

DEPAUL UNIVERSITY

# Radiation Safety Manual

---

Environmental Health & Safety

July 2016

---

**TABLE OF CONTENTS**

<b>SECTION</b>	<b>PAGE NO.</b>
<b>1. INTRODUCTION .....</b>	<b>1-1</b>
1.1 Purpose .....	1-1
1.2 Scope and Application.....	1-1
<b>2. REGULATORY REQUIREMENTS .....</b>	<b>2-1</b>
2.1 Radioactive Materials .....	2-1
2.2 Radiation-Producing Devices .....	2-1
2.3 Servicing Equipment .....	2-1
2.4 Generator Fees.....	2-2
<b>3. ROLES AND RESPONSIBILITIES .....</b>	<b>3-2</b>
3.1 Radiation Safety Committee .....	3-2
3.2 Radiation Safety Officer .....	3-2
3.3 Environmental Health & Safety (EHS) Office.....	3-2
3.4 Public Safety Department .....	3-2
3.5 Principal Investigator .....	3-2
3.6 Individual User .....	3-3
<b>4. AUTHORIZATION PROCESS .....</b>	<b>4-3</b>
4.1 Application for Initial Use.....	4-3
4.1.1 Information on User(s).....	4-3
4.1.2 Project Description.....	4-3
4.1.3 Facility Requirements and Description .....	4-4
4.2 Review and Approval .....	4-5
4.3 Amendments.....	4-5
<b>5. TRAINING .....</b>	<b>5-5</b>
5.1 Initial Training .....	5-5
5.1.1 RAM and RPD Users .....	5-5
5.1.2 Principal Investigators.....	5-5
5.1.3 Other Departmental Personnel.....	5-6
5.2 Refresher Training.....	5-6
<b>6. PROCUREMENT, RECEIPT AND TRANSFER OF RADIOACTIVE MATERIALS.....</b>	<b>6-6</b>
6.1 Ordering Radioactive Materials .....	6-6
6.2 Receipt of Radioactive Materials .....	6-6
6.3 On-Campus Transfers of RAM.....	6-6
<b>7. USE, SURVEYS AND STORAGE OF RADIOACTIVE MATERIALS .....</b>	<b>7-7</b>
7.1 Usage.....	7-7
7.2 Radiation Surveys.....	7-8
7.3 Storage .....	7-8
<b>8. OCCUPATIONAL EXPOSURES AND MONITORING .....</b>	<b>8-1</b>
8.1 Personnel Exposure Limits .....	8-1
8.1.1 Occupational Dose Limits.....	8-1
8.1.2 Annual Limits on Intake.....	8-2
8.1.3 Regulatory Dose Limits to Declared Pregnant Workers.....	8-2

8.2	Personnel Monitoring .....	8-2
8.2.1	Dosimeters .....	8-2
8.2.2	Bioassays .....	8-3
8.2.3	Recordkeeping and Reporting.....	8-3
8.2.4	ALARA Reviews.....	8-3
<b>9.</b>	<b>RADIOACTIVE WASTE .....</b>	<b>9-1</b>
9.1	Radioactive Waste Management .....	9-1
9.2	Radioactive Waste Minimization .....	9-1
<b>10.</b>	<b>REMOVING EQUIPMENT, VACATING SPACE AND ABANDONED MATERIAL .....</b>	<b>10-2</b>
10.1	Removal of Laboratory Equipment .....	10-2
10.2	Vacating Laboratory Spaces .....	10-2
10.3	Radioactive Contamination and Abandoned Radioactive Materials .....	10-2
<b>11.</b>	<b>SPILL AND EMERGENCY PROCEDURES .....</b>	<b>11-2</b>
11.1	Minor Spill and Contamination .....	11-2
11.2	Decontamination Procedures .....	11-3
11.3	Major Spills and Contamination.....	11-3
11.4	Accidents Involving Personal Injury or Exposure .....	11-4
<b>12.</b>	<b>RECORDKEEPING .....</b>	<b>11-4</b>
12.1	Recordkeeping Requirements.....	11-4

#### LIST OF TABLES

<b>TABLE</b>	<b>PAGE NO.</b>
Table 1. Annual Occupational Dose Limits for Adult Workers.....	8-1
Table 2. Limits of Radioactive Contamination on Surfaces or Items to Be Released for Unrestricted Use .....	11-3

#### APPENDICES

Appendix A:	Contamination Surveys
Appendix B:	Characteristics of Common Radioisotopes
Appendix C:	Forms
Appendix D:	Abbreviations, Conversions, Formulas & Examples
Appendix E:	Glossary
Appendix F:	Program History

---

## **ACKNOWLEDGEMENTS**

This Radiation Safety Manual was developed by the DePaul University Environmental Health and Safety (EHS) Office using best practice examples from the University of Iowa, Princeton University and the University of Illinois at Urbana-Champaign as well as Federal and State regulations and guidance documents. The manual was reviewed and revised by consultant, Woodard & Curran, as well as the DePaul University Radiation Safety Officer, Dr. John Dean.

---

## **1. INTRODUCTION**

### **1.1 PURPOSE**

This manual describes the policies and procedures of DePaul University for the control of all sources of, and exposures to, ionizing radiation that are within the jurisdiction of the University. Possession and use of radioactive materials and sources at the University must be in accordance with all applicable Federal, State and University requirements. The manual defines responsibilities of individuals and departments for radiation control, establishes general safety rules and procedures, and is intended to help satisfy regulatory requirements related to the possession and use of radioactive materials and sources for authorized University research and teaching activities. Where applicable, additional requirements and procedures will be developed, implemented and enforced as necessary to implement the overall philosophy and policies for radiation protection and for keeping doses as low as reasonably achievable (ALARA).

### **1.2 SCOPE AND APPLICATION**

This manual applies to all departments that possess radioactive materials and sources, as well as to all individual radiation users and others who may be exposed to ionizing radiation as a result of authorized University research and teaching activities. Certain individuals and departments play a supporting role in radiation control and program management. Individuals covered under this program will be informed of the applicable program requirements and of their individual responsibilities, and will be provided with training as appropriate based on his/her job duties.

## **2. REGULATORY REQUIREMENTS**

### **2.1 RADIOACTIVE MATERIALS**

Strict regulatory controls have been established for the possession and use of radioactive materials (RAM). The primary regulatory authority for most types and uses of RAM is the federal Nuclear Regulatory Commission (NRC); however, many states, including Illinois, have entered into agreements with the NRC to assume regulatory control of radioactive material use within their borders. As part of the agreement process, Illinois has adopted and must enforce regulations [see 32 Ill. Adm. Code Ch. II, Subchapters b and d] comparable to those found in Title 10 of the Code of Federal Regulations.

For most situations, the types and maximum quantities of RAM possessed, the manner in which they may be used, and the individuals authorized to use RAM are stipulated in the form of a “specific” license from the appropriate regulatory authority. In Illinois, this authority is issued by the State of Illinois, Illinois Emergency Management Agency, Division of Nuclear Materials (IEMA). The license for DePaul University has been issued by the IEMA as Illinois License No. IL-01277-01.

### **2.2 RADIATION-PRODUCING DEVICES**

Radiation producing equipment must be inspected annually. Inspections will be performed by Illinois Emergency Management Agency; the Environmental Health & Safety Office will pay all fees. The Radiation Safety Officer must be informed if equipment because non-operational and/or operational.

### **2.3 SERVICING EQUIPMENT**

Survey instruments must be calibrated annually. The calibrations will be performed by Standard Nuclear Consultants, Inc.; the Environmental Health & Safety Office will pay all fees. The Radiation Safety Officer must be informed whenever a new instrument is purchased, after significant repair or other calibration has been done.

---

## **2.4 GENERATOR FEES**

Non-Reactor Generator fees are to be paid annually. Fees will be paid to Illinois Emergency Management Agency; Division of Nuclear Safety. The Environmental Health & Safety Office will pay all fees.

## **3. ROLES AND RESPONSIBILITIES**

### **3.1 RADIATION SAFETY COMMITTEE**

DePaul University has established a Radiation Safety Committee (RSC) to establish and review university policy for the safe use of Radioactive Materials (RAM) and Radiation Producing Devices (RPD) on campus. In addition, the RSC reviews all requests for use of RAM and RPDs, performs periodic audits and program reviews, and decides whether authorization is to be granted. The Committee typically consists of two to three university personnel, including the Radiation Safety Officer (RSO) and a representative from the Environmental Health & Safety (EHS) Office.

### **3.2 RADIATION SAFETY OFFICER**

The Radiation Safety Officer (RSO) is the individual who has the responsibility for the day-to-day administration and operation of the university's radiation safety program. This individual is also a permanent member of the RSC.

### **3.3 ENVIRONMENTAL HEALTH & SAFETY (EHS) OFFICE**

The EHS Office has the responsibility for managing all University health and safety programs and works with the RSO in developing, implementing, and periodically reviewing the radiation safety program.

### **3.4 PUBLIC SAFETY DEPARTMENT**

The Public Safety Department provides for overall emergency response communication and coordination, and can assist in notification of appropriate response personnel and establishment of necessary communications links in the event of an emergency involving ionizing radiation.

### **3.5 PRINCIPAL INVESTIGATOR**

The individual authorized by the RSC as the Principal Investigator (PI) on a project involving the use of RAM or RPDs is responsible for all activities conducted under the scope of that authorization. The PI has the responsibility for ensuring that:

- All individuals working on the project have been formally authorized by the RSO, and are appropriately trained and supervised.
- Rules, regulations and procedures for the safe use of RAM or RPDs are observed on the project.
- An accurate record of the types, quantities and locations of RAM or RPDs in his/her possession is maintained.
- The RSO is notified of any proposed changes in the storage or use of the RAM or RPDs prior to the implementation of such changes.
- All uses of radiation are periodically evaluated to further reduce exposures to individuals (i.e., ALARA), and procedures for using RAM or RPDs are current and accurate.
- All radioactive sources or source material are secure from unauthorized access or removal.

---

### **3.6 INDIVIDUAL USER**

The individual user of RAM or RPDs is ultimately responsible for its safe, compliant use and must:

- Be familiar with the nature of all radiation sources in the work area and the potential risks.
- Follow the applicable provisions of this manual, the radiation safety training program, and other applicable procedures in order to keep his/her personal exposure as low as reasonably achievable (ALARA).
- Participate in all required training.
- Wear the necessary personal protective equipment, as well as any personnel monitoring devices if assigned.
- Monitor the work area frequently for contamination and document the results.
- Clean up minor spills immediately. Report spills and personal contamination to the PI and RSO.
- Dispose of radioactive waste as instructed and in an approved manner.
- Ensure that all sources, containers, and work areas are properly labeled or posted.
- Prevent unauthorized access to RAM and RPDs.
- Do not allow maintenance or repairs of potentially contaminated laboratory equipment or areas unless surveyed, cleaned and re-surveyed as necessary, and approved by the PI and the RSO.
- Notify the PI and RSO of any questions, concerns or potential difficulties related to the safe use of RAM or RPDs.

## **4. AUTHORIZATION PROCESS**

### **4.1 APPLICATION FOR INITIAL USE**

Each new project involving the use of radioactive material or radiation producing devices must be specifically authorized by the RSC. The individual who is to be in charge of the project, referred to as the Principal Investigator (PI), must complete an Application for Use of Radioactive Materials and Devices (Appendix C-1) and submit it to the RSO, who will coordinate the review by the RSC. The application must include detailed information in three general categories: Information on the user(s), a project description and a facility description.

#### **4.1.1 Information on User(s)**

In order to ensure that individuals working with RAM and RPDs have the proper qualifications, the application must outline the following information:

- Personal – Name, department, PI, major field, university address and phone number.
- Education and training – Title and credit hours of any course taken in nuclear science, radiation safety or radionuclide use; an indication of whether DePaul University Radiation Safety Training Program has been completed (including the completion date).
- Laboratory experience – Duration of experience, type and quantity of radionuclides used, the specific experimental procedures employed, procedures followed for laboratory safety and waste handling.

#### **4.1.2 Project Description**

The application must provide a basic description of the proposed new project involving RAM or RPDs, including the following items as applicable:

- 
- Scope of project: Purpose and experimental procedures to be used.
  - Radionuclides: Isotopes, form and amount.
  - Radiation-producing devices: Type and energy of radiation to be produced.
  - Radiation levels: Levels expected in the facility and in neighboring areas; potential for release of RAM.
  - Equipment – Assay, monitoring and dosimetric instruments available or needed; procedures for using these instruments.
  - Safety procedures – General, monitoring, waste handling.
  - Records – Receipt, use and disposal of radioactive material; radiation surveys, and other records.
  - Radioactive waste – Amounts generated per experiment, per month or year, and types of solids and liquids generated per experiment; building and rooms where waste will be collected.

#### **4.1.3 Facility Requirements and Description**

The laboratory or other facility must meet certain basic requirements in order to be used for work with radioactive materials or RPDs. For certain types and uses of RAM, additional facility requirements may apply. The specific facility requirements will be determined by the RSO. General facility design requirements for use of RAM may include:

- Floors must have smooth, nonporous, easily cleanable surfaces (e.g., vinyl, tile, sealed concrete).
- Benches must have nonporous, easily decontaminated surfaces. Surfaces of high-quality plastic laminate or stainless steel are preferable.
- Sinks should be stainless steel or of seamless molded construction.
- Hoods, when required, must be currently tested and certified by Facilities Operations, and preferably constructed of stainless steel or molded fiberglass.
- The ventilation rate for the laboratory should be 5 to 10 air changes per hour. The actual rate required will vary with the potential for radionuclide release to the air within the particular laboratory.
- Shielding must be provided when necessary (i.e., for laboratories using large quantities of gamma or high-energy beta-emitting radionuclides).

As part of the authorization process, determination of facility suitability includes a review of:

- Location of use – Building, floor, room number, department.
- Room plan drawing:
  - a. Radionuclide facility: Locations of hoods, sinks, benches, exterior/interior walls, windows, doors, intended use and storage areas.
  - b. Radiation (machine) facility: Location of radiation source, exterior/interior walls, windows, doors, shielding and direction of primary beam.
  - c. Construction materials: Floors, bench tops, hoods and sinks.
  - d. Ventilation: Air exchange rate for the laboratory and the number and type of hoods or glove boxes.
  - e. Radiation safety equipment: Shielding, waste containers, trays, absorbent paper, spill kit, type of survey meter or counting equipment.
  - f. Occupancy of facility and adjacent areas: Use of facility by individuals not approved for radionuclide work and use of areas adjacent to the facility.

---

## **4.2 REVIEW AND APPROVAL**

The completed application must be submitted to the RSO, where it will receive an initial review. At this time, the RSO may require additional information from the applicant. If the application appears to be adequate, the RSO prepares and signs a Radioactive Material Use Authorization (Appendix C-1). This is then forwarded to the RSC for final approval.

If the application is approved, the RSC signs the authorization form and returns it to the RSO where it is forwarded to the PI. Any conditions under which authorization is granted are also specified on the authorization form (e.g., if an individual requires radiation safety training prior to use/access). If approval is denied, a written notification is forwarded to the PI that includes an explanation for this decision and, where applicable, a description of the possible modifications to the project necessary to obtain approval.

## **4.3 AMENDMENTS**

Approval for any modifications to a PI's original authorized use of RAM or RPDs may be requested from the RSO in either written or electronic form (i.e., via an amended application or e-mail request). Minor changes, such as additional personnel or changes in location may be reviewed and approved by the RSO where appropriate. More extensive changes will be reviewed and approved by the RSC.

## **5. TRAINING**

### **5.1 INITIAL TRAINING**

Current state and federal regulations require that individuals working with sources of ionizing radiation be provided with appropriate training prior to beginning work with such materials or devices. In addition to the core laboratory training requirements, such as those specified in DePaul University's Chemical Hygiene Manual, specific radiation safety training is required prior to using RAM or RPDs.

#### **5.1.1 RAM and RPD Users**

All individuals using RAM at DePaul University must possess a basic understanding of ionizing radiation and its potential hazards, as well as knowledge of the particular rules and regulations governing the applicable radioactive material(s) or device(s). In order to accomplish this objective, the EHS Office coordinates radiation safety training and maintains training records for individuals seeking initial authorization for use of RAM or RPDs. Individuals will not be authorized to use RAM or RPDs until they have satisfactorily completed the appropriate training program.

In the addition, the PI is responsible for ensuring that all users of RAM or RPDs are provided with any additional, more specific training as necessary on the potential risks and radiation control procedures for the project and/or individual experiment.

#### **5.1.2 Principal Investigators**

In addition to the general training requirements for radiation safety, an individual desiring authorization as the PI on a project must also provide evidence that he/she has appropriate experience with the types and quantities of radionuclides to be used. When, in the judgment of the RSC, an applicant has insufficient experience to act as the PI on a project, the applicant may be advised to work under the supervision of another approved PI until sufficient experience is obtained.

---

### **5.1.3 Other Departmental Personnel**

Any departmental personnel that may be involved in the receipt of radioactive materials will be instructed by the RSO (or other authorized PI) in the safe handling and temporary storage of incoming packages.

## **5.2 REFRESHER TRAINING**

Users of radioactive materials must be provided with annual refresher training.

## **6. PROCUREMENT, RECEIPT AND TRANSFER OF RADIOACTIVE MATERIALS**

### **6.1 ORDERING RADIOACTIVE MATERIALS**

The RSO must approve or place all orders for radioactive material and must ensure that the requested material and quantities are authorized by the license and that possession limits are not exceeded.

### **6.2 RECEIPT OF RADIOACTIVE MATERIALS**

Licensed material ordered by an individual user will be received in the departmental office (Biological Sciences). Packages containing radioactive materials will not be accepted when the departmental office is closed (after 5:00 PM weekdays and on weekends).

The material will be held in the office until the RSO and/or designated authorized user:

- a. is notified of its arrival,
- b. checks the packing slip against the actual package contents and the amount of material actually ordered, and
- c. Personally examines the package for external indications of damage, leakage, tampering, or any significant abnormality.

The RSO or a designated authorized user must be available to receive the order at the time of delivery. In the event that the office personnel cannot locate the RSO and/or an authorized user, then the office personnel will place the radioactive materials in a locked room (McGowan 210) to ensure that the material will be secured from unauthorized access after receipt and prior to any distribution to other authorized PIs/users.

Departmental personnel involved in the receipt of radioactive materials must be instructed in the safe handling and temporary storage of incoming packages, as well as to immediately notify the RSO and/or other authorized PI on receipt of a package showing external indications of damage, leakage, tampering, etc. In addition, in such an event, the office personnel will attempt to detain the delivery person pending an examination of the individual and his/her vehicle for contamination; and/or will notify appropriate authorities such as police, security, and carrier, etc.

After the package has been checked by the RSO or other designated authorized user for leaking or contamination, the results of the survey along with the serial number of the survey instrument must be recorded. The departmental laboratory coordinator will apply or provide a label to enter the container into the University's electronic chemical inventory system.

### **6.3 ON-CAMPUS TRANSFERS OF RAM**

Approval to transfer radioactive material between individuals at DePaul University will depend primarily upon whether the PI receiving the material has been authorized for the type and quantity of radioactive material

---

involved and for the specific procedure(s) in which it is to be used. The authorized individual will be allowed to transfer the material only after authorization has been granted by the RSO.

Whenever radioactive material is transported from one laboratory to another, the RSO must be notified and provided with the following information:

- when the material will be moved
- the names of the person(s) sending and receiving the material
- the sending and receiving locations
- the isotope(s) being moved
- the chemical form of the isotope
- the total activity in millcuries (mCi) or Becquerels (Bq)
- number of containers
- phone numbers of responsible person(s)
- any special conditions

The RSO will work with the departmental laboratory coordinator(s) to ensure that the chemical inventory system is updated for both laboratories.

## **7. USE, SURVEYS AND STORAGE OF RADIOACTIVE MATERIALS**

### **7.1 USAGE**

In order to maintain exposures to ionizing radiation ALARA, the following general procedures, practices and rules have been established for usage of RAM:

- Smoking, eating or drinking, as well as food, beverages and their containers, are not permitted in radionuclide laboratories. Pipetting by mouth is prohibited.
- Security of radioactive material, sources, samples and waste must be maintained at all times to prevent unauthorized removal or tampering.
- Individuals who have not been approved for radionuclide use shall not work with, handle, or otherwise be provided access to RAM.
- Procedures involving RAM should be well-planned and, whenever possible, practiced in advance using non-radioactive materials.
- A "Caution-Radioactive Material" sign must be conspicuously posted at each entrance of a radionuclide laboratory. Such signs or labels should also be affixed at locations within the laboratory where radionuclides are used or stored (e.g., hoods, refrigerators, microwave ovens, etc.). The "Radiation Safety" posting including emergency procedures and "Notice to Employees" must also be posted in the laboratory.
- Radionuclide work areas must be clearly designated and should, to the extent possible, be isolated from the rest of the laboratory. Any volatile RAM must be used within the designated fume hood.
- All work surfaces should be covered with absorbent paper, which should be changed regularly to prevent the build-up of contamination. Work involving relatively large volumes or activities of liquid radioactive material should be performed in a spill tray lined with absorbent paper.

- 
- Protective clothing appropriate for the work conditions and tasks must be worn when working with RAM. This includes laboratory coats, gloves, closed-toe footwear and safety glasses. Sandals should not be worn in radionuclide laboratories.
  - Dosimeters, if issued, must be worn when working with radioactive material or radiation producing devices.
  - Containers of RAM and items suspected or known to be contaminated must be marked radioactive and indicate the isotope.
  - Contaminated waste items should be placed in a container specifically designated for radioactive waste.
  - A radiation survey must be performed by the radionuclide user at the end of each procedure involving RAM and the results of the survey recorded.
  - A record of the types and quantities of radionuclides possessed by each PI at a given time must be maintained. A Radioisotope Use and Waste Log form is provided as Appendix C-4.

Additional procedures or other usage requirements may be specified by the PI or by the RSO as part of the project approval process. The PI must review all specific usage requirements with authorized users working with RAM on his/her project.

## **7.2 RADIATION SURVEYS**

Surveys must be completed by laboratory personnel after each use of RAM. Periodic surveys must also be completed and recorded monthly or as otherwise specified on the approved RAM application. The survey may be made using a portable survey instrument, wipes or both, depending on the radionuclides used. All survey results must be recorded and the survey records maintained in the laboratory. Guidance and instructions for completing radiation surveys are included in Appendix A. A survey log form is provided as Appendix C-3.

All items found to be contaminated must be placed either in a radioactive waste container or marked radioactive, including the isotope, and placed in an appropriately designated area. Any surfaces found to be contaminated must be decontaminated and re-surveyed as soon as possible. The survey should always include a check of personnel for possible contamination. The PI and RSO must be notified immediately if extensive contamination is found within the laboratory or if any personnel are found to be contaminated.

Periodic surveys will also be conducted by the RSO and/or the EHS Office. A survey report form is provided as Appendix C-5. The RSO and/or EHS Office may also conduct periodic inspections of laboratories using RAM. An inspection form is provided as Appendix C-6.

## **7.3 STORAGE**

RAM must be protected from unauthorized removal or access at all times. Radioactive material must be stored in secured or locked cabinets, refrigerators (or lockboxes within refrigerators), freezers or waste areas, unless attended by the authorized user. All RAM must be labeled to indicate it is radioactive and the isotope.

RAM should be stored in sealed containers in such a way as to prevent accidental spillage, breakage, and contamination and to prevent release into the air. If the nuclide requires shielding, it should be stored in shielded containers in order to prevent excessive or unnecessary doses to personnel accessing the storage areas.

In the event that radioactive material is stored in a freezer, the material should be thawed, opened and handled in a fume hood or other appropriate enclosure where aerosols may be generated. Aerosols from stored RAM may cause contamination of adjacent areas and RAM intake by personnel if not handled properly after storage.

## 8. OCCUPATIONAL EXPOSURES AND MONITORING

### 8.1 PERSONNEL EXPOSURE LIMITS

The radiation safety program has as a primary goal to maintain all personnel radiation exposures below regulatory limits and ALARA.

#### 8.1.1 Occupational Dose Limits

Current limits for occupational radiation exposure have been established at levels that, in light of present knowledge, are believed to prevent acute radiation effects (erythematic, epilating) and limit the risks of late effects such as cancer or genetic damage to very low, “acceptable” levels. These limits are established at Title 10, Part 20 of the Code of Federal Regulations, and are based on external, internal, and external plus internal exposures as defined in Figure 1. Table 1 provides a summary of the current annual occupational dose limits for external and internal exposures.

**Figure 1: Dose Equivalents**

<b>External Dose</b>
<ul style="list-style-type: none"><li>• <b>Shallow-Dose Equivalent (SDE)</b> is the dose to the skin of the whole body or extremity from an external source of ionizing radiation.</li><li>• <b>Eye (Lens) Dose Equivalent (LDE)</b> is the dose equivalent to the lens of the eye from an external source of ionizing radiation.</li><li>• <b>Deep-Dose Equivalent (DDE)</b> is the whole-body dose from an external source of ionizing radiation.</li></ul>
<b>Internal Dose</b>
<ul style="list-style-type: none"><li>• <b>Committed Dose Equivalent (CDE)</b> is the dose equivalent to organs or tissue that will be received from an uptake of radioactive material.</li><li>• <b>Committed Effective Dose Equivalent (CEDE)</b> is the dose equivalent for the whole body from an uptake of radioactive material.</li></ul>
<b>Sum of External and Internal Doses</b>
<ul style="list-style-type: none"><li>• <b>Total Organ Dose Equivalent (TODE)</b> is the dose equivalent to the maximally exposed organ or tissue from external and internal sources of ionizing radiation. <b>TODE = DDE + CDE</b></li><li>• <b>Total Effective Dose Equivalent (TEDE)</b> is the dose equivalent to the whole body from the combination of external and internal sources of ionizing radiation. <b>TEDE = DDE + CEDE</b></li></ul>

**Table 1. Annual Occupational Dose Limits for Adult Workers**

Limit	rem*	Sievert (sv)
Total Effective Dose Equivalent**	5	0.05
DDE + CEDE to any individual organ or tissue other than the lens of the eye**	50	0.5
Shallow Dose Equivalent, Skin or any Extremity	50	0.5
Eye Dose Equivalent to the Lens of the Eye	15	0.15

\*rem = the special unit of dose equivalent. The dose equivalent in rem is equal to the absorbed dose in rads multiplied by the quality factor (1rem = 0.01 sievert). Sievert is the S.I. dose equivalent unit.

\*\*= the annual limit is based on the more limiting of these two values.

---

### **8.1.2 Annual Limits on Intake**

In addition, internal exposure limits are addressed through the establishment of “annual limits on intake” (ALI). These values represent the derived limit for the amount of radioactive material taken into an adult body by inhalation or ingestion in a year (in either single or multiple events), which would result in the individual receiving a CEDE of 5 rem (0.05 sv) or a CDE of 50 rem (0.5 sv).

### **8.1.3 Regulatory Dose Limits to Declared Pregnant Workers**

Because of the increased susceptibility of the human embryo and fetus to damage from ionizing radiation, the National Council on Radiation Protection and Measurement (NCRP) recommends that the whole-body radiation dose received by a female worker during the nine months of her pregnancy not exceed 500 millirem (mrem) (5 mSv), or 10% of the annual occupational dose limit. The NRC has published Regulatory Guide 8.13, which details potential health risks of prenatal exposures and suggests precautions and options for the pregnant worker.

The Illinois Department of Public Health (IDPH) and Centers for Disease Control and Prevention (CDC) has published guidance “Radiation Emergencies” which details potential health risks of prenatal exposures and suggests precautions and options for the pregnant worker.

Federal and state regulatory agencies have adopted the NCRP recommendations. However, the regulations only apply when a worker voluntarily declares their pregnancy. If a declaration of pregnancy is made, the worker grants consent to their employer to limit their dose to a TEDE of 500 mrem (5 mSv) throughout the entire pregnancy. If no declaration is made to the employer, the occupational dose limits remain the same.

A declaration of pregnancy must be made to the RSO in writing, and can be made at any time during the pregnancy. The “Declaration of Pregnancy” form is included as Appendix C-2. Upon receiving the declaration of pregnancy form, the RSO will schedule a counseling session with the worker to review the worker’s dose history, current work, and dose limits and explore methods for minimizing radiation exposure.

## **8.2 PERSONNEL MONITORING**

A number of devices and methods exist for assessing an individual’s exposure to ionizing radiation. Whether one or more of these personnel monitoring methods is employed for a given situation will depend upon a number of factors, including the type and quantity of radioactive material used and the amount of time spent working with the material. The need for personnel monitoring is made by the RSO as part of the application review and approval process for new or modified projects.

### **8.2.1 Dosimeters**

State and federal laws require that any individual likely to receive a dose in excess of 10% of the limits should be monitored. The need for dosimeters will be determined by the RSO at the time of initial project approval, and if required, will be specified on the approved application form.

Dosimeters may be issued to monitor both whole-body and extremity exposures. Whole-body dosimeters monitor external exposure to areas of the body where organs reside and the skin of the body and may be issued for work with or near sources emitting penetrating radiation (energetic beta particles, x-rays, gamma rays or neutrons). Rings dosimeters may be issued in addition to individuals handling relatively large quantities of energetic beta or gamma emitting radionuclides (e.g., <sup>32</sup>P) in order to monitor extremity exposures or exposures to limbs beyond the elbow and knee.

In order for a dosimeter to provide an accurate indication of an individual’s dose, it must be worn 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. If a protective lead apron is worn and only one dosimeter has been issued, it should be worn near the midline of the body and under the apron. If a second badge has been issued, it should be worn on the collar. Ring badges should be worn beneath gloves and turned towards the radiation source. The ring is normally worn upside down or facing the palm side of the hand.

### **8.2.2 Bioassays**

Bioassays may be necessary for work with certain types of radionuclides in order to assess internal radiation exposures. The need for bioassays will be determined by the RSO at the time of initial project approval, and if required, will be specified on the approved application form.

In the event of projects involving radionuclides of iodine, internal exposure may be assessed by using a NaI scintillation probe to externally measure the amount of ionizing radiation emitted from the thyroid.

Urinalysis will only be required for unusual situations such as accidents involving potential radionuclide uptake or for certain experimental procedures where ingestion or inhalation of radionuclides is possible. If required, urinalyses will be performed by a physician from Northwestern Memorial Hospital.

Any worker who is believed to have received an intake of radioactive material will be referred to Northwestern Memorial Hospital, Corporate Health.

### **8.2.3 Recordkeeping and Reporting**

Where dosimeters are required (i.e., for any radiation worker who is likely to receive 10% of any annual occupational dose limit in the course of normal job duties), regulations require that annual reports of occupational doses be given to those individuals. At DePaul University, all personnel required to wear dosimeters will receive an annual occupational dose report, regardless of whether they meet the aforementioned monitoring requirement.

A report of annual occupational doses must be given to the monitored individual annually, upon termination or upon request by that individual. The results of all personnel monitoring performed for individuals working with ionizing radiation at DePaul University are maintained on file by the RSO. Personnel monitoring results are continuously reviewed by the RSO to assure that radiation doses are kept ALARA. Each individual's dosimeter record is available upon request. Information on a person's radiation exposures is only released to the person directly or to a specified party authorized by the exposed individual. A permanent record of this release information, dated and signed by the individual involved, is kept on file.

### **8.2.4 ALARA Reviews**

The RSO reviews dose reports upon receipt from the vendor. An individual is notified immediately by the RSO whenever current monitoring results exceeds established ALARA limits. The RSO will meet with the individual (and authorized PI, if applicable) to determine the cause of elevated dose and to review work practices and attempt to identify methods to reduce the worker's exposure.

---

## 9. RADIOACTIVE WASTE

### 9.1 RADIOACTIVE WASTE MANAGEMENT

The RSO works with the responsible PI and the EHS Office to ensure the collection, treatment and disposal of all radioactive waste generated at DePaul University. A Radioisotope Use and Waste Log form is provided as Appendix C-4. To facilitate these processes, radioactive material users are required to follow any specific procedures for radioactive waste generated in their laboratories as specified on the approved application, as well as the following general provisions:

- Radioactive waste should be separated and labeled according to its radionuclide half lives:
  - a. Very short-lived – half-lives of less than 15 days
  - b. Short-lived – half-lives between 15 and 90 days
  - c. Long-lived – half-lives greater than 90 days
- Solid radioactive waste must be separated and labeled according to whether it is combustible (plastics, paper, etc.) or noncombustible (glass, metal, etc.). Each solid waste container must be lined with a plastic bag, which must be removed, sealed and a radioactive waste tag affixed when full.
- Lead source containers and source vials must be separated from other solid waste.
- Liquid radioactive waste must be separated and labeled according to whether it is aqueous (miscible in water) or bears solvents. Liquid waste can contain a mix of certain isotopes.
- If flammable solvent bearing waste will be generated, such as those containing toluene or xylene, it must be placed in containers approved for flammable liquids, such as original solvent containers (with the label modified or removed as appropriate). Solvent bearing waste may only contain  $^3\text{H}$ ,  $^{14}\text{C}$ ,  $^{137}\text{Cs}$  and  $^{60}\text{Co}$ . Solvent bearing wastes containing other isotopes requires the approval of the RSO prior to generation.
- In the event that radioactive animal carcasses, viscera and blood will be generated, such waste must be sealed in a plastic bag or container, labeled and frozen prior to removal. Laboratory personnel must also notify the RSO in advance of any special problems regarding the waste (animal size, fluid leakage, purification, biohazard, etc.) and be prepared to provide assistance at the time of removal.
- All radioactive waste awaiting collection must be properly packaged and labeled, and placed in a designated waste storage area.

The RSO will work with the EHS Office to provide guidance for unwanted RAM and RPDs that do not fit established disposal processes. Such items may include equipment with embedded RAM sources such as gas chromatographs and liquid scintillation counters, contaminated equipment, legacy materials and materials with multiple hazards.

### 9.2 RADIOACTIVE WASTE MINIMIZATION

Each PI and individual user is encouraged to practice methods and procedures to reduce the amount of radioactive waste generated. Waste minimization techniques may include but are not limited to:

- Substituting non-radioactive materials or methods;
- Substituting very short-lived isotopes whenever possible
- Ordering the minimum amounts of RAM necessary for the experiment, whenever possible;
- Periodically reviewing procedures to ensure that unnecessary waste is not being generated;
- Ensuring that only radioactive waste is placed in the radioactive waste containers; and that normal trash is segregated and disposed of separately;

- 
- Working on easily decontaminated surfaces (e.g., trays, absorbent paper) to minimize the amount of waste generated from a small spill;
  - Washing glassware and surveying for contamination.

## **10. REMOVING EQUIPMENT, VACATING SPACE AND ABANDONED MATERIAL**

### **10.1 REMOVAL OF LABORATORY EQUIPMENT**

Any equipment in the laboratory which could have been contaminated with radioactive material must be surveyed before removal to another laboratory, transfer to a repair shop, or other removal from the laboratory (e.g., for disposal, re-sale, etc.). After a satisfactory survey and before the equipment is transferred, all “radioactive” warning signs and stickers must be removed.

### **10.2 VACATING LABORATORY SPACES**

The RSO and the EHS Office must be informed of all changes in authorized laboratory spaces, including transfers or departures from the University and laboratory relocations. Written notification to the RSO **is required** prior to vacating a laboratory that used radioactive materials or moving into different labs. The PI is responsible for ensuring that surveys are completed for all affected spaces and equipment and that all radioactive waste and radioactive sources are properly removed, transferred or disposed of prior to vacating the laboratory. The RSO must provide final approval of the laboratory decommissioning and prior to re-occupancy of the vacated space.

### **10.3 RADIOACTIVE CONTAMINATION AND ABANDONED RADIOACTIVE MATERIALS**

The PI is responsible for any radioactive contamination and/or abandoned radioactive materials related to his/her possession and use of radioactive materials. Where the responsible PI is no longer employed at the University, departments are responsible for decontamination of facilities and for identification and proper disposal of any RAM abandoned by their personnel. This may include performing surveys and analyses, disposing of the materials, and/or decontaminating the laboratory. It is recognized that departments are not always able to assume these responsibilities or perform these required tasks within a reasonable time frame. In such cases, a department may arrange for the services of the RSO, or work with the EHS Office to engage a qualified consultant/contractor, to accomplish the necessary tasks.

## **11. SPILL AND EMERGENCY PROCEDURES**

### **11.1 MINOR SPILL AND CONTAMINATION**

Incidents involving the release or spillage of less than 100  $\mu\text{Ci}$  of a radionuclide in a nonvolatile form can generally be regarded as minor. For small spills and contaminations, authorized RAM users are required to clean up the spill immediately, closely following these steps:

1. Notify all other persons in the room at once.
2. Clear the room of all persons except those needed to clean up the spill.
3. Contain the spill immediately.
  - a. **Liquids:** Cover with absorbent paper or chemicals (calcium bentonite) on the spill.
  - b. **Solids:** Dampen thoroughly, taking care not to spread contamination. Use water, unless a chemical reaction would release air contaminants; otherwise use oil.
4. Notify the PI and RSO.
5. After hours, notify the Public Safety Department (325-7777).

6. During work hours, the RSO will notify the EHS Office (325-4201 or 325-4170) if necessary for assistance. After hours, the Public Safety Department will contact an EHS Office representative.

## 11.2 DECONTAMINATION PROCEDURES

In the event that surfaces or equipment within the laboratory are suspected or determined to be contaminated with radioactive material, the radionuclide user must initiate and complete appropriate decontamination procedures. For most relatively minor contamination incidents, the following general steps should be taken upon discovery of the contamination:

1. Mark the perimeter of the contaminated area.
2. Notify the PI and RSO of the contamination.
3. Assemble cleaning supplies such as paper towels, detergent in water, plastic bags and plastic gloves.
4. Proceed with scrubbing the area from the borders to the center, cleaning small areas at a time.
5. Periodically monitor the effectiveness of the decontamination effort with surface wipes and instrument surveys (see Table 2).
6. Place all contaminated cleaning materials, such as paper towels, rags and gloves, in a plastic bag and label as radioactive waste.
7. Notify the RSO and the EHS Office upon completion of the decontamination effort so that a follow-up contamination survey can be made.

**Table 2. Limits of Radioactive Contamination on Surfaces or Items to Be Released for Unrestricted Use**

Contamination Type	Limit
Removable alpha (wipe)	10 dpm/100 cm <sup>2</sup>
Removable beta/gamma (wipe)	200 dpm/100 cm <sup>2</sup>
Fixed Alpha (direct measure)	* Non-detectable
Fixed beta/gamma (direct measure)	** 0.1 mrem/hr at 1 inch

*NOTE: The survey instrument used for contamination monitoring must be appropriate for the radiation being detected.*

*\* Non-detectable is a reading less than the average instrument background plus 10%.*

*\*\* Reading from a survey instrument with the beta shield open and a maximum distance of 1 inch from the surface of the detector tube to the surface being monitored.*

## 11.3 MAJOR SPILLS AND CONTAMINATION

An incident occurring outside of the hood and involving the release of more than 100  $\mu$ Ci of a radionuclide in a nonvolatile form, or the release of any amount of a radionuclide in a volatile form, should be considered major. Laboratory personnel are responsible for immediately completing the following steps:

1. Evacuate the room immediately shutting doors and windows on the way out.
2. Immediately notify the PI and RSO.
3. During working hours, the RSO will notify EHS (325-4201 or 325-4170) to assist in the response.

- 
4. After hours, immediately notify the Public Safety Department (325-7777). Public Safety will contact an EHS Office representative and the RSO, who will determine the necessary response actions and resources.
  5. Post a "Keep Out" sign on the laboratory door.
  6. Assemble those persons who were present in the laboratory at the time of the spill and await for instructions from Public Safety, the RSO or EHS Office..

#### **11.4 ACCIDENTS INVOLVING PERSONAL INJURY OR EXPOSURE**

For any accident involving personal injury or exposure, medical treatment or assistance will always be the first priority. This may involve administering first aid and/or calling 911 for emergency medical assistance. In accidents involving RAM, contamination and exposure control are also important, but should never delay or impede medical assistance. If RAM is involved, the RSO and EHS Office must be notified as soon as possible. After the injured person is treated and removed from the accident site, all personnel involved in helping the injured person should remain in the vicinity until checked for contamination or exposure and the extent of the radiological hazard has been evaluated. RECORDKEEPING

#### **11.5 RECORDKEEPING REQUIREMENTS**

DePaul University is required to maintain accurate, timely records of the receipt, use, transfer and disposal of radiation sources in its possession. These records must be maintained by the RSO, or if designated by the PI, for at least three (3) years and be readily available for periodic review by the EHS Office and/or regulatory personnel. Records for any radioactive waste to be disposed by a qualified vendor will be maintained by the EHS Office, while the RSO maintains records for decay-in-storage.

Records for general radiation safety training coordinated by the EHS Office will be maintained via by EHS, preferably as part of the University learning management system. Records of more specific training and review of the experimental protocol and radiation control requirements conducted by the PI should be maintained in the laboratory.

---

**APPENDIX A:**

**CONTAMINATION SURVEYS**

- **Types of Contamination**
- **Types of Surveys**
- **Survey Instrumentation**
- **How to Perform a Meter Survey**
- **How to Perform a Wipe Test**

---

## Types of Contamination

- **Removable contamination** can be readily removed using proper decontamination procedures. Removable contamination in any amount may present both an external and internal hazard because it can be picked up on skin and possibly ingested.
- **Fixed contamination** cannot be readily decontaminated. Fixed contamination generally does not present a significant hazard unless the material comes loose or is present in such large amounts that it presents an external radiation hazard.

## Types of Surveys

- **Meter surveys**, using Geiger detectors or scintillation probes, can identify gross contamination (total contamination consisting of both fixed and removable contamination) but will detect only certain isotopes.
- **Wipe surveys**, using “wipes” counted on a liquid scintillation counter or a gamma counter, can identify removable contamination only but will detect most isotopes used at DePaul. Wipe tests are the most versatile and most sensitive method of detecting low-level contamination in the laboratory.

## Survey Instrumentation

- The portable **Geiger-Muller (G-M) 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 G-M meter can also be used to identify areas heavily contaminated with lower energy betas, such as C-14 or S-35, for which the G-M meter has a relatively low efficiency. G-M meters should not be used to survey for I-125 contamination, since G-M meters will detect I-125 only when there are very high levels of contamination.
- The portable **thin crystal NaI scintillation survey meter** is used to locate 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**, used for counting wipe tests, is not portable but is the most versatile counting instrument because it has a high counting efficiency for a wide range of radionuclides.
- **Gamma counters** are not portable and are used to count wipe tests for photon emitters, such as Cr-51 or I-125.

## How to Perform a Meter Survey

1. Check the survey meter’s battery by turning the meter knob to the battery test position. If the battery is adequately charged, the meter needle will swing to the battery test position on the meter face. Replace the batteries if the batteries are low.
2. Perform an operational check the first time you use the meter each day or when you suspect it may have been misused or damaged. Look at the calibration sticker on the side of the meter and note what the expected reading for the operational check source should be. Turn the meter on and turn the meter’s multiplier switch to a setting that will measure the check source and will provide a mid-scale reading but will not cause the needle to swing beyond full scale. For a Ludlum G-M survey meter the multiplier knob should generally be set to the X1 position. Place the probe firmly against the check source on the side of the meter and note the meter response. If the observed meter response differs from the expected response by more than 20%, the meter should be considered nonfunctional and should be taken out of service.
3. Take the meter to an area away from sources of radiation and note the meter background reading. Typically, the background for a G-M meter with a pancake survey probe should be less than 100 counts per minute (cpm) while the background reading for a meter with a NaI scintillation crystal should be less than 300 cpm. If the meter’s background reading is substantially greater than expected, confirm that

---

there are no unexpected sources of radiation or radioactive materials in the vicinity, and then call the Radiation Safety Officer to report a contaminated meter.

4. Do not cover the probe surface with parafilm or other protective covering. Parafilm and similar materials will shield the low energy betas from C-14, P-33 and S-35 and will prevent the meter from detecting contamination.
5. Slowly move the probe about 1 centimeter above the area of interest.
6. If an item or area with a sustained count rate more three times background is found, the item or area should be considered to be contaminated.
7. Immediately label the area or item and promptly decontaminate it. If an area cannot be decontaminated, the contaminated area should be marked and labeled to indicate the isotope, date and level of contamination.
8. Sometimes, especially in the presence of other radioactive materials, the meter survey may be equivocal. When the meter survey indicates that low level contamination may be present, a wipe survey should be performed to confirm or disprove the presence of contamination.
9. Document the survey results whenever contamination is discovered or if 250  $\mu\text{Ci}$  or more have been handled. Record survey results in the survey log. This is a University requirement.

#### **How to Perform a Wipe Test**

Wipe surveys must be performed when H-3 is used and is the survey method of choice to detect the presence of low levels of removable C-14, P-33 and S-35 contamination. Wipe surveys should also be performed to confirm the presence of contamination when a meter survey suggests that low level contamination may be present.

1. Using a piece of filter paper (about 1" in diameter), Q-tip or other swab/wipe the area being surveyed. If the area is very large, subdivide it into smaller areas and use several wipes to better pinpoint the location of contamination. For some surfaces, including skin and clothing, the wipe media should be moistened with water or other appropriate solvent.
2. Prepare the sample for counting as suggested in the counter's operating manual. Analyze the wipe samples in a liquid scintillation counter for H-3 and other beta emitters and preferably in a gamma counter for Cr-51 and I-125.
3. Sample activity is determined by dividing the sample count by the counter's efficiency for the isotope in question. The counter's operating manual should provide information about efficiencies and activity determination.
4. Contact the Radiation Safety Officer with questions about liquid scintillation and gamma counter use.

---

**APPENDIX B:**

**CHARACTERISTICS OF COMMON RADIOISOTOPES**

- H-3
- C-14
- P-32
- Si-32
- P-33
- S-35
- Fe-55
- Co-57
- Fe-59
- Ni-63
- Zn-65
- Se-75
- Cd-109
- I-125
- Hg-203

Isotope	Half-life	Emission	Max Energy (keV)	ALI for Ingestion	Badging Needed?	Shielding	Detection	More Info
H-3	12.3y	B-	19	80	NO	NONE	LSC ONLY	
C-14	5730y	B-	156	2	NO	NONE**	LSC; G-M	
P-32	14.3d	B-	1710	0.6	≥5mCi	PLEXIGLASS	G-M	
Si-32	104y							
P-33	25d	B-	250	6	NO	NONE**	LSC	
S-35	87.4d	B-	167	10	NO	NONE**	LSC	
Fe-55	2.7y							
Co-57	271.8d							
Fe-59	44.6d							
Ni-63	100.1y							
Zn-65	243.9d							
Se-75	119.8d							
Cd-109	462.6d							
I-125	60.1d	X,g	27-35	0.04	>1mCi	Lead	Nal;g	
Hg-203	47d							

\*\*Unless handling tens of millcuries

\*\*\*LSC: Liquid Scintillation Counting

G-M: Geiger-Muller Counting

Nal: Sodium iodide scintillation survey meter

g: gamma counter

---

## Hydrogen-3

### **Physical Characteristics:**

- Half-life: 12.3 years
- Emissions: Beta particles with a maximum energy of 18.6 keV and an average energy of 5.7 keV.
- Maximum Range in Air: 4.7 mm in air; 6 mm in tissue.
- Fraction transmitted through the dead layer of the skin: none

### **Dose and Shielding:**

- Dose rate to the skin at 10 cm: None
- Dose rate to epidermal basal cells from skin contamination of 1 mCi/cm<sup>2</sup>: None
- Shielding: None needed.
- Annual Limit on Intake (ALI): 80 millicuries via ingestion, assuming intake as tritiated water. The ingestion of one ALI will produce a dose of 5 rem.

### **Detection:**

Liquid scintillation counting is the preferred method for detecting H-3. Most G-M detectors will not detect the presence of H-3.

### **Precautions:**

H-3 contamination cannot be detected with a G-M meter, and special precautions are needed to keep the work environment clean. The regular use of wipe testing, using a liquid scintillation counter, is the only way to insure that your work space does not contain contamination.

### **Waste Disposal:**

- Solid Wastes/Liquid Scintillation Wastes: through the Off-Site Radioactive Waste Disposal Program
- Liquid Wastes: through the Sewer Disposal Program. The monthly secondary disposal limit is 3 mCi.

## Carbon-14

### **Physical Characteristics**

- Half-life: 5,730 years
- Emissions: Beta particles with a maximum energy of 156 keV and an average energy of 49 keV.
- Maximum Range in Air: 22 cm in air; 0.027 cm in tissue.
- Fraction transmitted through the dead layer of the skin: 0.11

### **Dose and Shielding:**

- Dose rate to the skin at 10 cm: 600 mrad/hour/mCi (for an unshielded point source)
- Dose rate to epidermal basal cells from skin contamination of 1 mCi/cm<sup>2</sup>: 1400 mrad/hour
- Shielding: None needed, when used in millicurie quantities under normal laboratory conditions.

- 
- Annual Limit on Intake (ALI): 2 millicuries via ingestion. The ingestion of one ALI will produce a dose of 5 rem.

**Detection:**

Liquid scintillation counting is the preferred method for detecting C-14. Most G-M detectors are not likely to detect the presence of C-14 in amounts less than about 100,000 dpm (0.05  $\mu$ Ci).

**Precautions:**

Low-level C-14 contamination cannot be easily detected with a G-M meter, and special precautions are needed to keep the work environment clean. The regular use of wipe testing, using a liquid scintillation counter, is the only way to insure that your work space does not contain low-level removable contamination.

**Waste Disposal:**

- Solid Wastes/Liquid Scintillation Wastes: through the Off-Site Radioactive Waste Disposal Program
- Liquid Wastes:

**Phosphorus-32**

**Physical Characteristics:**

- Half-life: 14.3 days
- Emissions: Beta particles with a maximum energy of 1.71 MeV and an average energy of 0.7 MeV.
- Maximum Range: 620 cm in air; 0.8 cm in tissue; 0.6 cm in plexiglas
- Fraction transmitted through the dead layer of the skin: 0.95

**Dose and Shielding:**

- Dose rate to the skin at 10 cm: 4070 mrad/hour/mCi (for an unshielded point source)
- Dose rate to epidermal basal cells from skin contamination of 1 mCi/cm<sup>2</sup>: 9200 mrad/hour
- Shielding: 3/8" plexiglas/lucite will shield all P-32 betas. For high activity sources exceeding a few millicuries, it may be desirable to add lead shielding outside the plexiglas shielding to shield against bremsstrahlung x-rays. Plexiglas should be placed closest to the P-32 source as primary shielding, and lead should be used outside the plexiglas as secondary shielding.
- Annual Limit on Intake (ALI): 600 microcuries via ingestion. The intake of one ALI will produce a dose of 5 rem.

**Detection:**

A G-M detector will readily detect low-level P-32 contamination, although liquid scintillation counting is also an acceptable method for detecting removable P-32 contamination.

**Precautions:**

High localized doses are possible while handling millicurie amounts of P-32 and as a result of skin contamination. Reduce doses by wearing safety glasses (for shielding the eyes), using remote handling tools such as tongs, using shielding extensively to shield storage and experimental containers and work areas, and performing thorough and frequent surveys of the work area, clothing and the body.

---

### ***Waste Disposal:***

Solid Wastes: through the Decay-in-Storage Program.

Liquid Wastes:

### **Silicon-32**

#### ***Physical Characteristics***

- Half-life: 104 years
- Emissions: Beta particles with a maximum energy of 0.224 MeV and an average energy of 0.067 MeV. Since Si-32 decays to P-32, emissions from a Si-32 source also include the 1.71 MeV beta from P-32  
Maximum Range: 37 cm in air; <.05 cm in tissue.
- See the P-32 fact sheet for information about the properties of the beta from the P-32 progeny.

#### ***Dose and Shielding***

- Dose rate to the skin at 10 cm: See the P-32 fact sheet for information about the dose from the P-32 progeny.
- Dose rate to epidermal basal cells from skin contamination of 1  $\mu\text{Ci}/\text{cm}^2$ : See the P-32 fact sheet for information about the dose from the P-32 progeny.
- Shielding: Depending on the age of the material, plexiglas shielding may be required for the P-32 progeny.
- Annual Limit on Intake (ALI): 2000 microcuries via ingestion and 200 microcuries via inhalation.
- The intake of one ALI will produce a dose of 5 rem.

#### ***Detection***

Liquid scintillation counting is the preferred method for detecting Si-32. Most G-M detectors are not likely to detect the presence of Si-32 in amounts less than about 100,000 dpm (0.05  $\mu\text{Ci}$ ). However, if the sample is older than a week, it may be appropriate to use a G-M detector to detect the P-32 progeny.

#### ***Precautions***

Appropriate precautions will depend on the age of the sample of Si-32. A sample of Si-32 will reach equilibrium with the P-32 progeny in approximately 120 days, i.e., a 1 mCi sample of Si-32 will also contain 1 mCi P-32 in 120 days. Within the first week, it is appropriate to take precautions based on the properties of Si-32. However, after that point, the sample will contain enough P-32, that precautions based on the properties of P-32 should be taken.

Low-level Si-32 contamination cannot be easily detected with a G-M meter, and special precautions are needed to keep the work environment clean. The regular use of wipe testing, using a liquid scintillation counter, is the only way to insure that the work space does not contain low-level removable contamination.

High localized doses are possible while handling millicurie amounts of P-32 and as a result of skin contamination. Reduce doses by wearing safety glasses (for shielding the eyes), using remote handling tools such as tongs, using shielding extensively to shield storage and experimental containers and work areas, and performing thorough and frequent surveys of the work area, clothing and the body.

Radiation Monitoring Requirements: Radiation monitoring badges may be required for Si-32 users, depending on the amount of Si-32 used.

---

**Waste Disposal**

Solid Wastes: through the Off-Site Radioactive Waste Disposal Program.

Liquid Wastes:

**Phosphorus-33****Physical Characteristics:**

- Half-life: 25.3 days
- Emissions: Beta particles with a maximum energy of 249 keV and an average energy of 76 keV.
- Maximum Range: 45 cm in air; 0.06 cm in tissue
- Fraction transmitted through the dead layer of the skin: 0.35

**Dose and Shielding:**

- Dose rate to the skin at 10 cm: 2000 mrad/hour/mCi (for an unshielded point source)
- Dose rate to epidermal basal cells from skin contamination of 1 mCi/cm<sup>2</sup>: 4500 mrad/hour
- Shielding: None needed, when used in millicurie quantities or less, under normal laboratory conditions
- Annual Limit on Intake (ALI): 6 millicuries via ingestion. The intake of one ALI will produce a dose of 5 rem.

**Detection:**

Liquid scintillation counting is the preferred method for detecting P-33. Most G-M detectors are not likely to detect the presence of P-33 in amounts less than about 100,000 dpm (0.05  $\mu$ Ci).

**Precautions:**

Low-level P-33 contamination cannot be easily detected with a G-M meter, and special precautions are needed to keep the work environment clean. The regular use of wipe testing, using a liquid scintillation counter, is the only way to insure that the work space does not contain low-level removable contamination.

**Waste Disposal:**

Solid Wastes: through the Decay-in-Storage Program.

Liquid Wastes:

**Sulfur-35****Physical Characteristics:**

- Half-life: 87.6 days
- Emissions: Beta particles with a maximum energy of 167 keV and an average energy of 49 keV.
- Maximum Range: 24 cm in air; 0.030 cm in tissue.
- Fraction transmitted through the dead layer of the skin: 0.12

---

**Dose and Shielding:**

- Dose rate to the skin at 10 cm: 625 mrad/hour/mCi (for an unshielded point source)
- Dose rate to basal cells from skin contamination of 1 mCi/cm<sup>2</sup>: 1460 mrad/hr
- Shielding: None needed, when used in millicurie quantities under normal laboratory conditions
- Annual Limit on Intake (ALI): 10 millicuries via ingestion for most compounds of sulfur. The intake of one ALI will produce a dose of 5 rem.

**Detection:**

Liquid scintillation counting is the preferred method for detecting S-35. Most G-M detectors are not likely to detect the presence of S-35 in amounts less than about 100,000 dpm (0.05  $\mu$ Ci).

**Precautions:**

<sup>35</sup>S-labeled methionine/cysteine compounds can volatilize. Stock solutions and thawed materials should be opened within a fume hood. Activated charcoal can be used to trap contamination within equipment such as incubators. Contact EHS for further information.

Low-level <sup>35</sup>S contamination cannot be easily detected with a G-M meter, and special precautions are needed to keep the work environment clean. The regular use of wipe testing, using a liquid scintillation counter, is the only way to insure that the work space does not contain low-level removable contamination.

**Waste Disposal:**

Solid Wastes: through the Decay-in Storage Program

Liquid Wastes:

**Iron-55****Physical Characteristics:**

- Half-life: 2.70 years
- Emissions: Principal emissions are a 6 keV x-ray and 5.2 keV [average] Auger electrons.
- Electron Maximum Range: 0.15 cm in air; 0.0 cm in tissue

**Dose and Shielding:**

- Dose rate at 10 cm: negligible
- Dose rate to basal cells from skin contamination of 1  $\mu$ Ci/cm<sup>2</sup>: 59 mrem/hr
- Shielding: None needed, when used in millicurie quantities, under normal laboratory operations.
- Annual Limit on Intake (ALI): 2,000 microcuries via inhalation, and 9,000 microcuries via ingestion. The intake of one ALI will produce a dose of 5 rem.

**Detection:**

Liquid scintillation counting is the preferred method for detecting Fe-55 contamination, although a low energy sodium iodide crystal scintillation detector will also detect Fe-55 with a lower efficiency. The regular use of wipe testing, using a liquid scintillation counter, is the only way to insure that the work space does not contain low-level removable contamination.

---

**Precautions:**

External radiation from Fe-55 is low energy and does not normally present an external exposure hazard. Low-level Fe-55 contamination is not readily detected with a survey meter, and special precautions are needed to keep the work environment clean. The regular use of wipe testing, using a liquid scintillation counter, is the only way to insure that your work space does not contain low-level removable contamination.

Radiation Monitoring Requirements: Radiation monitoring badges are not required for Fe-55 users.

**Waste Disposal:**

Solid Wastes: through the Off-Site Radioactive Waste Disposal Program.

Liquid Wastes:

**Cobalt-57****Physical Characteristics:**

- Half-life: 271.8 days
- Emissions: Principal emissions are 122 keV gammas (86%) and 137 keV gammas (11%), accompanied by electrons with energies ranging up to 7 keV
- Half-Value Layer: < 1 mm lead
- The half-value layer is the amount of material required to reduce the radiation intensity by 50%.

**Dose and Shielding:**

- Gamma dose rate (deep tissue dose) at 30 cm: 0.93mrem/hour per millicurie at 30 cm (for an unshielded point source)
- Dose rate to epidermal basal cells from skin contamination of 1  $\mu\text{Ci}/\text{cm}^2$ : 444 mrem/hr
- Shielding: Lead foil or sheets, when used in hundreds of microcuries or in millicurie quantities.
- Annual Limit on Intake (ALI): 4000 microcuries via ingestion and 700 microcuries via inhalation.
- The ingestion of one ALI will produce a dose of 5 rem.

**Detection:**

A sodium iodide crystal scintillation detector is the preferred method for detecting Co-57.

Additionally a G-M detector will detect Co-57 contamination with a significantly lower efficiency of detection. Liquid scintillation counting is also an acceptable method for detecting removable contamination.

**Precautions:**

High localized doses are possible while handling Co-57 and as a result of skin contamination. Reduce doses by using remote handling tools such as tongs, using shielding extensively to shield storage and experimental containers and work areas, and performing thorough and frequent surveys of the work area, clothing and the body.

Radiation Monitoring Requirements: Radiation monitoring badges must be worn by any person who uses open sources of Co-57 in amounts of 0.5 mCi or more for extended operations (applies to most operations other than simple aliquoting from a stock vial).

---

**Waste Disposal:**

Solid Wastes/Liquid Scintillation Wastes: through the Off-Site Radioactive Waste Disposal Program

Liquid Wastes:

**Iron-59****Physical Characteristics:**

Half-life: 44.6 days

**Emissions:**

- Beta particles: 0.273 MeV (46%) and 0.466 MeV (53%) maximum energies with average energies of 0.081 MeV and 0.149 MeV respectively.
- Gamma rays: 1.099 MeV (56%) and 1.292 MeV (44%).
- Beta Maximum Range: ~ 100 cm in air; 0.14 cm in tissue; 0.12 cm in plexiglas
- Fraction transmitted through the dead layer of the skin: 0.95
- Half-Value Layer: 15 mm lead.
- The half-value layer is the amount of material required to reduce the radiation intensity by 50%.

**Dose and Shielding:**

- Gamma dose rate (deep tissue dose) at 30 cm: 7.0 mrem/hour/mCi (for an unshielded point source)
- Beta dose rate to the skin at 30 cm: 130 mrem/hour/mCi (for an unshielded point source)
- Dose rate to epidermal basal cells from skin contamination of 1  $\mu\text{Ci}/\text{cm}^2$ : 3593 mrem/hour
- Shielding: Generally, lead is the preferred shielding material for Fe-59 for lower activity operations. However, it may be desirable to use a combination of plexiglas and lead/steel as shielding when working with multi-millicurie amounts to minimize the amount of bremsstrahlung produced by the betas. In such a case, plexiglas should be placed closest to the source as primary shielding, and lead should be used outside the plexiglas as secondary shielding.
- Annual Limit on Intake (ALI): 800 microcuries via ingestion and 300 via inhalation. The intake of one ALI will produce a dose of 5 rem.

**Detection:**

A sodium iodide crystal scintillation detector is the preferred method for detecting Fe-59. Additionally a G-M detector will readily detect Fe-59 contamination, although liquid scintillation counting is also an acceptable method for detecting removable contamination.

**Precautions:**

High localized doses are possible while handling Fe-59 and as a result of skin contamination. Reduce doses by wearing safety glasses (for shielding the eyes), using remote handling tools such as tongs, using shielding extensively to shield storage and experimental containers and work areas, and performing thorough and frequent surveys of the work area, clothing and the body.

---

Radiation Monitoring Requirements: Radiation monitoring badges must be worn by any person who uses open sources of Fe-59 in amounts of 0.5 mCi or more for extended operations (applies to most operations other than simple aliquoting from a stock vial).

***Waste Disposal:***

Solid Wastes: through the Decay-in-Storage Program

Liquid Wastes:

**Nickel-63**

***Physical Characteristics:***

- Half-life: 100.1 years
- Emissions: Beta particles with a maximum energy of 66 keV and an average energy of 17 keV
- Maximum Range in Air: 5 cm in air; < 0.01 cm in tissue.

***Dose and Shielding:***

- Dose rate to the skin at 10 cm: negligible (for an unshielded point source)
- Dose rate to epidermal basal cells from skin contamination of 1  $\mu\text{Ci}/\text{cm}^2$ : negligible
- Shielding: None needed.
- Annual Limit on Intake (ALI): 9000 microcuries via ingestion and 2000 microcuries via inhalation.
- The ingestion of one ALI will produce a dose of 5 rem.

***Detection:***

Liquid scintillation counting is the preferred method for detecting Ni-63. G-M detectors will not detect Ni-63 contamination.

***Precautions***

Ni-63 contamination cannot be detected with a G-M meter, and special precautions are needed to keep the work environment clean. The regular use of wipe testing, using a liquid scintillation counter, is the only way to insure that your work space does not contain low-level removable contamination.

Radiation Monitoring Requirements: Radiation monitoring badges are not required for Ni-63 users, since the monitoring badges will not detect Ni-63.

***Waste Disposal:***

Solid Wastes/Liquid Scintillation Wastes: through the Off-Site Radioactive Waste Disposal Program

Liquid Wastes:

**Zinc-65**

***Physical Characteristics:***

- Half-life: 243.9 days

- 
- Emissions: Beta (positron) particles with a maximum energy of 0.33 MeV (2%) and an average energy of 0.099 MeV. Gamma rays: 1.116 MeV (51%) and 0.511 MeV (2%).
  - Beta Maximum Range: 76.2 cm in air; 0.10 cm in tissue; 0.08 cm in Plexiglas
  - Fraction transmitted through the dead layer of the skin: 0.95
  - Half-Value Layer: 14 mm lead; 2 cm in tissue
  - The half-value layer is the amount of material required to reduce the radiation intensity by 50%.

***Dose and Shielding:***

- Beta Dose rate to the skin at 30 cm: 1.93 mrem/hour/mCi (for an unshielded point source)
- Gamma Dose rate (deep tissue dose) at 30 cm: 3.44 mrem/hour/mCi (for an unshielded point source)
- Dose rate to epidermal basal cells from skin contamination of 1  $\mu\text{Ci}/\text{cm}^2$ : 281 mrem/hour
- Shielding: Shield stock vials with lead. Generally, lead is the preferred shielding material for Zn-65 for lower activity operations. However, since significant bremsstrahlung may be produced with higher activities, it may be desirable to use a combination of plexiglas and lead/steel as shielding when working with multi-millicurie amounts. In such a case, plexiglas should be placed closest to the source as primary shielding, and lead should be used outside the plexiglas as secondary shielding.
- Annual Limit on Intake (ALI): 400 microcuries via ingestion and 300 microcuries via inhalation. The intake of one ALI will produce a dose of 5 rem.

***Detection:***

A G-M detector will readily detect low-level Zn-65 contamination, although liquid scintillation counting is also an acceptable method for detecting removable contamination.

***Precautions:***

High localized doses are possible while handling millicurie amounts of Zn-65 and as a result of skin contamination. Reduce doses by wearing safety glasses (for shielding the eyes), using remote handling tools such as tongs, using shielding extensively to shield storage and experimental containers and work areas, and performing thorough and frequent surveys of the work area, clothing and the body.

Radiation Monitoring Requirements: Radiation monitoring badges must be worn by any person who uses open sources of Zn-65 in amounts of 0.5 mCi or more for extended operations (applies to most operations other than simple aliquoting from a stock vial).

***Waste Disposal:***

Solid Wastes: through the Off-Site Radioactive Waste Disposal Program

Liquid Wastes:

**Selenium-75**

***Physical Characteristics***

- Half-life: 119.8 days
- Emissions: Principal emissions are 136 keV and 265 keV x-rays.
- Half-Value Layer: 0.02 mm lead; 2 cm in tissue

- 
- The half-value layer is the amount of material required to reduce the radiation intensity by 50%.

#### ***Dose and Shielding***

- Gamma Dose rate (deep tissue dose) at 30 cm: 2.74 mrem/hour/mCi (for an unshielded point source)
- Dose rate to epidermal basal cells from skin contamination of 1  $\mu\text{Ci}/\text{cm}^2$ : 519 mrem/hour
- Shielding: Lead foil or sheets, when used in hundreds of microcuries or in millicurie quantities. None needed when used in low microcurie amounts.
- Annual Limit on Intake (ALI): 700 microcuries via inhalation, and 500 microcuries via ingestion. The intake of one ALI will produce a dose of 5 rem.

#### ***Precautions***

High localized doses are possible while handling millicurie amounts of Se-75 and as a result of skin contamination. Reduce doses by using remote handling tools such as tongs, using shielding extensively to shield storage and experimental containers and work areas, and performing thorough and frequent surveys of the work area, clothing and the body.

Radiation Monitoring Requirements: Radiation monitoring badges must be worn by any person who uses open sources of Se-75 in amounts of 0.5 mCi or more for extended operations (applies to most operations other than simple aliquoting from a stock vial).

#### ***Waste Disposal***

Solid Wastes: through the Decay-in-Storage Program.

Liquid Wastes:

### **Cadmium-109**

#### ***Physical Characteristics***

- Half-life: 462.6 days
- Emissions: Principal emissions are 22.1 keV x-rays (83%), accompanied by electrons with energies ranging up to 87 keV.
- Half-Value Layer: 0.01 mm lead; 2 cm in tissue
- The half-value layer is the amount of material required to reduce the radiation intensity by 50%.

#### ***Dose and Shielding***

- Beta dose rate to the skin at 30 cm: 0 mrem/hour/mCi (for an unshielded point source)
- Gamma Dose rate (deep tissue dose) at 30 cm: 0.778 mrem/hour/mCi (for an unshielded point source)
- Dose rate to epidermal basal cells from skin contamination of 1  $\mu\text{Ci}/\text{cm}^2$ : 2000 mrem/hour
- Shielding: Lead foil or sheets are used to shield the x-rays (the electrons are too low in energy to require shielding) when Cd-109 is used in hundreds of microcuries or in millicurie quantities. Shielding is not needed when Cd-109 is used in low microcurie amounts.
- Annual Limit on Intake (ALI): 40 microcuries via inhalation, and 300 microcuries via ingestion. The intake of one ALI will produce a dose of 5 rem. The critical organ for protection are the kidneys.

---

### **Detection**

A sodium iodide crystal scintillation detector is the preferred method for detecting Cd-109. G-M detectors are not likely to detect the presence of Cd-109 in amounts less than about 100,000 dpm (0.05  $\mu$ Ci).

### **Precautions**

Skin contamination and ingestion are the chief concerns when working with Cd-109, and appropriate precautions must be taken to limit contamination. Contamination of work areas and individuals is a more significant hazard than the external dose, unless working with millicurie quantities.

Radiation Monitoring Requirements: Radiation monitoring badges must be worn by any person who uses open sources of Cd-109 in amounts of 1 mCi or more for extended operations (applies to most operations other than simple aliquoting from a stock vial).

### **Waste Disposal**

Solid Wastes: through the Off-Site Radioactive Waste Disposal Program.

Liquid Wastes:

## **Iodine-125**

### **Physical Characteristics:**

- Half-life: 60.1 days
- Emissions: Principal emissions are a 35 keV gamma ray and 27 - 32 keV x-rays.
- Half-Value Layer: 0.02 mm lead; 2 cm in tissue. (The half-value layer is the amount of material required to reduce the radiation intensity by 50%.)

### **Dose and Shielding:**

- Dose rate at 10 cm: 15 mrem/hour/mCi (for an unshielded point source)
- Shielding: Lead foil or sheets, when used in hundreds of microcuries or in millicurie quantities. None needed when used in low microcurie amounts such as for RIA kits.
- Annual Limit on Intake (ALI): 60 microcuries via inhalation, and 40 microcuries via ingestion. The intake of one ALI will produce a dose of 5 rem. The critical organ for protection is the thyroid gland.

### **Detection:**

A sodium iodide crystal scintillation detector is the preferred method for detecting I-125. G-M detectors are not likely to detect the presence of I-125 in amounts less than about 100,000 dpm (0.05  $\mu$ Ci).

### **Precautions:**

Volatile iodine can be released from NaI-125 or from iodinated compounds containing hundreds of microcuries or more of I-125. Containers of I-125, including sample vials of iodinated compounds, should always be opened in a fume hood. Personnel using I-125 in hundreds of microcuries or more must wear double gloves and should change gloves as soon as the gloves become contaminated. Iodinations must be performed under EHS surveillance and thyroid count bioassays must be performed following an iodination.

### **Waste Disposal:**

Solid Wastes: through the Decay-in-Storage Program.

---

Liquid Wastes:

## **Mercury-203**

### ***Physical Characteristics***

- Half-life: 47 days
- Emissions: Beta particles: 0.210 MeV maximum energy (100 %) and 0.070 MeV average energy.
- Gamma rays: 0.279 MeV (100%).
- Beta Maximum Range: 34 cm in air; 0.04 cm in tissue; 0.04 cm in Plexiglas

### ***Dose and Shielding***

- Dose rate to the skin at 30 cm: 15.2 mrem/hour/mCi (for an unshielded point source)
- Gamma Dose rate (deep tissue dose) at 30 cm: 1.63 mrem/hour/mCi (for an unshielded point source)
- Dose rate to epidermal basal cells from skin contamination of 1  $\mu\text{Ci}/\text{cm}^2$ : 3296 mrem/hour
- Shielding: Shield stock vials with lead.
- Half-Value Layer: 0.2 cm lead  
The half-value layer is the amount of material required to reduce the radiation intensity by 50%.
- Annual Limit on Intake (ALI): 500 microcuries via ingestion and 800 microcuries via inhalation.  
The intake of one ALI will produce a dose of 5 rem.

### ***Detection***

A G-M detector will readily detect low-level Hg-203 contamination, although liquid scintillation counting is also an acceptable method for detecting removable contamination.

### ***Precautions***

High localized doses are possible while handling millicurie amounts of Hg-203 and as a result of skin contamination. Reduce doses by wearing safety glasses (for shielding the eyes), using remote handling tools such as tongs, using shielding extensively to shield storage and experimental containers and work areas, and performing thorough and frequent surveys of the work area, clothing and the body.

Radiation Monitoring Requirements: Radiation monitoring badges must be worn by any person who uses open sources of Hg-203 in amounts of 0.5 mCi or more for extended operations (applies to most operations other than simple aliquoting from a stock vial).

### ***Waste Disposal***

Solid Wastes: through the Decay-in-Storage Program

Liquid Wastes:

---

**APPENDIX C:**

**FORMS**

- **Radiation Application (C-1)**
- **Declaration of Pregnancy (C-2)**
- **Survey Log (C-3)**
- **Radioisotope Use and Waste Log (C-4)**
- **Radiation Safety Survey Report (C-5)**
- **Radiation Safety Inspection Form (C-6)**

---

**APPENDIX D:                    ABBREVIATIONS, CONVERSIONS, FORMULAS & EXAMPLES**

**Abbreviations**

ALARA – As Low As Reasonably Achievable

Bq – Becquerel

Ci – Curie

cpm – counts per minute

dpm – disintegration per minute

GM – Geiger-Mueller

Gy – Gray (unit of absorbed dose)

HPLC – high performance liquid chromatography

IEMA – Illinois Emergency Management Agency (formerly Illinois Department of Nuclear Safety (IDNS))

LDPE – low density poly ethylene

LSC – liquid scintillation count or liquid scintillation counter

mCi – millicurie

Nal – sodium iodide

PI – Principal Investigator

μCi – microcurie

R – Roentgen

Rad – radiation absorbed dose

Rem – Roentgen equivalent man

Sv – Sievert

**Conversions**

$2.22 \times 10^6$  dpm = 1 microcurie

1000 microcuries = 1 millicurie

1000 millicuries = 1 Curie

---

### **Formulas and examples**

For determination of meter or wipe survey results, use:

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

Example: The GM meter response on a bench top scan was 150 cpm. The background count rate was 40 cpm. For P-32, the GM efficiency is approximately 50%. What is the amount of activity on the bench top?

$$\text{Activity (dpm)} = \frac{150 \text{ cpm} - 40 \text{ cpm}}{0.50} = 220 \text{ dpm}$$

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:

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

---

**APPENDIX E: GLOSSARY**

**"Absorbed dose"** means the energy imparted by ionizing radiation per unit mass of irradiated material. The units of absorbed dose are the gray (Gy) and the rad.

**"Accelerator"** (particle accelerator) means any machine capable of accelerating electrons, protons, deuterons or other charged particles in a vacuum and of discharging the resultant particulate or other radiation into a medium at energies usually in excess of 1 million electron volts (MeV).

**"Accelerator-produced material"** means any material made radioactive by a particle accelerator.

**"Activity"** means the rate of disintegration (transformation) or decay of radioactive material. The units of activity are the becquerel (Bq) and the curie (Ci).

**"Adult"** means an individual 18 or more years of age.

**"Agreement State"** means any state with which the U.S. Nuclear Regulatory Commission or the U.S. Atomic Energy Commission has entered into an effective agreement under subsection 274b of the Atomic Energy Act of 1954, as amended.

**"Airborne radioactive material"** means any radioactive material dispersed in the air in the form of dusts, fumes, particulates, mists, vapors or gases.

**"Airborne radioactivity area"** means any room, enclosure, or operating area in which airborne radioactive material, composed wholly or partly of licensed material, exists in concentrations: (1) In excess of the derived air concentrations (DAC's) specified in Appendix B to 10 CFR 20.1001 - 20.2401, effective January 1, 1998, exclusive of subsequent amendments or editions; or (2) To such a degree that an individual present in the area without respiratory protective equipment could exceed, during the hours an individual is present in a week, an intake of 0.6 percent of the annual limit on intake (ALI) or 12 DAC-hours.

**"ALI or Annual Limit on Intake"** means the derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year.

**"As Low As Is Reasonably Achievable"** (ALARA) means making every reasonable effort to maintain exposures to radiation as far below the dose limits in 32 Ill. Adm. Code: Chapter II, Subchapters b and d as is practical, consistent with the purpose for which the licensed or registered activity is undertaken, and taking into account the state of technology, the economics of improvements in relation to the state of technology, the economics of improvements in relation to benefits to the public health and safety and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed or registered sources of radiation in the public interest.

**"Background radiation"** means radiation from cosmic sources; naturally occurring radioactive materials, including radon (except as a decay product of source or special nuclear material) and global fallout as it exists in the environment from the testing of nuclear explosive devices. Background radiation does not include radiation from radioactive materials regulated by the Illinois Department of Nuclear Safety.

**"Becquerel"** (Bq) means the SI unit of activity. One becquerel (Bq) is equal to 1 disintegration (transformation) per second (dps or tps).

---

**"Bioassay"** (radio bioassay) means the determination of kinds, quantities or concentrations and, in some cases, the locations of radioactive material in the human body, whether by direct measurement (in vivo counting) or by analysis and evaluation of materials excreted or removed from the human body.

**"Byproduct material"** means; (1) Any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident or to the process of producing or utilizing special nuclear material; and (2) The tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content, including discrete surface wastes resulting from underground solution extraction processes but not including underground ore bodies depleted by such solution extraction processes.

**"Calendar quarter"** means not less than 12 consecutive weeks nor more than 14 consecutive weeks. The first calendar quarter of each year shall begin in January and subsequent calendar quarters shall be so arranged such that no day is included in more than one calendar quarter and no day in any one year is omitted from inclusion within a calendar quarter. No licensee or registrant shall change the method observed by him for determining calendar quarters except at the beginning of a year.

**"Calibration"** means the determination of: (1) The response or reading of an instrument relative to a series of known radiation values over the range of the instrument; or (2) The strength of a source of radiation relative to a standard.

**"CFR"** means Code of Federal Regulations.

**"Chelating Agent"** means amine polycarboxylic acids (e.g., EDTA, DTPA), hydroxycarboxylic acids and polycarboxylic acids (e.g., citric acid, carbonic acid and glucinic acid).

**"Committed dose equivalent"** ( $H[T,50]$ ) means the dose equivalent to organs or tissues of reference (T) 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"** ( $H[E,50]$ ) means the sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to each of these organs or tissues ( $H[E,50] = \text{SUM } w[T]H[T,50]$ ).

**"Critical Organ"** means that organ (or tissue) in which the dose equivalent would be the most significant due to a combination of the organ's radio sensitivity and a particular dose pattern throughout the body.

**"Curie"** means a unit of quantity of radioactivity. One curie (Ci) is that quantity of radioactive material which decays at the rate of  $3.7 \times 10^{10}$  disintegrations (transformations) per second (dps or tps).

**"Declared pregnant woman"** means any woman who has voluntarily informed her employer, in writing, of her pregnancy.

**"Deep dose equivalent"** ( $H[d]$ ) means the dose equivalent at a tissue depth of 1 centimeter (1,000 milligrams per square centimeter) from external whole-body exposure.

**"Depleted uranium"** means the source material uranium in which the isotope uranium-235 is less than 0.711 weight percent of the total uranium present. Depleted uranium does not include special nuclear material.

**"Dose"** (radiation dose) means either absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, total organ dose equivalent, or total effective dose equivalent.

---

**"Dose equivalent"** (H[T]) means the product of the absorbed dose in tissue, quality factor and all other necessary modifying factors (e.g., a distribution factor for non-uniform deposition) at the location of interest. The units of dose equivalent are the sievert (Sv) and the rem.

**"Dose limits"** (limits) means the permissible upper bounds of radiation doses established by, or in accordance with, 32 Ill. Adm. Code: Chapter II, Subchapters b and d.

**"Dose rate"** means the dose per unit of time, such as rem per minute (rem/min) and millirem per hour (mrem/hr). See also "Exposure rate"

**"Effective dose equivalent"** (H[E]) means the sum of the products of the dose equivalent to each organ or tissue (H[T]) and the weighting factor (W[T]) applicable to each of the body organs or tissues that are irradiated (H[E] =  $\sum w[T]H[T]$ ).

**"Embryo/fetus"** means the developing human organism from conception until the time of birth.

**"Exposure"** means: (1) The quotient of dQ divided by dm where "dQ" is the absolute value of the total charge of the ions of one sign produced in air when all the electrons (negatrons and positrons) liberated by photons in a volume element of air having mass "dm" are completely stopped in air; or (2) Irradiation by ionizing radiation or radioactive material. NOTE: The context makes clear which is the appropriate definition.

**"Exposure rate"** means the exposure per unit of time, such as roentgen per minute (R/min) and milliroentgen per hour (mR/hr). See also "Dose rate".

**"External dose"** means that portion of the dose equivalent received from any source of radiation outside the body.

**"Extremity"** means a hand, elbow, arm below the elbow, foot, knee and leg below the knee.

**"Eye dose equivalent"** or "lens dose equivalent" means the external dose equivalent to the lens of the eye at a tissue depth of 0.3 centimeter (300 milligrams per square centimeter).

**"Gray"** (Gy) is the SI unit of absorbed dose. One gray is equal to an absorbed dose of 1 joule per kilogram (J/kg) (1 Gy = 100 rad).

**"Half life, biological"** is the time required for the body to eliminate one-half of an administered dosage of any substance by regular process of elimination.

**"Half life, effective"** is the time required for a radioactive element in a body to decrease to one half of its original value as a result of the combined action of radioactive decay and biological elimination. The effective half life is always shorter than either the radiological or biological half life.

**"Half life, radiological"** is the time required for the amount of a particular radionuclide to decrease to one half of its original value.

**"Healing Arts"** means the art or science or group of arts or sciences dealing with the prevention and cure or alleviation of human ailments, diseases or infirmities, and has the same meaning as "medicine" when the latter term is used in its comprehensive sense.

**"High radiation area"** means any area, accessible to individuals, in which radiation levels from radiation sources external to the body could result in an individual receiving a dose equivalent in excess of 1 mSv (0.1 rem) in 1 hour at 30 centimeters from any source of radiation or from any surface that the radiation penetrates.

**"Human use"** means the internal or external administration of radiation or radioactive materials to human beings.

---

**"Individual"** means any human being.

**"Individual monitoring"** means the assessment of: (1) Dose equivalent by the use of individual monitoring devices or by the use of survey data; or (2) Committed effective dose equivalent by bioassay or by determination of the timeweighted air concentrations to which an individual has been exposed (i.e., DAChours). (For the definition of DAC-hours, see 32 Ill. Adm. Code 340.30.)

**"Individual monitoring devices"** (personnel dosimeter or dosimeter) means devices designed to be worn by a single individual for the assessment of dose equivalent. Examples of individual monitoring devices are film badges, thermoluminescence dosimeters (TLDs), optically stimulated luminescence dosimeters (OSLs), pocket ionization chambers, personal air sampling devices and electronic dosimeters (e.g., silicon diode dosimeters).

**"Inspection"** means an official examination or observation including, but not limited to, tests, surveys and monitoring to determine compliance with rules, regulations, orders, requirements and conditions of the Illinois Department of Nuclear Safety.

**"Ionizing Radiation"** (see "Radiation")

**"Isotope"** is a different form of the same chemical element distinguished by having a different number of neutrons (but the same number of protons) in the nucleus. Nearly identical chemical properties exist between isotopes of a particular element. Isotope should not be used as a synonym for nuclide.

**"License"** means any license issued by the Illinois Emergency Management Agency in accordance with 32 Ill. Adm. Code: Chapter II, Subchapters b and d.

**"Licensed material"** means radioactive material received, possessed, used, transferred or disposed of under a general or specific license issued by the Illinois Department of Nuclear Safety.

**"LSC or Liquid scintillation counting"** is a standard laboratory method for measuring radiation from low energy beta-emitting nuclides. Samples are dissolved or suspended in a "cocktail" containing an aromatic solvent and small amounts of other additives known as fluors. Beta particles emitted from the sample transfer energy to the solvent molecules, which in turn transfer their energy to the fluors; the excited fluor molecules dissipate the energy by emitting light. In this way, each beta emission (ideally) results in a pulse of light. The samples are placed in small transparent or translucent (often glass or plastic) vials that are loaded into an instrument known as a liquid scintillation counter.

**"Lost or missing source of radiation"** means any licensed or registered source of radiation whose location is unknown. This definition includes, but is not limited to, radioactive material that has been shipped but has not reached its planned destination and whose location cannot be readily traced in the transportation system.

**"Member of the public"** means any individual, except an individual who is performing assigned duties for the licensee or registrant involving exposure to sources of radiation.

**"Minor"** means an individual less than 18 years of age.

**"Monitoring"** (radiation monitoring or radiation protection monitoring) means the measurement of radiation, radioactive material concentrations, surface area activities or quantities of radioactive material and the use of the results of these measurements to evaluate potential exposures and doses.

**"NORM" or "NARM"** means any naturally occurring or accelerator-produced radioactive material. It does not include byproduct, source or special nuclear material.

**"Natural radioactivity"** means radioactivity of naturally occurring nuclides.

---

**"Non-ionizing radiation"** means radiation that does not produce ionization. Examples are sound, radio waves, visible, infrared, and ultraviolet light.

**"Occupational dose"** means the dose received by an individual in the course of employment in which the individual's assigned duties for the licensee or registrant involve exposure to sources of radiation. Occupational dose does not include dose received from background radiation, from any medical administration the individual has received, from exposure to individuals administered radioactive material and released as authorized by the Illinois Department of Nuclear Safety, from voluntary participation in medical research programs, or as a member of the public.

**"Package"** means the packaging, together with its radioactive contents, as presented for transport.

**"Person"** means any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, agency, political subdivision of this State, any other State or political subdivision or agency thereof, and any legal successor, representative, agent, or agency of the foregoing, other than the U.S. Nuclear Regulatory Commission, or any successor thereto, and other than federal government agencies licensed by the U.S. Nuclear Regulatory Commission, or any successor thereto. "Person" also includes a federal entity (and its contractors) if the federal entity agrees to be regulated by the State or as otherwise allowed under federal law.

**"Public dose"** means the dose received by a member of the public from sources of radiation from licensed or registered operations. Public dose does not include occupational dose, or dose received from background radiation, from any medical administration the individual has received, from exposure to individuals administered radioactive material and released as authorized by the Illinois Department of Nuclear Safety, or from voluntary participation in medical research programs.

**"Rad"** is a unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs per gram or 0.01 joule per kilogram (J/kg) (0.01 Gy).

**"Radiation"** (ionizing radiation) means gamma rays and X-rays, alpha and beta particles, high-speed electrons, neutrons, protons, and other nuclear particles, or electromagnetic radiations capable of producing ions directly or indirectly in their passage through matter; but does not include sound or radio waves, or visible, infrared or ultraviolet light.

**"Radiation area"** means an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.05 mSv (0.005 rem) in 1 hour at 30 centimeters from the source of radiation or from any surface that the radiation penetrates.

**"Radiation emergency"** means the uncontrolled release of radioactive material from a radiation installation which poses a potential threat to the public health, welfare and safety.

**"Radiation Installation"** is any location or facility where radiation machines are used or where radioactive material is produced, transported, stored, disposed or used for any purpose, except where such radioactive materials or facility are subject to regulation by the Nuclear Regulatory Commission.

**"Radiation machine"** means any device that produces radiation when in use, except those which produce radiation only from radioactive materials.

**"Radiation safety officer"** means an individual who has the knowledge and responsibility to apply appropriate radiation protection regulations and has been assigned such responsibility by the licensee or registrant.

**"Radioactive material"** means any solid, liquid or gaseous substance, which emits radiation spontaneously.

**"Radioactivity"** means the disintegration (transformation) of unstable atomic nuclei by the emission of radiation.

---

**"Rem"** means the special unit of any of the quantities expressed as dose equivalent. The dose equivalent in rem is equal to the absorbed dose in rad multiplied by the quality factor (1 rem = 0.01 Sv).

**"Restricted area"** means any area to which access is limited by the licensee or registrant for purposes of protecting individuals against undue risks from exposure to sources of radiation. Restricted area shall not include areas used for residential quarters, but separate rooms in a residential building may be set apart as a restricted area.

**"Roentgen"** means the special unit of exposure. One roentgen (R) equals  $2.58 \times 10^{-4}$  coulombs per kilogram (C/kg).

**"Scintillation counter"** measures ionizing radiation. The counter consists of a transparent crystal (such as NaI or Ge), usually phosphor, plastic, or organic liquid (see liquid scintillation counting) that fluoresces when struck by ionizing radiation. A sensitive photomultiplier tube (PMT) measures the light from the crystal. The PMT is attached to an electronic amplifier and other electronic equipment to count and possibly quantify the amplitude of the signals produced by the photomultiplier.

**"Sealed source"** means any device containing radioactive material to be used as a source of radiation which has been constructed in such a manner as to prevent the escape of any radioactive material.

**"Shallow dose equivalent"** (H[S]), which applies to the external exposure of the skin or an extremity, means the dose equivalent at a tissue depth of 0.007 centimeter (7 milligrams per square centimeter) averaged over an area of 1 square centimeter.

**"SI"** means the abbreviation for the International System of Units.

**"Sievert"** (Sv) means the SI unit of any of the quantities expressed as dose equivalent. The dose equivalent in sievert is equal to the absorbed dose in gray multiplied by the quality factor (1 Sv = 100 rem).

**"Source of radiation"** means any radioactive material or any device or equipment emitting, or capable of producing, radiation.

**"Special nuclear material"** means: (1) Plutonium, uranium 233, uranium enriched in the isotope 233 or in the isotope 235, and any other material which the Illinois Emergency Management Agency declares by order to be special nuclear material after the U.S. Nuclear Regulatory Commission, or any successor thereto, has determined the material to be such, but does not include source material; or (2) Any material artificially enriched by any of the foregoing, but does not include source material.

**"Survey"** means an evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal, or presence of sources of radiation. Such an evaluation includes, but is not limited to, measurements or calculations of levels of radiation, or concentrations or quantities of radioactive material present.

**"Thermoluminescent dosimeter or TLD"** is a device that measures ionizing radiation exposure by measuring the amount of visible light emitted from a crystal in the detector when the crystal is heated. The amount of light emitted is dependent upon the radiation exposure upon the crystal.

**"Total effective dose equivalent"** (TEDE) means the sum of the deep dose equivalent for external exposures and the committed effective dose equivalent for internal exposures.

**"Total organ dose equivalent"** (TODE) means the sum of the deep dose equivalent and the committed dose equivalent to the organ receiving the highest dose as described in 32 Ill. Adm. Code 340.1160(a)(6).

**"Unrestricted area"** means any area to which access is not controlled by the licensee or registrant for purposes of protection of individuals from exposure to radiation and radioactive material, and any area used for residential

---

quarters. NOTE: Licensees or registrants may control access to certain areas for purposes other than radiation protection, but such action does not affect whether the areas are unrestricted areas as defined in this Part.

**"Very high radiation area"** means an area, accessible to individuals, in which radiation levels from radiation sources external to the body could result in an individual receiving an absorbed dose in excess of 5 Gy (500 rad) in 1 hour at 1 meter from a source of radiation or from any surface that the radiation penetrates. NOTE: For very high doses received at high dose rates, units of absorbed dose (e.g., gray and rad) are appropriate rather than units of dose equivalent (e.g., sievert and rem).

**"Whole body"** means, for purposes of external exposure, head, trunk (including male gonads), arms above the elbow or legs above the knee.

**"Worker"** means any individual engaged in work under a license or registration issued by the Department and controlled by a licensee or registrant, but does not include the licensee or registrant.

**"Year"** means the period of time beginning in January used to determine compliance with the provisions of 32 Ill. Adm. Code: Chapter II, Subchapters b and d. The licensee or registrant may change the starting date of the year used to determine compliance by the licensee or registrant provided that the decision to make the change is made not later than December 31 of the previous year. If a licensee or registrant changes a year, the licensee or registrant shall assure that no day is omitted or duplicated in consecutive years.

