

RADIATION SAFETY MANUAL
FOR
RADIOACTIVE MATERIAL USERS

Environmental Health and Safety

Indiana University

Revision 14

January 2021

EMERGENCY INFORMATION

In the event of an accident involving radioactive material that occurs during regular office hours contact:

- Radiation Safety Officer 855-3230**
- Radiation Safety Office 855-9928**
- MESH Administrative Office 855-9365**
- Environmental Health and Safety 855-6311**

If the accident occurs after hours, contact:

- IU Police 855-4111**

If the accident involves personal injury or fire, immediately call: **911**

PREFACE

The Radiation Safety Manual was prepared by the Radiation Safety Officer as the official guide to the safe use of radioactive materials at Indiana University - Bloomington. The manual presents information and procedures that must be understood and practiced in order to ensure that all uses of radioactive materials at Indiana University - Bloomington are in compliance with existing regulatory requirements and that any resultant radiation exposures are "as low as is reasonably achievable."

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APPENDIX (STANDARD FORMS)24

- (RS-1) Application for Approval as a Principal Investigator in the Use of Radioactive Material
- (RS-2) Application for Individual Use of Radioactive Material
- (RS-3) Radioactive Material Authorization Form
- (RS-4) Radioactive Material Use Log
- (RS-5) Radioactive Contamination Survey

1.0 UNIVERSITY POLICY

It is the policy of Indiana University - Bloomington (IUB) to support the use of radioactive materials for purposes of research and teaching. At the same time, the university is committed to ensuring the safety of its students and employees and to complying with all regulatory requirements that impact its facilities and operations. For this reason, the administration encourages employees and students who work with radioactive materials to promote positive attitudes regarding safety, to incorporate safety into their work practices, and to cooperate fully in the implementation of the campus radiation safety program.

2.0 REGULATORY REQUIREMENTS

Concern over health risks associated with exposure to ionizing radiation led early in its use to recommended exposure limits and, ultimately, to mandatory limits and strict regulatory controls over the possession and use of all sources of ionizing radiation.

Regulatory jurisdiction over radioactive materials varies both with individual states and with the types of materials involved. Most types of radioactive materials in use at IUB are controlled under Title 10 of the Code of Federal Regulations. Compliance with these regulations is enforced through the licensing and inspection activities of the U.S. Nuclear Regulatory Commission (NRC).

Activities involving federally controlled radioactive materials at IUB are conducted under the authority of the university's Type B "broad scope" license with the NRC. This type of license allows the university considerable flexibility in its use of radioactive materials in exchange for the establishment of an appropriate administrative structure and comprehensive program for ensuring safety and regulatory compliance.

3.0 ADMINISTRATIVE ORGANIZATION

In fulfillment of its commitment to personnel safety and regulatory compliance, Indiana University has established specific administrative entities with responsibilities for controlling the use of radioactive materials on the Bloomington campus.

3.1 Radiation Safety Officer (RSO)

The Radiation Safety Officer is a professional staff member who has the responsibility for the administration and operation of the university's radiation safety program. The Radiation Safety Officer establishes and communicates the requirements for the safe use of radioactive materials on campus, reviews and approves all projects involving radioactive materials, and ensures that safety and regulatory requirements are met during the course of such projects. Essential components of the radiation safety program include continuous accountability of radioactive material, radiation safety training, safety audits of laboratories and other facilities, personnel monitoring, and radioactive waste management.

3.2 Department of Environmental Health and Safety

At IUB, the radiation safety program and its support staff are administratively contained within the Department of Environmental Health and Safety (EHS). This department has the responsibility for administering various university safety programs including those that pertain to the research environment. EHS reports to the Executive Vice President for University Academic Affairs.

4.0 AUTHORIZATION PROCESS

All uses of radioactive materials at Indiana University - Bloomington must be specifically authorized by the Radiation Safety Officer (RSO).

An individual who wishes to use radioactive material may seek approval as either a "Principal Investigator" or an "Individual User". The Principal Investigator directs and supervises a project whereas an Individual User works under the supervision of a Principal Investigator.

4.1 Application for Approval as a Principal Investigator

The individual seeking approval as a Principal Investigator begins the authorization process by completing the appropriate application form (see Form RS-1 in the Appendix). This form requests information on the purpose and scope of the project, the facilities and equipment to be utilized, the safety procedures to be observed, the individuals who will work on the project, and the training and experience of the applicant (see Sections 5 and 13 of the Radiation Safety Manual for requirements in these areas). Any supplemental information needed to adequately describe the project should be attached to the application form. Completed copies of Form RS-2 detailing the training and experience of each Individual User on the project must also be submitted.

4.2 Review and Approval of Initial Application

The completed application must be submitted to the Radiation Safety Officer. As part of the application review, the RSO meets at least once with the applicant to discuss various details of the project. Based upon this review, the RSO determines whether authorization is to be granted. If the application is approved, the RSO completes and signs the authorization form (Form RS-3) and forwards it to the Principal Investigator. Any possible conditions under which authorization is granted are specified on the authorization form.

Should approval of a project not be granted, a written notification, which includes an explanation for this decision, is forwarded to the applicant. This notification contains a description of the possible modifications to the project that would be necessary for it to be approved.

4.3 Application to Amend Use

Requests for changes in a Principal Investigator's use of radioactive material, as originally approved by the RSO, must be made in writing to the RSO. Requested changes will be subject to the same review and approval process as was the original application. The Principal Investigator is notified of the approval of a change through an amendment to his or her authorization form (Form RS-3).

4.4 Renewal of Project Authorizations

Each authorization for use of radioactive materials is issued with a formal expiration date. Prior to this date, the Principal Investigator will receive from the RSO a renewal request form that must be completed and submitted in order to reauthorize the project. Most projects involving radioactive material must be renewed on an annual basis.

4.5 Application for Approval as an Individual User

Any person who wishes to be approved as an Individual User of radioactive material must indicate that he or she has completed the required training (see Section 5) by submitting a completed Form RS-2 to the RSO. Note that this application must be approved and signed by the Principal Investigator of the project on which the Individual User wishes to work.

Form RS-2 can be submitted for an Individual User at the time of the Principal Investigator's initial application for project approval or at any time thereafter. The Principal Investigator will be notified of the approval of personnel additions to his or her project through an amended authorization form.

5.0 TRAINING REQUIREMENTS

State and federal regulations require that individuals who work with radioactive material be provided with sufficient training to enable them to conduct their work safely. This training must include information on the potential hazards associated with the use of radioactive material; the means by which these hazards can be minimized; emergency procedures; and institutional procedures for the procurement, use, and disposal of radioactive material.

5.1 General

In order to meet the current regulatory requirements for training, all individuals who wish to use radioactive material at Indiana University - Bloomington must accomplish the following:

1. Attend a Radiation Safety Orientation by the Radiation Safety Officer (contact RSO for information on the next scheduled session).
2. Review training slides on Radiation Safety Procedures (contact RSO for access).
3. Read the *IU Radiation Safety Manual* and other written material provided.
4. Pass a written examination.
5. Complete an "in-lab" performance review of laboratory safety procedures.

5.2 Principal Investigators

In addition to the general training requirements for radioactive material use, an individual who wishes to be authorized as the Principal Investigator (PI) of a project must give evidence that he or she has significant training and experience in the use of radioactive material, including appropriate experience with the specific types and quantities of radioactive material for which approval is requested. When in the judgment of the RSO an applicant has insufficient experience to act as the PI of a project, the applicant may be requested to work under the supervision of an approved PI until sufficient experience is obtained.

5.3 Individual Users

In addition to the general training requirements for radioactive material use, personnel who wish to be authorized as Individual Users must be provided, by the Principal Investigator, safety training appropriate to the particular techniques and materials to be employed.

5.4 Training Records

All relevant training and experience an individual has received prior to his or her application for approval must be documented on the appropriate form (Form RS-1 for Principal Investigators, Form RS-2 for Individual Users). Documentation of training received after approval has been granted is the responsibility of the Principal Investigator.

6.0 PRINCIPAL INVESTIGATOR RESPONSIBILITIES

The individual authorized by the Radiation Safety Officer as the Principal Investigator in the use of radioactive material is responsible for all activities conducted under the scope of that authorization. This includes responsibility for ensuring that:

1. All Individual Users are appropriately trained and supervised.
2. All Individual Users have been formally approved by the RSO.
3. All uses of radioactive materials are as represented in the Principal Investigator's application as approved by the RSO.
4. All rules, regulations, and procedures for the safe use of radioactive materials are observed.
5. Accurate records are maintained of the use, storage, and disposal of radioactive materials and of contamination surveys conducted.
6. The RSO is notified, and has approved, any changes in the storage or use of radioactive material prior to the implementation of such changes.

7.0 EMPLOYEE RIGHTS

Under federal and state regulations, employees who work with radioactive materials have the right to:

1. Be kept informed of the storage, transfer, and use of radioactive materials in the work area.
2. Be instructed in the potential health hazards posed by ionizing radiation and in the appropriate safety precautions for minimizing these hazards.
3. Request an annual summary of their radiation exposure (if they have been monitored with a dosimeter or through bioassay).
4. Report to the RSO any condition that they believe is a violation of state, federal, or university regulations or could cause unnecessary radiation exposure (this is a responsibility as well as a right).

8.0 PROCUREMENT OF RADIOACTIVE MATERIAL

Indiana University - Bloomington is required by the conditions of its NRC license to control the types and quantities of radioactive material that enter and are maintained on campus. This is accomplished through the establishment and observance of various procedures for ordering, receipt, transfer, and inventory of such materials.

8.1 Ordering Radioactive Material

Effective January 1, 2021, all radioactive material orders are placed through the Radiation Safety Office. Contact the Radiation Safety Officer for the procedures for placing an order.

All orders of radioactive material are shipped to:

*Attn: Radiation Safety
Indiana University
Biology Building, Room 071
1001 E. Third Street
Bloomington, Indiana 47405*

8.2 Receipt of Radioactive Material

Upon arrival, radioactive material shipments are checked by a radiation safety staff member for damage and for external contamination. Information regarding the package contents is obtained from the packing slip, entered into an inventory database, and recorded on the "Radioactive Material Use Log" (Form RS-4).

Once package "check-in" procedures have been completed, a radiation safety staff member notifies the intended research group of the shipment's arrival. An Individual User must then come to the Radiation Safety Office, sign for the package, transport the package to the laboratory, complete the procedures described in Section 8.3, sign and date on the indicated lines at the top of Form RS-4, and transfer the package to a secure storage/use area.

8.3 Opening Packages of Radioactive Material

Once a package containing radioactive material is received in the laboratory, it should be opened immediately by an approved user in accordance with the following procedures:

1. Place the package on a bench with absorbent paper at least 2 meters away from any other radiation sources.
2. Turn radiation survey meter on, check it for proper operation, and place it near the package.
3. Remove the Use Log from the external surface of the package.
4. Put on lab coat and disposable gloves.
5. Open package and check labels on inner container and source vial to confirm that the contents are as ordered.
6. Inspect inner container, source vial, and packing materials for evidence of damage or leakage.
7. Monitor package, packing material, and containers for contamination (for H-3 compounds, this must be done through a wipe test analyzed in a liquid scintillation counter).
8. Notify the Radiation Safety Officer immediately of any leakage, contamination, or discrepancies observed for the shipment.
9. Sign and date the top of Form RS-4 on the indicated line.
10. Place the container with source vial of radioactive material in a designated storage location.
11. Deface radioactive labels on outer package and place the empty package and any other materials shown to be free of contamination in normal trash.

8.4 Inventory and Use Records

Each Principal Investigator is responsible for ensuring that accurate records are maintained of the use and storage of radioactive material in his or her possession. Form RS-4 (see Appendix), which accompanies each new shipment of radioactive material, has been developed to assist in this process. The form must be kept up-to-date and returned to the Radiation Safety Officer (along with the associated source vial) once the material has been used or consigned to waste.

9.0 TRANSFER OF RADIOACTIVE MATERIAL

Any transfer of radioactive material between Principal Investigators or between a Principal Investigator and an individual not associated with Indiana University must be approved by the Radiation Safety Officer before the transfer takes place. Requests for transfer approval should be made in the form of a memo to the RSO.

9.1 On-Campus Transfers

Approval of a transfer of radioactive material between individuals on the Indiana University - Bloomington campus (IUB) will depend primarily upon whether the individual who wishes to receive the material is a Principal Investigator with authorization for the type of material to be transferred. Should the proposed recipient for the material not be authorized for its use, he or she may submit an application requesting authorization. Only after authorization has been granted will the RSO approve the transfer of material.

9.2 Off-Campus Transfers

Approval of a transfer of radioactive material to an individual at IUB from an off-campus, non-vendor source will also depend upon whether the proposed recipient has appropriate authorization to possess and use the material. If the transfer is approved by the RSO, the shipper must be instructed to address the package to Radiation Safety/Jordan Hall (see Section 8.1). Upon receipt, the shipment will then be processed in the same manner as are all radioactive materials entering the university.

In order for an individual at IUB to receive approval to transfer radioactive material off-campus, he or she must obtain a copy of the intended recipient's radioactive material license, the name and phone number of the facility's RSO, and the facility's proper shipping address for radioactive material. This information must be submitted with the request for transfer to the RSO. If the license covers the type and quantity of material to be shipped, the RSO will approve the transfer and assist in preparing the package for shipment.

10.0 RADIOACTIVE WASTE MANAGEMENT

The Radiation Safety Officer (RSO) is responsible for ensuring that all radioactive waste generated at Indiana University - Bloomington is managed in accordance with strict federal and state regulatory requirements. Toward this end, the RSO has established various procedures that must be observed by individuals who generate such waste.

10.1 Laboratory Waste Procedures

1. Place only contaminated items in the radioactive waste container. Discard shipment boxes and packing material in normal trash after checking for contamination and defacing any radioactive labels.
2. Deface all radioactive labels on contaminated items prior to placing such items in radioactive waste.
3. Inactivate any viable biological material (e.g., viral/bacterial/recombinant cell structures or animal or human cells/tissues/fluids) before placing items in radioactive waste.
4. Separate radioactive waste by radionuclide and physical form (H-3 and C-14 waste may be combined).
5. Place solid waste in thick plastic bags (appropriate bags are available from Biology and Chemistry stores). Do not use "biohazard" red bags or containers labeled as "biohazardous".
6. Place all "sharps" (including needles, razor blades, capillary tubes, and pipettes) in a puncture proof container.
7. Place all source vials and lead "pigs" in a plastic bag separate from other solid waste.
8. Separate liquid waste according to whether it is aqueous, organic, or flammable. Nonflammable liquids may be placed in glass or plastic containers.
9. Empty cocktail from liquid scintillation counting (LSC) vials into container separate from other liquid waste (screen filters and other solid material from the cocktail). Place empty LSC vials in a plastic bag separate from other solid waste.
10. Place all radioactive animal carcasses, tissues, and blood in plastic bags or containers and freeze in an appropriately posted freezer.
11. Properly seal, and attach a completed waste tag to, each separate item of radioactive waste. Pending transfer for disposal, place radioactive waste items in a designated waste storage area.

10.2 Waste Transfer Procedures

Radioactive material users are responsible for contacting the Radiation Safety Office to arrange for disposal of radioactive waste. The Radiation Safety Office maintains waste collection and storage rooms in certain buildings on campus where radioactive wastes are generated. In some instances, it may be necessary for the radioactive material user to deliver his/her waste to one of these locations at an arranged time. In transporting radioactive waste within buildings, particular care must be taken to ensure that all waste items are properly packaged and secured on a cart (containers of liquids should be placed inside a secondary container). When it is necessary to move radioactive waste between floors, a freight elevator (not a passenger elevator) should be used.

In order to schedule a waste appointment, contact the Radiation Safety Office at 855-9928.

10.3 Disposal Through Sanitary Sewer

Current state and federal regulations allow for the disposal of various aqueous solutions of radioactive material by way of the sanitary sewer. At IUB, radioactive material users may routinely dispose of certain types of radioactive solutions in specifically designated sinks within approved laboratories. A total of up to 500 microcuries of radioactivity consisting of H-3, C-14, P-32, S-35, Ca-45, Cr-51, or I-125 may be disposed of per laboratory per month in this way. Sewer disposal of radioactive material of a type or amount other than that listed above must be approved in advance by the RSO.

The following additional rules apply to disposal by sanitary sewer:

1. All radioactive materials eliminated in this manner must be freely soluble or readily dispersible in water.
2. All materials must be diluted in a dispersant that will not render the radioactive material volatile.
3. Disposal shall be limited to specifically designated drains in areas approved and posted for radioactive material use.
4. Traps must be flushed with large quantities of water during and after entrance of the eliminated material.
5. Appropriate records shall be maintained for all disposal of radioactive materials into the sanitary sewer.

11.0 PERSONNEL EXPOSURES

A primary goal of Indiana University's radiation safety program is to ensure that all personnel exposures are maintained below regulatory limits and "as low as is reasonably achievable."

11.1 Occupational Dose Limits

Current dose limits for occupational radiation exposure have been established at levels which, in light of present knowledge, should: (1) prevent all acute radiation effects (e.g., erythema, epilation); and (2) limit the risks of late effects such as cancer or genetic damage to very low, "acceptable" levels. These limits can be found in Title 10, Part 20 of the Code of Federal Regulations (10 CFR 20). Dose-related terms and limits found in these regulations include the following:

Committed dose equivalent (CDE) - the dose-equivalent to a given organ or tissue that will be received from an intake of radioactive material by an individual during the 50 year period following the intake.

Committed effective dose equivalent (CEDE) - the sum of the products of the risk based weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to these organs or tissues.

Deep-dose equivalent (DDE) - the dose-equivalent resulting from an external whole-body exposure, as determined at a tissue depth of 1 cm.

Effective dose equivalent (EDE) - the sum of the products of the dose equivalent to the organ or tissue and the weighting factors applicable to each of the body organs or tissues irradiated.

Lens dose equivalent (LDE) – the dose equivalent at a tissue depth of 0.3 cm from external exposure to the lens of the eye.

Shallow-dose equivalent (SDE) - the dose-equivalent resulting from an external exposure of the skin, as determined at a tissue depth of 0.007 cm.

Total effective dose equivalent (TEDE) - the sum of the effective dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).

Table 1. Dose Equivalent Limits for Occupational Exposures

| | Annual |
|--|---------------|
| Whole body (TEDE) | 5 rem |
| Skin and extremities (SDE) | 50 rem |
| Individual organ or tissue (DDE + CDE) | 50 rem |
| Lens (LDE) | 15 rem |

In addition to specific dose equivalent limits, 10 CFR 20 contains derived "annual limits on intake" (ALIs). These represent the smaller activity value which, if taken up by the body during the course of a year (in either single or multiple events), would result in the individual receiving a committed effective dose equivalent of 5 rem or a committed dose equivalent of 50 rem to any single organ or tissue. Table 2 lists ALIs for some commonly used radionuclides.

Table 2. Annual Limits on Intake (ALI) for Ingestion of Selected Radionuclides

| Radionuclide | ALI (mCi) |
|---------------------|------------------|
| H-3 (water) | 80 |
| C-14 | 2 |
| P-32 | 0.6 |
| S-35 | 6 |
| Ca-45 | 2 |
| I-125 | 0.04 |

11.2 Dose Limits for an Embryo/Fetus

Because of their increased susceptibility to radiation damage, the human embryo or fetus may receive a dose of no more than 500 mrem. This is generally accomplished by limiting the total effective dose equivalent of a "declared" pregnant worker to 500 mrem over the course of her pregnancy. However, for this lower limit to be in effect, the worker must voluntarily declare her pregnancy in writing to the RSO. The Nuclear Regulatory Commission has published Regulatory Guide 8.13 that details potential health risks of prenatal exposure and suggests precautions and options for the pregnant worker. Copies of Regulatory Guide 8.13 may be obtained from the RSO.

11.3 Dose Limits for Members of the Public

Under current federal regulations (10 CFR 20), the total effective dose equivalent to any member of the general public from licensed activities must be limited to 100 mrem per year. This is in addition to the 300 mrem/person/year received, on average, by individuals in the United States from natural background radiation and the 300 mrem/person/year received, on average, from medical exposures.

12.0 PERSONNEL MONITORING

Various devices and methods exist for assessing an individual's dose from exposure to ionizing radiation. Whether or not one or more of these personnel monitoring methods is employed for a given situation will depend upon such factors as the type and quantity of radioactive material used, the way in which the material is used, and the duration of use.

12.1 Personnel Dosimeters

Federal regulations (10 CFR 20) require that any individual who is likely to receive, from external sources, more than 10 percent of an applicable dose limit be monitored for radiation exposure. Devices or materials used to assess an individual's cumulative dose from external sources are collectively called "dosimeters."

A commonly used dosimeter is the thermo-luminescent dosimeter (TLD). This consists of a small chip of material (e.g., LiF or CaF₂), which, when heated after an exposure to penetrating radiation, gives off light in proportion to the dose received. TLDs are used both in body badges and within rings to assess hand and finger doses to individuals handling relatively large quantities of energetic beta or gamma emitting radionuclides. More recent dosimeter technology relies upon "optically stimulated" materials such as aluminum oxide that are stimulated with lasers to give off light in proportion to their previous exposure to ionizing radiation. Body dosimeters and rings are generally exchanged on a quarterly basis.

At IUB, "whole body" monitoring is required for any individual who, in any one experiment, works with 10 mCi or more of P-32, 5 mCi or more of I-125 or Cr-51, or 1 mCi or more of any energetic gamma ray emitter. Extremity monitoring (i.e. ring badge) is required for any individual who, in any one experiment, works with 1 mCi or more of P-32 or 1 mCi or more of any gamma emitting nuclide.

In order for a dosimeter to provide an accurate indication of an individual's exposure, it must be used and stored properly. For assessing whole body doses, the dosimeter should be worn on some area of the torso such as a breast pocket, lapel, or belt. Ring badges should be worn beneath gloves with the sensitive surface on the palm side of the hand. When not in use, dosimeters must be stored away from radiation sources and under conditions of relatively stable temperature and humidity.

12.2 Bioassays

Federal regulations also require that individuals likely to exceed 10 percent of the applicable annual limit on intake be monitored for internal irradiation. Assessing internal irradiation from intakes via ingestion, inhalation, or dermal puncture or absorption is accomplished through the use of various procedures collectively termed "bioassays." For many water soluble compounds labeled with beta emitters (e.g., H-3, C-14), the bioassay consists of analyzing the amount of radioactivity in a sample of urine. For radioiodines, internal irradiation is assessed by using a low-energy gamma ray probe to measure the amount of radiation being emitted from the thyroid.

In general, urine analyses are performed by the Radiation Safety Officer only for unusual situations such as accidents involving potential radionuclide intake or for certain experimental procedures where ingestion or inhalation of radionuclides is likely. Thyroid bioassays, on the other hand, are conducted routinely for all individuals performing radioiodinations.

12.3 Personnel Exposure Records

The results of all personnel monitoring performed for individuals working with radioactive material or other sources of ionizing radiation at IUB are maintained on file by the RSO. Each individual's exposure records are available to him or her upon request. An individual is notified immediately by the RSO should his/her reported dose for a particular monitoring period appear to be excessive.

13.0 LABORATORY SAFETY

The potential hazards associated with working with radioactive materials can be minimized through the use of appropriate facilities and equipment and by observing standard safety rules and practices.

13.1 Facility Requirements

The majority of research laboratories at Indiana University can be classified as chemical-use laboratories. These laboratories are generally adequate for most radiotracer uses. For certain types and uses of radioactive materials, however, additional facility requirements must be met. The specific requirements, which will vary from one situation to another, are determined by the Radiation Safety Officer.

The following are minimum facility requirements for use of radioactive materials:

1. Floors must have smooth, nonporous, easily cleaned surfaces. Appropriate floor materials include vinyl, tile and sealed concrete.
2. Benches must have nonporous, easily decontaminated surfaces. Surfaces of high quality plastic laminate or stainless steel are preferable.
3. Sinks should be stainless steel or of seamless molded construction.
4. Hoods (when required) must be currently certified fume hoods, preferably of stainless steel or molded fiberglass construction.
5. The room's ventilation rate should be 5 to 7 air changes per hour. The actual rate required will vary with the potential for radionuclide release to the air within the particular laboratory.
6. Structural shielding shall be provided when appropriate (e.g., for facilities in which large quantities of radionuclides emitting penetrating radiations are used). Specific requirements will be determined by the Radiation Safety Officer on a case-by-case basis.

13.2 Requirements for Equipment and Supplies

Laboratories in which radioactive materials are to be used must have the following basic equipment and supplies:

1. Absorbent paper and spill trays for establishing bench-top work areas for radioactive material use.
2. A portable radiation survey meter for performing contamination surveys (this is not required for laboratories in which only H-3 is used).
3. Access to a liquid scintillation counter for analyzing wipes from contamination surveys.
4. A portable beta-shield (for laboratories in which quantities of 1 mCi or more of P-32 are routinely used).
5. Appropriate containers for solid and liquid radioactive waste.
6. Personal protective apparel (e.g., lab coats and disposable gloves).
7. Radioactive material warning tape for marking contaminated areas or equipment.
8. Appropriate absorbent materials and cleaning supplies for spill control and decontamination (located within the work area for easy access).

13.3 General Rules for the Safe Use of Radioactive Materials

Radioactive material users can ensure that exposures to ionizing radiation are maintained "as low as is reasonably achievable" by observing the following standard safety rules:

1. Do not eat, drink, smoke, or apply cosmetics in areas where radioactive materials are used or stored.
2. Do not store food or use food containers in areas where radioactive materials are used or stored.
3. Wear protective clothing when working with radioactive material. This includes laboratory coat, gloves, safety goggles and appropriate footwear (sandals are prohibited).
4. Clearly designate radionuclide work areas (e.g., with "Caution-Radioactive Material" tape) and, to the extent possible, isolate these areas from the rest of the laboratory.
5. Cover work surfaces with absorbent paper and change the paper frequently. Use a spill tray when working with relatively large volumes of liquids.
6. Wear appropriate personnel monitoring device (e.g., body or ring dosimeter) if required.
7. Carefully plan procedures involving radionuclides and, when possible, practice them in advance using non-radioactive materials.
8. Do not mouth pipette radioactive solutions.
9. Label materials known to be, or suspected of being, contaminated with appropriate "Caution Radioactive Material" tape or tag.
10. Dispose of contaminated items in receptacles specifically designated for radioactive wastes.
11. Monitor hands, clothing, and work area for contamination after each procedure or before leaving the laboratory.
12. Maintain accurate records of the use, storage, and disposal of radioactive materials in the laboratory and of contamination surveys conducted.

13.4 Contamination Survey Procedures

Radioactive material users are required to monitor themselves and their work areas for contamination after each procedure involving radioactive material, or before leaving the laboratory (see item 11 in Section 13.3). For a laboratory in which only high energy beta or gamma emitting radionuclides are in active use, the contamination survey may consist of either direct monitoring with an appropriate survey meter (e.g., thin-window GM for P-32) or a wipe test. For a laboratory in which low to medium energy beta emitting radionuclides such as C-14 or S-35 are used, the survey should include a wipe test (a wipe test is the only method capable of detecting H-3).

Meter surveys are used to assess the "total" contamination present. In performing such surveys, the probe must be moved slowly and in close proximity (1 cm) to the surface being checked. Any surface whose count rate exceeds three times the background count rate of the meter will be considered contaminated. The surface must be decontaminated (see section 13.7) until it can be shown through a wipe test or direct monitoring that the contamination is less than the allowable limits (see Table 3).

Wipe tests are used to assess "removable" contamination and involve "wiping" surfaces with a small piece of absorbent paper (or other suitable material). The wipe sample is then analyzed in an appropriate counting system, generally a liquid scintillation counter (LSC). The data readout of the LSC will typically be in "cpm" (counts per minute). Conversion to "dpm" (disintegrations per minute) is accomplished by dividing the "net cpm" value (sample cpm value minus the background cpm value) by the efficiency of the LSC for the particular radionuclide (e.g., 0.5 for H-3).
$$[\text{Sample (cpm)} - \text{BKG (cpm)}] / \text{Effic.} = \text{Sample (dpm)}$$

13.5 Survey Records

The inventory form that accompanies each radioactive material shipment (Form RS-4) includes a column for recording the completion of "end-of-procedure" contamination monitoring. In addition, Form RS-5 has been developed as a means for researchers to document more comprehensive contamination surveys of the laboratory. This form (or its equivalent) should be completed with the date of the survey, the name of the individual performing the survey, the type of survey (e.g., direct meter/wipe), the areas surveyed, and the results (see Form RS-5). In most cases, the frequency of completion of recorded surveys for the laboratory is at the discretion of the Principal Investigator.

13.6 Notification of Contamination

The Radiation Safety Officer (RSO) must be notified immediately upon the discovery of any personnel contamination or of extensive laboratory contamination (e.g., numerous locations or a single location reading greater than ten times the background count rate). The RSO must also be notified immediately if a decontamination effort does not successfully reduce surface contamination levels below the prescribed limits.

13.7 Decontamination Procedures

Radioactive material users are responsible for decontaminating any surfaces or equipment within the laboratory found to be contaminated with radioactive material. This may be accomplished by following these general procedures:

1. Monitor the affected surfaces with a survey instrument and wipes to define the extent of contamination.
2. Mark the perimeter of the contaminated area.
3. Assemble cleaning supplies such as paper towels, cleaning solutions, plastic bags, and disposable gloves.
4. Put on protective apparel (i.e., lab coat and gloves).
5. Proceed with scrubbing the area from the borders to the center, cleaning small areas at a time (do not use a scrub brush).
6. Periodically monitor the effectiveness of the decontamination effort with wipes and instrument surveys (see Table 3 for contamination limits).
7. Place all contaminated cleaning materials such as paper towels, rags, and gloves in a plastic bag and label as radioactive waste.

Table 3. Limits of Radioactive Contamination within Radionuclide Laboratories.

| Contamination Type | Limit |
|-----------------------------|-----------------------------|
| Removable alpha (wipe) | 20 dpm/100 cm ² |
| Removable beta/gamma (wipe) | 200 dpm/100 cm ² |
| Alpha (direct measure) | Non-detectable |
| Beta/gamma (direct measure) | 3 x BKG cpm at 1 cm* |

* Reading from a thin-window GM survey instrument with beta shield open. Direct measure readings higher than three times background are acceptable only if the removable levels have been shown by a wipe test to be less than 200 dpm/100 cm².

13.8 Laboratory Posting

The entrances to laboratories in which radioactive materials are used or stored are posted with appropriate warning signs. In most cases, the sign will include the purple or black propeller symbol on a field of yellow and the words, "Caution-Radioactive Material". The sign may also contain the names and phone numbers of individuals to be contacted in the event of an emergency.

13.9 Security and Control of Radioactive Material

All radioactive material must be secured from unauthorized access or removal. Toward this end, doors to the laboratory must be locked or radioactive material must be secured in lockable storage whenever the laboratory is unattended. Control of radioactive material also implies that radioactive material users will maintain surveillance over radioactive material in use and confront any unauthorized personnel who enter the laboratory. The Radiation Safety Officer must be notified immediately upon the discovery that any radioactive material is missing.

13.10 Laboratory Audits

Radiation safety staff members conduct periodic audits of all locations where radioactive materials are stored or used. The frequency of audits ranges from bi-weekly to annually depending upon the types, quantities, and uses of radioactive materials. Each audit includes a contamination survey, a review of safety procedures, and a check of inventory and survey records. Any problems encountered during the audits are discussed with appropriate laboratory personnel and, when warranted, with the Principal Investigator.

The periodic contamination surveys conducted by radiation safety staff in no way relieve radioactive material users from their responsibility to survey personnel and work areas for contamination at the end of each radionuclide procedure.

14.0 EMERGENCY PROCEDURES

Despite the strict observance of all laboratory safety rules, it is likely that accidents involving radioactive material will occur. For this reason, it is important that radioactive material users are aware of the proper procedures to follow for various types of accidents.

14.1 Minor Spills

An incident involving the release or spillage of less than one millicurie of a radionuclide in a nonvolatile form can generally be regarded as minor. In such cases:

1. **Notify** persons in the area that a spill has occurred.
2. **Confine** the spill by covering with absorbent paper.
3. **Monitor** hands, shoes, and clothing for contamination.
4. **Report** the incident to the Radiation Safety Officer and to the laboratory supervisor.
5. **Clean up** spill and initiate decontamination procedures.

14.2 Major Spills or Releases

An incident, which occurs outside of the hood and involves the release of a radionuclide in a volatile form or the release of one millicurie or more of a radionuclide in any form, should be considered major. In such cases:

1. **Notify** persons in the area that a spill has occurred.
2. **Evacuate** the room, shutting doors on the way out.
3. **Monitor** hands, shoes, and clothing for contamination.
4. **Notify** the Radiation Safety Officer and lab supervisor.
5. **Post** the laboratory door with a "Keep Out" sign.
6. **Assemble** those persons involved near the laboratory entrance and await assistance.

14.3 Accidents Involving Personal Injury

For any accident in which a person requires medical attention, the first priority for other laboratory personnel is to assist that individual in getting such attention. This may involve administering first aid and/or calling for emergency medical assistance. Once this has been accomplished, the previously described procedures for contamination control should be followed as appropriate.

**APPENDIX
(STANDARD FORMS)**