rate is not attenuated in air. Use proper shielding during liquid transfers and related work.
- Use acrylic glass (Plexiglas®; Lucite®) shielding. Do not use lead shielding, which can create Bremsstrahlung radiation.

Phosphorus ^{33}P

Radiological half-life, $T_{1/2}$……………………………………………………….25.4 days

Principle emission…………………………………………0.249 MeV beta (maximum)

Dose rate (1 cm from a beta point source, isotropic in air, unshielded). 350 R/h per mCi

Annual limit on intake (ALI) by ingestion……………………………………….6x10^3 µCi

Biological monitoring method……………………………………………….urine samples

Range in air……………………………………………………………………….49 cm

Range in water…………………………………………………………………0.6 mm

Shielding required………………………………1 cm acrylic glass (Plexiglas®; Lucite®)

Monitoring method for contamination…………………………………………..GM counter

Sanitary sewer release concentration limit………………………………….8x10^{-4} µCi/ml

Special considerations

- P-33 poses primarily an internal hazard. Skin contact can lead to a significant dose to the basal cells of the skin.
- External hazard to P-33 in closed containers is minimal as the container provides sufficient shielding to stop the beta particles.
- Do not work over open containers and use proper shielding during liquid transfers and related work.

Sulphur ^{35}S

Radiological half-life, $T_{1/2}$……………………………………………………87.4 days

Principle emission…………………………………………….…167 keV beta (maximum)

Dose rate ……. minimal skin penetration, see below

Annual limit on intake (ALI) by ingestion…………….……………….……….$6x10^3$ µCi

Biological monitoring method…………………………………………....urine samples

Range in air………………………………………………………………………26 cm

Range in water……………………………………………………………....0.32 mm

Shielding required………………………………1 cm acrylic glass (Plexiglas®; Lucite®)

Monitoring method for contamination……….............. wipe survey and LSC analysis

Sanitary sewer release concentration limit…...................…………....$1x10^{-3}$ µCi/ml

Special considerations

- Sulfur-35 is primarily an internal hazard. In addition, skin contact can result in high local doses.
- Exposure from external millicurie (or less) sources ***without contacting*** those materials is low due to the minimal penetration of the outer dead layer of skin.
- Be aware of the vapor pressure of the chemical. Some compounds such as S-35 methionine show significant evaporation upon opening of the container. Heating of S-35 compounds can pose an inhalation hazard. Such activities should be done in a fume hood.
- Surveys for gross levels of contamination may be performed using a Geiger counter. However, a Geiger counter is NOT sensitive enough for the required contamination surveys.

Chromium ^{51}Cr

Radiological half-life, $T_{1/2}$…………………………………………………….27.7 days

Principle emissions……………….……....0.32 MeV gamma (9.8%), 5 keV X-ray (22%)

Exposure rate (1 cm from a point source)…………………………………..180 mR/h per mCi

Annual limit on intake (ALI) by ingestion…………………..…………….……….4x10^4 µCi

Biological monitoring method…………………………..……………...whole body count

Half-value layer…………………………………………………………………3 mm lead

Monitoring method for contamination……….………NaI or other scintillation detector

Sanitary sewer release concentration limit…...………………………….....5x10^{-3} µCi/ml

Technetium ^{99m}Tc

Radiological half-life, $T_{1/2}$……………………………………………………6.02 hours

Principle emission……………………………………………141 MeV gamma (89.1%)

Dose rate (1 cm from a point source)………………………………720 mrad/h per mCi

Annual limit on intake (ALI) by ingestion…………………………….……….8 mCi

Biological monitoring method……………………….…………………..urine samples

Half value layer…………………………………………………….……0.3 mm lead

Monitoring method for contamination……….……………………………..NaI probe

Sanitary sewer release concentration limit…..……………………………....$1x10^{-2}$ μCi/ml

Special considerations

- Tc-99m poses an external and internal hazard.
- Drying can cause airborne Tc-99m dust contamination. Rapid boiling and expelling solutions through syringe needles and pipette tips can generate airborne aerosols.
- A survey meter equipped with a 1" x 1" or a low-energy NaI scintillation probe is preferred for the detection of Tc-99m contamination. Typical counting efficiencies: [1" x 1" NaI probe (39%)] and [low-energy NaI probe (12%-18%)].
- Survey meters equipped with a G-M pancake/frisker (15.5 cm^2 surface area) can be used; however, they exhibit very low counting efficiencies (approximately, 1.2%) for detecting low-energy Tc-99m gamma rays. G-M probes are effective only for gross Tc-99m contamination.
- Indirect counting using a liquid scintillation counter (LSC), gamma counter, or gas proportional counter (GPC) should be used to detect removable Tc-99m contamination on smears, swabs, or swipes.

Iodine ^{125}I

Radiological half-life, $T_{1/2}$……………………………………………………….60 days

Principle emission……………………….35 keV gamma (7%), 27-32 keV X-rays (140%)

Exposure rate (1 cm from a point source)……………………………………..1.4 R/h per mCi

Annual limit on intake (ALI) by ingestion…………….………………….………..40 µCi

Biological monitoring method……………………….……………………thyroid scan

Half-value layer…………………………………………………………….0.02 mm lead

Monitoring method for contamination…………..……NaI or other scintillation detector

Sanitary sewer release concentration limit…..………………………………..2x10^{-5} µCi/ml

Special considerations

- I-125 poses an external and internal hazard. Amounts that enter the body accumulate in the thyroid.

- Bioassays are required when handling >1 mCi carrier-free iodine on the open bench or >10 mCi carrier-free iodine in a fume hood. A thyroid scan must be performed within 24-48 hours after use and the results reported to the Division of Research Safety. Contact the Division of Research Safety before performing such work.

- Reduce unbound fractions of carrier-free iodine as soon as possible with sodium metabisulfate or thiosulfate.

- A survey meter equipped with a thin crystal (low energy) NaI scintillation probe should be used for contamination surveys.

Iodine ^{131}I

Radiological half-life, $T_{1/2}$…………………………………………………..8.05 days

Principle emission……………………………………………..364 keV gamma (81.2%)

Exposure rate (1 cm from a point source)…………………………………..2.0 R/h per mCi

Annual limit on intake (ALI) by ingestion………………….……………..………..30 µCi

Biological monitoring method……………………..…………………thyroid scan

Half-value layer……………………………………………………………0.3 cm lead

Monitoring method for contamination…………..……NaI or other scintillation detector

Sanitary sewer release concentration limit….……………………………...$1x10^{-5}$ µCi/ml

Special considerations

- I-131 poses an external and internal hazard. Amounts that enter the body accumulate in the thyroid. Emission also includes 606 keV beta that can penetrate the dead layer of skin.
- Bioassays are required when handling >1 mCi carrier-free iodine on the open bench or >10 mCi carrier-free iodine in a fume hood. A thyroid scan must be performed within 24-48 hours after use and the results reported to the Division of Research Safety. Contact the Division of Research
- Reduce unbound fractions of carrier-free iodine as soon as possible with sodium metabisulfate or thiosulfate.
- A survey meter equipped with a thick crystal (high energy) NaI scintillation probe should be used for contamination surveys.

12. Abbreviations, Units of Measure, and Detection Efficiency

Abbreviations

ALARA – As Low As Reasonably Achievable
Bq – Becquerel (unit of radioactivity)
Ci – Curie (unit of radioactivity)
cpm – counts per minute
DRS – Division of Research Safety
dpm – disintegrations per minute
GM – Geiger-Mueller
Gy – Gray (unit of absorbed dose)
IEMA – Illinois Emergency Management Agency (formerly Illinois Department of Nuclear Safety (IDNS))
LSC – liquid scintillation count or liquid scintillation counter
mCi – millicurie (unit of radioactivity)
NaI – sodium iodide
µCi – microcurie (unit of radioactivity)
R – Roentgen (unit of exposure)
Rad – radiation absorbed dose (unit of absorbed dose)
Rem – Roentgen equivalent man (equivalent absorbed dose)
Sv – Sievert (equivalent absorbed dose)

Units of Measure

1 microcurie = 2.22 x 10^6 dpm
1 Bequerel = 1 disintegration per second (dps)
1 Ci = 37 GBq = 10^9 disintegrations per second (dps)
1 Gy = 100 rad
1 Sv = 100 rem

Detection Efficiency

To calculate activity from meter or wipe survey results, use:

$$\text{Activity (dpm)} = \frac{\text{(gross count rate – background count rate)}}{\text{instrument efficiency}}$$

Example: The LSC count of a wipe sample was 150 cpm. The background was 30 cpm. Efficiency for H-3 is 67%.

$$\text{Activity (dpm)} = \frac{150\text{ cpm} - 30\text{ cpm)}}{0.67} = 179\text{ dpm}$$

A survey instrument's efficiency can be determined for an individual radionuclide using a known standard (decay-corrected, if necessary) of the radionuclide. The standard is counted in a fixed geometry and the instrument count rate observed. The efficiency is then determined by the formula:

$$\text{Efficiency (\%)} = \frac{\text{(gross count rate – background count rate) x 100}}{\text{Activity of standard (dpm)}}$$