Radiation Safety Manual

University of Nebraska Medical Center

Emergency Numbers

1. For incidences not involving personal injury:

Normal Working Hours

Radiation Safety Office: (402) 559-6356

Security Dispatch: On Campus: 9-5555 Off-Campus: (402) 559-5555

After Normal Working Hours

Security Dispatch: On Campus: 9-5555 Off-Campus: (402) 559-5555

Radiation Safety Pager: (402) 888-1880

Radiation Safety Cell Phone: (402) 680-5444

2. For incidences involving personal injury and radiation:

Security Dispatch: On Campus: 9-5555 Off-Campus: (402) 559-5555

Be prepared to state:

- Your name
- Location
- If Radioactive Material is Involved, the Nuclide & Quantities
- Brief Description of Incidence
- A call back number where you may be reached

INTRODUCTION

The University of Nebraska Medical Center (UNMC) is a unit of the University of Nebraska system and is the health sciences training center for the state of Nebraska. UNMC and its teaching hospital, Nebraska Medicine, have gained recognition as a center of excellence for teaching, quality patient care, and research programs. Radiation is used extensively in the hospital in the treatment of patients and in UNMC research laboratories to learn more about normal body function and diseases with the goal of developing better means of treating them. The high quality of medical care that we have today would not exist without the use of radiation.

UNMC is authorized to procure and use radioactive materials under a "specific Type A license of broadscope" issued by the Nebraska Department of Health and Human Services (NDHSS). This type of license is issued only to institutions who have demonstrated extensive experience and proficiency in the safe use of radioactive materials as evidenced by an outstanding regulatory compliance history. It should be noted that all radioactive material use in patients or human subjects fall under a separate radioactive material license issued to the hospital, Nebraska Medicine.

UNMC also employs the use of machines that electronically generate ionizing radiation (x-rays) in research and UNMC dental departments. These devices are listed on a "Certification of Registration of for Radiation Generating Equipment" issued by the NDHSS and are subject to the state regulations applicable to the device type and internal UNMC policies and procedures. Nebraska Medicine has been issued a registration for its own x-ray devices.

This manual describes the policies and procedures required of UNMC under the conditions of the radioactive material license and State of Nebraska regulations on the use of ionizing radiation. Additionally, it reflects authoritative standards, guidelines, recommendations and research data concerning the physical aspects and bioeffects of ionizing radiation obtained from the scientific literature.

Sections A through C address the use of radioactive material at UNMC. Section A contains information relevant to administrative policies. Section B contains specific procedures associated with the use and documentation of radioactive materials. Section C contains general information and guidance pertaining to radioactive material. Section D was added to address the procedures and requirements associated with the machines that generate x-rays (section D may reference previous sections that are applicable both to radioactive material and x-ray devices).

Frank Rutar, MS, CHP, CHMM
Director, Radiation Safety

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Section A-1

UNMC Radiation Safety Organization

Ionizing radiation is among the most versatile and useful tools of modern medicine and biomedical research. Like many other instruments of medicine and research, ionizing radiation is potentially hazardous unless used with strict adherence to safety rules and procedures.

The rules and procedures set forth in the Manual have one single, straightforward purpose—to protect UNMC patients, employees, and the public against unnecessary and potentially harmful radiation exposure.

A flow chart of the overall UNMC Radiation Safety Organization is provided at the end of this section. However, the five major categories of group and individual responsibility that are involved in the radiation safety program at UNMC are:

A. Chancellor:
This individual delegates sufficient authority to the Radiation Safety Committee to establish and enforce UNMC policies and procedures.

B. Radiation Safety Committee (RSC):
This is a high-level group of scientists and researchers appointed by the Chancellor to establish policies and regulations governing the use of ionizing radiation in UNMC intramural programs.

C. Radiation Safety Office (RSO):
An operating group of trained health physicists and technicians which is responsible for UNMC-wide compliance with these policies and regulations; it also provides a variety of technical services and audits necessary to achieving such compliance.

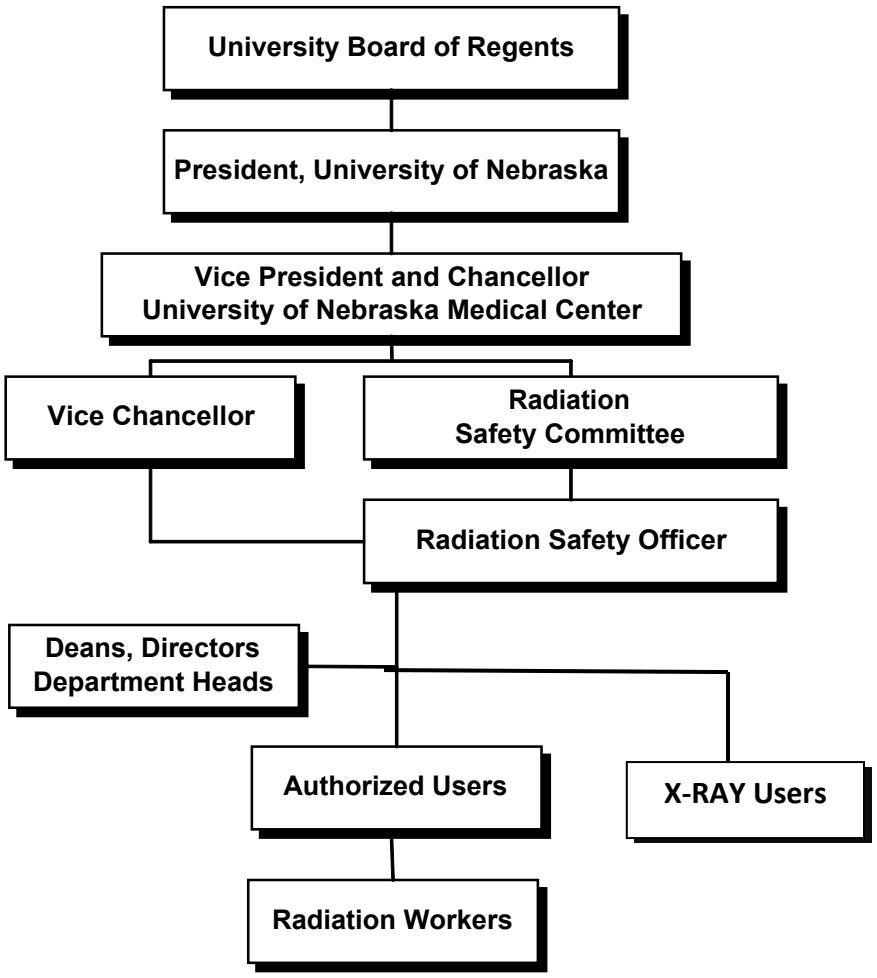
D. Authorized User (AU):
Individuals whose training and experience are such that they have been authorized by the Radiation Safety Committee to use ionizing radiation in

their clinical research and/or laboratory research activities.

E. Radiation Worker:
Individuals engaged in clinical and laboratory research activities which involve actual use and handling of materials producing ionizing radiation. These personnel work under the supervision of Authorized Users.

All of these groups/individuals are equally important. The detailed descriptions are given of the responsibilities of each are described in the *Section A-2 (Responsibilities)*.

Organization for UNMC Radiation Safety



Section A-2
Responsibilities

This section describes the responsibilities of the various members of the UNMC Radiation Safety Program:

A. Chancellor (Executive Committee)
B. Radiation Safety Committee (RSC)
C. Radiation Safety Office (RSO)
D. Authorized User (AU)
E. Radiation Worker

A. Chancellor (Executive Management)

The UNMC Chancellor or his/her delegate is responsible for oversight of UNMC's radiation safety program and has the ultimate responsibility of the license and the activities associated with the license. Executive management has an important role in implementing and managing the radiation safety program. Executive Management will ensure that the "As Low as Reasonably Achievable" (ALARA) concept is utilized by all employees, staff, students, patients and visitors. This responsibility is carried out by means of:

1. Authority to delegate resources for the program and appropriate funds in a timely manner.
2. Available to facilitate effective and immediate action on behalf of management, the RSC, and the RSO, particularly in the event of an emergency.
3. Authority to make prompt decisions without having to consult with higher management officials, including the authority to take whatever action is necessary to ensure that all radiation safety practices are in accordance with the regulations and conditions of

the license.

B. Radiation Safety Committee

The purpose of the UNMC Radiation Safety Committee (RSC) is to ensure the safe and compliant handling and use of radiation sources and that radiation exposure to employees, staff, patients, and the environment are to be maintained As Low as Reasonably Achievable. The Radiation Safety Committee (RSC) works with executive management and the Radiation Safety Officer (RSO) in implementing the radiation safety program, and is involved in establishing policies and procedures for managing the UNMC radiation safety program.

A chairperson is selected for the committee. The Chairperson will be selected upon several factors including knowledge of radiation safety issues, good leadership abilities, the authority and credibility by virtue of his or her position within the facility, and with time to devote to the position in addition to other responsibilities he or she might have within the facility. In general, the RSO should not be appointed as the chairperson of the committee, since the RSO is responsible for the day-to-day operation of the radiation safety program and may be too closely involved with the licensed activities to be objective.

The purview of the RSC extends throughout areas where UNMC maintains jurisdiction.

1. Regulatory requirements state that the RSC shall be composed of a Radiation Safety Officer (RSO), a representative of the UNMC executive management, and persons trained and experienced in the safe use of radioactive materials representing each type of use.

2. At UNMC, the RSC and its chairperson are appointed by and are responsible to the executive management. The RSC will conduct business at formal meetings held as often as necessary, but at a

minimum will meet at intervals not exceeding six (6) months. The RSO will serve as the executive secretary.

3. To establish a quorum and to conduct business, one-half of the Committee's membership shall be present, including quorum consisting of the chairperson of the committee (or his or her designee), the RSO, the executive management (or his or her alternate), a representative from each area of use from which specific issues will be discussed, and any other member whose field of expertise is necessary for the discussion.

The RSC is responsible for the radiation safety aspects of all programs to ensure that ionizing radiation is used safely and compliantly with federal, state, and local regulations. Duties and responsibilities of the RSC include:

1. Evaluate and approve new authorized users of radioactive material. The evaluation will be based upon minimum criteria developed by the RSC (e.g., training and experience requirements, protocol for using radioactive material, general design of facilities, protective equipment, surveys for removable contamination, waste disposal, etc.). To approve a new User, a simple majority of a quorum of the Radiation Safety Committee is required prior to authorization.

2. Evaluate and approve new uses of ionizing radiation (radioactive material and machine produced radiation) To approve a new use, a simple majority of a quorum of the Radiation Safety Committee is required prior to authorization.

3. Evaluate and approve modifications to existing uses (e.g., amendments to an authorized user's radioactive material license). To approve a modification/amendment, a simple majority of a quorum of the Radiation Safety Committee is required prior to authorization. The exception is simple amendments including addition/deletion or rooms for authorized use and irradiator operators.

4. The RSO and RSC Chairperson must sign all Radioactive Material Licenses and amendments. In their absence, the license may be signed by an alternate, provided the alternate meets applicable regulatory requirements and is approved by the Radiation Safety Committee (typically another RSC member).

5. Review and approval of policy or procedural changes to the radiation safety program. To approve a new policy or procedure, a simple majority of a quorum of the Radiation Safety Committee is required prior to authorization. The approved change will be documented and will state the reason for the changes and summarize the radiation safety matters that were considered prior to approval of the change. The RSC will oversee the implementation of the change including training of personnel and audits to ensure compliance.

6. Receive, review, and take appropriate action on reports from the RSO, (e.g., area monitoring; personnel monitoring; accidents in handling, storage, and use of radioactivity; items of non-compliance identified in audits, loss or theft of any amount of radioactivity; records of radionuclide procurement and disposal).

7. Review the program for maintaining doses ALARA and provide any necessary recommendations to ensure this.

8. Work with the executive management to share responsibility with the RSO for conducting periodic audits of the radiation safety program. Additionally, the RSC reviews any consultant's audit findings and documents the acceptance or rejection of the consultant's findings in the RSC Committee minutes.

9. Review the results of the annual review of the radiation safety program. Licensees should analyze possible trends and implement timely corrective actions as needed.

C. Radiation Safety Officer

The Radiation Safety Officer (RSO) who is qualified by training and experience in radiation protection who is responsible for radiation safety and compliance with the regulations for the use of byproduct material. The RSO is a member of the RSC and works closely with the RSC and executive management in implementing the radiation safety program.

The Radiation Safety Office, which is comprised of trained health physicists and technicians under the direction of the Radiation Safety Officer, is responsible for: UNMC-wide compliance with policies and regulations which includes performing audits of all areas of use and individuals who are authorized to use byproduct material to ensure work is done in accordance with the license, regulations, and user permit conditions. The Radiation Safety Office also provides a variety of technical services and audits necessary to achieving such compliance. Specific duties and responsibilities include but are not limited to:

1. Monitoring and surveys of all areas in which radioactive material is used
2. Overseeing ordering, receipt, surveys, and delivery of byproduct material
3. Packaging, labeling, surveys, etc., of all shipments of byproduct material leaving the institution
4. Monitoring programs, including determining the need for and evaluating bioassays, monitoring personnel exposure records, and developing corrective actions for those exposures approaching maximum permissible limits
5. Developing and implementing an ALARA program
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13. Develop and implement of a security program for radioactive material in accordance with 180 NAC Chapter 24, “Physical Protection of Radioactive Material”
14. Maintaining all required records

D. Authorized User

The Authorized Users (AU) is responsible for ensuring that individual responsibilities are discharged by those under their control, and are further responsible for:

1. Adequate planning. Before an experiment is performed, the AU should determine the types and amount of radiation or radioactive material to be used. This will generally give a good indication of the protection required. The procedure must be well outlined. In many cases, before the procedure is actually performed with radiation, it should be rehearsed so as to preclude problem areas or unexpected circumstances. In any situation where there is an appreciable radiation hazard, the Radiation Safety Office shall be consulted before proceeding.

2. Instructing supervised employees in safe techniques and in the application of approved radiation safety practices. Ensuring attendance at required radiation safety courses.

3. Furnishing the Radiation Safety Office with information concerning individuals and activities in their areas — particularly, changes in their personnel rosters and authorized room locations.

4. Contacting the Radiation Safety Office whenever major changes in

operational procedures, alterations in use locations (e.g., the removal of radiochemical fume hood), or when new operations, which might lead to personnel exposure, are anticipated.

5. Complying with the regulations governing the use of radioactive materials, as established by the UNMC Radiation Safety Committee. This includes:

    a) Utilizing the correct procedure for the procurement of radioactive materials by purchase or transfer.

    b) Posting areas where radionuclides are kept or used, or where radiation areas may exist.

    c) Performing and recording laboratory surveys consistent with nuclide use and license requirements.

    d) Recording the receipt, transfer, and disposal of radioactive materials.

    e) Ensuring that radioactive waste requirements are followed.

    f) Taking steps to prevent the transfer of radioactive materials to unauthorized individuals. This includes the proper disposition of radioactive materials possessed by terminating workers and securing radioactive materials against unauthorized removal.

6. Keeping stocks of stored radioactive materials to a minimum within laboratory areas. Maintaining radionuclide inventory under proper security to prevent unauthorized use.

7. Complying with the proper procedure for termination of employment or termination of any experiment using radioactive materials. The Authorized User is reminded, under the terms and conditions of the UNMC license, to return to the Radiation Safety

Office all radioactive materials (including waste) assigned under his/her license. Particular care should also be exercised to see that specialized equipment such as personnel monitoring devices (e.g., badges), and shielding materials are returned to the Radiation Safety Office. A final termination survey must also be performed.

E. Radiation Worker

Each individual at UNMC who has any contact with radioactive materials is responsible for:

1. Keeping his/her exposure to radiation as low as reasonably achievable (ALARA), and specifically below the maximum permissible doses as listed in the following table:

ANNUAL OCCUPATIONAL DOSE LIMITS FOR ADULTS	
Whole body - Total Effective Dose Equivalent (TEDE)	5 Rem
Lens of the eye (LDE)	15 Rem
Extremities - Shallow Dose Equivalent (SDE)	50 Rem
Skin - Shallow Dose Equivalent (SDE)	50 Rem
Total Organ Dose Equivalent (TODE)	50 Rem

2. Applying the principles of time, distance and shielding to reduce exposures.

3. Wearing the prescribed monitoring equipment such as badges or pocket dosimeters in radiation areas. Personnel who work only with pure alpha emitters or only with pure beta emitters having a maximum energy of less than 0.25 MeV will not be required to wear badges. This includes H-3, C- 14 and S-35.

4. Surveying hands, shoes, and body for contamination, and removing all loose contamination before leaving the laboratory.

5. Utilizing appropriate protective measures such as:

    a) Wearing protective clothing whenever contamination is possible. Do not wear such clothing outside of the laboratory area if contaminated. Contaminated clothing should be checked by Radiation Safety to determine appropriate actions.

    b) Wearing gloves or double gloves when necessary.

    c) Using protective barriers and other shields whenever practical.

    d) Using pipette filling devices. Never pipette radioactive solutions by mouth.

6. The use of food, drink, candy, handling of contact lenses, tobacco, and application of cosmetics, lotion, or lip balm is prohibited in areas where radioactive material is used or stored. Refrigerators shall not be used jointly for foods and radioactive materials.

7. Maintaining good safety practices.

    a) Gloves should be worn at all times when working with radioactive material.

    b) Do not work with radioactive materials if there is a break in the skin below the wrist without first covering it.

    c) Wash hands thoroughly after handling radioactive materials.

8. Surveying the immediate areas, (e.g., hoods, benches, etc.), in which radioactive materials are being used. Any contamination observed

should be clearly marked and decontaminated.

9. Keeping the laboratory neat and clean. The work area should be free from equipment and materials not required for the immediate procedure. Wherever practical, keep work surfaces covered with absorbent material, preferably in a stainless steel tray or pan, to limit and collect spillage in case of an accident.

10. Labeling and isolating radioactive waste and equipment, such as glassware, used in laboratories for radioactive materials. Once used for radioactive substances, equipment should not be used for other work, and shall not be sent from the area to central cleaning facilities, repair shops, or to surplus, until demonstrated to be free of contamination.

11. Requesting Radiation Safety Office supervision of any emergency repair of contaminated equipment in the laboratory by shop personnel or by commercial service contractors. At no time shall service personnel be permitted to work on equipment in radiation areas without the presence of a member of the laboratory staff to provide specific information.

12. Reporting accidental inhalation, ingestion, or injury involving radioactive materials to the supervisor and the Radiation Safety Office, and carrying out their recommended corrective measures. The individual shall cooperate in any and all attempts to evaluate his exposure.

13. Carrying out decontamination procedures when necessary, and for taking the necessary steps to prevent the spread of contamination to other areas.

14. Complying with the Radiation Safety Office requirements for thyroid burden measurements, and the submission of urine samples for radioassay when needed.

15. Ensuring training requirements are followed.

16. Complying with the “Safety Rules”, “Emergency Procedures”, and “Notice to Employees” posted in the laboratory.

Section A-3

Overview of the ALARA Policy

A. Introduction

As defined in Title 10, Section 20.1003, of the Code of Federal Regulations (10 CFR 20), ALARA is an acronym of "as low as (is) reasonably achievable", which means that making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical, consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to the benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of ionizing radiation in the public interest.

UNMC is committed to maintaining radiation exposures to workers and the public from radiation sources to "As Low As is Reasonably Achievable" or ALARA. ALARA is a professional philosophy of excellence and a program designed to achieve that excellence. ALARA is not intended to be a "Standard of Care" but rather a professional philosophy of excellence.

The policy used by UNMC is based on State of Nebraska Department Health and Human Services (DHHS) regulations and incorporates United States Nuclear Regulatory Commission (NRC) Regulatory Guides. The ALARA Program at UNMC emphasizes the following objectives:

1. Maintain individual and collective radiation doses ALARA.

2. Identify responsibilities at all levels of organization.

3. Training of workers regarding the policies, goals and methods to achieve dose reduction with emphasis on personal responsibility in

the performance of their duties.

4. Incorporate design features into plans when evaluating existing or new protocols to maintain ALARA.

B. Responsibilities

As mentioned above, responsibilities at all levels of UNMC must be identified. Overall program responsibility for efforts to maintain exposures ALARA resides with the Chancellor and then with the Radiation Safety Committee. The Committee serves as an advisory panel to the Chancellor. The Committee is responsible for reviewing the effectiveness of the ALARA Program and reviews tasks and procedures with potentially significant personal exposures.

The Radiation Safety Officer has the responsibility for administering the day-to-day operations of the ALARA Program and ensures recommendations provided by the Committee are properly implemented. If needed, this individual provides radiological engineering assistance and special training in proper radiation protection practices and procedures.

The Authorized User has a responsibility to ensure the radiation workers under their supervision utilize ALARA principles. They will provide training to individuals under their supervision in protocol techniques which will reduce radiation exposure, and to work with the Radiation Safety Officer and/or Radiation Safety Committee in achieving ALARA goals.

Radiation Workers and X-Ray Users/Operators have the responsibility to maintain their exposures as low as reasonably achievable. With proper training, the duties required by their jobs can be completed in a manner which consistently follows ALARA guidelines.

C. Standards

Standards for achievement of ALARA goals are provided in Table 1. The ALARA action levels are set by the UNMC Radiation Safety Committee and evaluated annually.

Any doses above the ALARA action levels require that the Radiation Safety Officer review the circumstances pertaining to this dose and determine if additional actions need to be taken or if further investigation is required. An investigation requires that the Radiation Safety Officer investigate the cause of the dose and steps that may be required to prevent this dose level in the future with consideration of cost and scientific impact. All doses above the ALARA action levels will be reported to the Radiation Safety Committee.

D. Guidelines

These guidelines are intended to ensure that appropriate practices are incorporated at UNMC. A cost-benefit evaluation of dose reduction measures and evaluation are provided.

1. When scheduled or anticipated workloads are anticipated that may incur higher radiation doses, the Radiation Safety Committee may set person-rem goals for the project or year. The goals are not an estimate of the person-rem commitment but are a quantity that requires planning and proper execution to attain.

2. Periodic review and audits of Authorized User progress in meeting ALARA goals is performed by the UNMC Radiation Safety Officer or his designee. Progress in meeting goals will be reviewed by the UNMC Radiation Safety Committee.

3. When requested, the Radiation Safety Officer or his designee will assist in the planning of special procedures which involve large

quantities of radioactivity or unusual protocols, so that proper guidance can be provided in exposure reduction techniques.

4. Suggestions for dose reductions and other concerns regarding radiation protection are encouraged. These suggestions are reviewed by the Radiation Safety Committee and may be adopted as a good practice at UNMC for implementation at a later date.

Table 1: ALARA Action Levels

Dose Quantity	Regulatory Limit	ALARA Level
Total Effective Dose Equivalent (TEDE) Note 1	5000 mrem/yr	**300 mrem/monitoring period**
Lens of Eye (LDE)	15,000 mrem/yr	**900 mrem/ monitoring period**
Skin (SDE-WB)	50,000 mrem/yr	**3000 mrem/ monitoring period**
Extremity (SDE-ME)	50,000 mrem/yr	**3000 mrem/ monitoring period**
Embryo/Fetus Note 2	500 mrem/gestation	**40 mrem/month**
Internal Dose	5000 mrem TEDE or 50,000 mrem TODE	**Evaluation > 0.02 ALI Investigation > 0.10 ALI**
Member of the General Public	100 mrem/yr or > 2 mrem in any hour	**Regulatory Limit but evaluated on a case by case basis**

Note 1: For most workers the deep dose equivalent (DDE) measured by their radiation badge can be assumed to be a reasonable measurement of their TEDE.

Note 2: Only applicable to a Declared Pregnant Worker (DPW).

E. Cost-Benefit

Justification of radiation exposure reduction efforts may require that cost and other impacts be weighed against expected benefits of the action. This is to determine what level of protection is practicable or is "reasonably achievable". Due to budget limitations, alternative methods of achieving exposure reduction may be considered. Methods such as cost-benefit or value impact techniques can be used to aid in decisions regarding dose reduction actions.

1. Quantitative cost-benefit analysis methods require that tangible and intangible costs, impacts and benefits be reduced to a common monetary basis. UNMC arbitrarily assigns a monetary value to a person-rem of personnel exposure for cost-benefit analysis.

2. Dose reduction measures or projects whose estimated total cost is $50,000 or more may be supported by cost-benefit analysis which will be performed by the requestor.

3. Individual projects, such as modifications for large scale shielding, may be supported by a cost-benefit analysis.

4. Cost-benefit analysis will also be performed at the direction of the UNMC Radiation Safety Committee.

F. Implementation

Overall ALARA Program direction is the responsibility of the UNMC Chancellor, under advisement by the Radiation Safety Committee. Implementation includes the individual responsibilities outlined in the Responsibilities section (presented earlier) and summarized here:

1. Use of temporary shielding when needed.

2. Achieving ALARA goals.

3. Protocol reviews to ensure elimination of unsafe practices.

4. Recognizing good radiation protection practices.

5. Providing required annual radiation protection training/workshops for all individual users.

6. Providing periodic audits on each Authorized User by the Radiation Safety Officer or his designee(s) to include evaluation of:

   a) Proper storage and shielding of radioactive material.

   b) Inventory control.

   c) Record keeping (i.e., amount of activity on hand, contamination surveys, sewer disposal).

   d) Radiation surveys.

   e) Instrument operation.

   f) Verification of training completed.

   g) ALARA techniques being implemented during protocols, etc.

   h) Proper security of radioactive material.

7. Account for engineering changes and updates such as fume hood modifications, to include annual inspections for proper performance.

8. Notifications to affected personnel when systems are to be taken out of service for maintenance purposes.

9. Monitoring exposure through dose tracking for applicable individuals. Data and information acquired from the above activities are evaluated by the Radiation Safety Committee to assess the effectiveness of the UNMC policies, procedures and engineering measures established for reduction purposes.

G. Conclusion

The diversity of situations encountered in research should encourage individuals at UNMC to work together to maintain exposure levels As Low As is Reasonably Achievable (ALARA). With professional experience, reasoning and judgment of those involved, ALARA goals can be obtained.

Section A-4

Radioactive Material License

A. What is a Radioactive Material License?

The use of non-exempt amounts of radioactive material must be authorized under a radioactive material license issued by the Nebraska Department of Health and Human Services (DHHS), Office of Radiological Health. The DHHS has issued the University of Nebraska Medical Center (UNMC) broadscope, Type A radioactive material license. This type of license is issued for the largest licensed programs and encompasses a broad range of use. This broad scope license requires a **Radiation Safety Committee (RSC)** and **Radiation Safety Officer (RSO),** and the establishment of appropriate administrative procedures to assure:

- Proper control of procurement and use of radioactive material;
- Completion of safety evaluations of proposed uses that take into consideration adequacy of facilities and equipment, training and experience of the user, and operating and handling procedures; and
- Review, approval and recording by the RSC of safety evaluation of proposed uses.

***NOTE**: The hospital (The Nebraska Medical Center) has been issued its own radioactive material license. The use of radioactive material involving a patient or human subject is subject to the conditions of the hospital radioactive material license.*

This broadscope license also allows the Radiation Safety Committee to issue internal licenses to individual researchers to use radioactive material at UNMC (a researcher granted radioactive material licenses is referred to as **Authorized User** or **AU**). The radioactive material license will specify what radioactive material the Authorized User is permitted to use and where, e.g.;

- Rooms authorized for radioactive material usage

- Radionuclides authorized for use, including chemical form and total possession limit (e.g., how much radioactivity the AU may possess)
- Any special conditions of use of radioactive material on this license

B. How to Become an Authorized User

An **Authorized User (AU)** is an individual who has been issued a radioactive material license by the Radiation Safety Committee (RSC) to use radioactive material at UNMC. The following are the steps are involved in obtaining a license:

1. An Authorized User must be an individual whose training and experience satisfies the State of Nebraska regulations as outlined in *Section A-5, Training*, and summarized below:

    a. Completion of the **Initial UNMC Radiation Worker Training**. This training consists of an online training module covering radiation basics and a classroom training session covering how radioactive material is specifically used at UNMC. Contact the Radiation Safety Office to sign up for this training.

    b. A total of **40 hours** of training pertaining to topics related to various aspects of radiation usage. Refer to the *Section A-5, Training,* which will provide a list of classes and assigned clock hours (e.g., Organic Chemistry has been approved for 10 Training is approved for **8 clock hours**).

    c. A total of **160 hours** of actual experience working with radioactive material. You will need to provide the facility name, radioactive material used, and dates of usage. UNMC Radiation Safety will contact the facility to verify this information.

2. Contact the Radiation Safety Office and request an ***Application for a UNMC Radioactive Material License*** (form on the Radiation Safety website). If animal use is intended a ***Radioactive Material Use in Animals Application*** for each animal protocol must also be

completed (form on the Radiation Safety website). It is recommended that an initial appointment be scheduled with Radiation Safety review and clarify the requirements prior to filling out the actual applications.

3. Complete all sections of the application, including signature approval from the Dean or Director in whose department the radioactive material will be used, and submit to Radiation Safety.

4. The Radiation Safety Office will review the application to ensure all necessary requirements are met. Submission of an incomplete application will often result in the delay of license issuance because of the correspondence necessary to obtain the requested information.

5. A "New User" audit will be conducted by Radiation Safety to review the proposed facility, protocols and record keeping requirements. A facilities posting checklist will normally be used to document that the area is properly labeled and acceptable for radioactive material use.

6. Approval is granted when the Radiation Safety Committee determines that the license application is complete. Approval of a new license is by a simple majority vote of the committee or by a quorum of the committee. This approval allows the Authorized User to order and use radioactive material.

C. When Are Amendments Required?

Revisions to an existing license must be submitted to the Radiation Safety Office in writing (memo, license application form, or email from AU). Amendments must be approved prior to initiating any changes.

Amendments must be made for any of the following revisions:

- Adding a new radionuclide.
- Any increase in the maximum amount of activity to be possessed at any one time (includes waste).
- Any new procedure involving radioactive material use (protocol must be submitted and if a new animal protocol is involved, a ***Radioactive Material Use in Animals Application*** for that use must also be submitted).
- Changes in authorized use locations (adding/deleting a room).
- Addition or deletion of operators of irradiators that use a radioactive source.
- Use of a different chemical and/or physical form that increases the radiological risk to personnel (e.g., changing from an I-125 labeled compound to NaI).
- Change in authorized use (e.g., adding animal studies).

The Radiation Safety Officer may approve the addition or deletion of authorized locations of use and irradiator operators, and specific functions approved by the Radiation Safety Committee. All other amendments must be approved by a majority vote of the Radiation Safety Committee members. The Radiation Safety Officer will report all amendments in the Radiation Safety Committee meeting.

D. License Renewals

The expiration date of a radioactive material license will be indicated on the license. Most UNMC radioactive material licenses are valid for five (5) years. However, the actual length of the license depends upon the type and usage of radioactive material by the Authorized User (AU) and by the AU's inspection history.

The Radiation Safety Office (RSO) will notify the AU prior to their license expiration date. To make the renewal process easier for the AU, the Radiation Safety Office will send a copy of the radioactive material license application filled out based upon the information the RSO has on file. The AU should carefully review the application for accuracy, paying particular

attention to:

- New or deleted radionuclides and possession limits
- New or deleted rooms of authorized radioactive material use
- New or deleted radiation workers
- Addition of a new protocol or chemical form (protocol must be included with the renewal application)

If any changes are necessary, the AU may simply indicate these on the application form (e.g., cross-out a current room, write in a new possession limit). After completing any revisions and obtaining signature approval from the AU's Department Head, the application is submitted to Radiation Safety for review.

A renewal request received prior to the expiration date is considered to be in "timely renewal". Under a "timely renewal" status, the Authorized User may continue to order and use radioactive material until final approval or disapproval by the Radiation Safety Committee is determined. If a renewal is not received prior to the expiration date, the Authorized User will be notified that the license is suspended and subsequent orders will not be approved. Revocation of the license may be initiated.

E. Terminations

A license can be terminated upon written request of the Authorized User. At least 30 days prior to vacating the premises the Radiation Safety Office should be notified so that a "Facility Termination Checklist" can be completed. It is the Authorized User's responsibility to ensure that all radioactive material has been removed and a closeout swipe survey has been completed. In order to release an area for unrestricted use the area must be decontaminated to levels as low as reasonably achievable, but in no case should contamination exceed **contamination action levels:**

Radionuclide/Emission	Contamination Wipe Action Level*
Beta-gamma emitters (nuclides with decay modes other than alpha emission)	1000 dpm 100 cm^2
I-131	200 dpm 100 cm^2
Any alpha emitters	100 dpm 100 cm^2
I-125	20 dpm 100 cm^2

*Above background levels

Contact the Radiation Safety Office for assistance in termination of a license.

F. Revocations

Permission to use Radioactive Material can be revoked at any time by a simple majority of the Radiation Safety Committee. The Radiation Safety Officer has also been granted authority by the Chancellor to stop work if unsafe and/or non-compliant work conditions exist. The criteria for revocation include, but are not limited to:

a. Unsafe use of Radioactive Material posing a health and safety problem (as determined by the Radiation Safety Committee).
b. A serious violation of the Radiation Safety Manual or State Regulations (e.g., failure to provide personnel monitoring when required).
c. Repeated violations of the Radiation Safety Manual or State Regulations (e.g., failure to conduct contamination surveys at required frequencies).

G. Audits

A Radioactive Material License may be subject to an audit at any time. The purpose of any audit is to ensure the safe and compliant use of radioactive material. Audits may be conducted by either the regulatory agency (State of Nebraska Office of Radiological Health) or by the UNMC Radiation Safety Office.

1. **Regulatory Agency Audit**: The State of Nebraska Department of Health & Human Services, Office of Radiological Health, conducts routine inspections of the UNMC license. During these inspections, the State will select a suitable number of Authorized Users to review. The audit of the selected laboratories will include both a Standard and Performance-Based Audit (both of these audits are described in detail later in this section).

   Any items of noncompliance (e.g., violations) identified during the audit will be addressed to the Chancellor-UNMC or his/her delegate.

2. **Radiation Safety Office Audit**: Radiation Safety performs internal audits for the purpose of identifying problem areas which can be corrected intramurally. These audits are intended to model State inspections so that the Authorized Users are better prepared for a State audit. There are two types of audits performed; a standard audit and a performance-based audit.

   a. Standard Audit

   In this audit, both the facility/equipment and required documentation are reviewed for regulatory compliance. In addition, items of noncompliance previously identified are reviewed so that they are not repeated. Some of the items that are inspected at during this audit include:

   - Ensure that radioactive material is properly secured at all time
   - Review contamination survey records
   - Inspect postings and labels
   - Review records pertaining to inventory (e.g., physically inspect current inventory on file and ensure RSO-8 forms are available and usage documented)
   - Review waste disposal records

   Items of non-compliance identified in the audit are reported to the Radiation Safety Committee at its next

meeting.

The AU is typically contacted to schedule a convenient time to conduct the audit, although unannounced audits may be performed. The frequency of this audit depends upon the radioactive material usage in a lab and the lab's past audit history. At a minimum, the Radiation Safety Office will perform these audits when renewing a license (usually every five years), but in most cases a standard audit is performed annually. These audits may also be performed at the discretion of the RSO/RSC or at the request of the Authorized User.

b. Performance-Based Audit

A performance-based audit is an assessment of the comprehension and abilities of Authorized Users or Radiation Workers in performing tasks related to the safe and compliant use of radioactive material. In this audit the AU or a radiation worker in the lab is asked to demonstrate or discuss tasks/topics related to the safe use of radioactive material. This audit may also be accomplished by observing the actual use of radioactive material by workers in the lab. Although classified as an audit, Radiation Safety tends to think of the performance-based audits more as "training" sessions. If the individual(s) being audited has trouble demonstrating a task/requirement, Radiation Safety will train that individual to ensure competency in that topic.

A performance-based audit is conducted in conjunction with a standard audit and may also be conducted at the discretion of the Radiation Safety Office, Radiation Safety Committee, or Authorized User. The following is a list of some of the items/tasks that will be audited:

i) Are individuals wearing their dosimetry in the proper manner? Whole body OSL badges are to be worn on the

collar or front trunk region of the body. Ring badges are to be worn on the dominant hand with TLD chip turned inward toward the palm.

ii) Are all individuals wearing protective clothing while working with radioactive material? Lab coats and gloves are to be worn when working with radioactive material.

iii) Are individuals monitoring their gloves for radioactivity in order to determine if they should be put in the radioactive waste or normal waste? Gloves which read above background must be put in the radioactive waste. Gloves which are indistinguishable from background may be put in the normal waste. An appropriate meter that detects the type of radiation used must be selected. Gloves must be monitored in a low background area.

iv) Are individuals monitoring their hands and lab coat before leaving the lab area? To prevent the spread of contamination, individuals should perform a thorough survey prior to leaving the laboratory.

v) No food, chewing gum, or drinks are allowed in a restricted area.

vi) Is radioactive material secured at all times when not attended? All radioactive material above exempt quantities should be locked in freezers, refrigerators or storage areas to prevent unauthorized removal.

vii) Is appropriate shielding being used to maintain the dose ALARA at all times? All sources should be stored in a suitably shielded pig. Waste must also be shielded in a secure area.

viii) Are all areas covered with an absorbent pad or paper

where unsealed radioactive material is used? Absorbent pads will contain any spills and facilitate cleanup.

ix) Are survey instruments checked each time prior to use? The instrument must be turned to the battery check position to verify that there is ample power to the instrument. The instrument must be presented to a check source to verify that the probe is functioning properly. The check source reading must be within ±20% of the calibration sticker.

x) Are all individuals familiar with the appropriate frequencies and actions levels for area surveys in their laboratories? Work areas should be surveyed with a meter after each use. Readings that are twice above background should be wiped.

xi) Are all individuals familiar with the wipe test requirements? The removable contamination from a wipe test should not contamination action levels for the radionuclides in use. The frequencies are based on the amount of radioactive material processed during a month.

xii) Are all wipe test results being recorded in dpm or if results are in cpm, are conversion factors correlating cpm to dpm documented? Recording results as “background” or “cpm” alone is not acceptable.

Section A-5

Training Requirements

A. Types of Workers Requiring Radiation Safety Training

The State of Nebraska regulations and conditions of the UNMC radioactive material license dictate training requirements to work with ionizing radiation sources. The extent of training will vary upon the type and frequency of radiation used. For most workers initial and annual refresher training are required or provided. The categories of workers requiring some type of radiation safety training include the following (refer to each group's training section for specific training requirements):

Worker Category	Description
Authorized Users (AU):	Researcher who have been granted a UNMC radioactive material license by the Radiation Safety Committee to work with radioactive material; **Refer to Section A-5(B)**
Radiation Workers:	Individuals working under an Authorized User that are authorized to use radioactive material under the AU's license; **Refer to Section A-5(C)**
Irradiator Operators:	Individuals authorized to use an irradiator; **Refer to Section A-5(D).** Note X-ray tube irradiators are discussed in Section D.
Ancillary Personnel:	Workers who may be required to enter rooms/areas where radioactive material/radiation is used, which may include the following groups: Environmental Services, Security, Maintenance, Comparative Medicine, and Laboratory Assistants; **Refer to Section A-5(E)**
X-Ray Users:	The training for users of x-ray devices is dependent upon the type of device used; **Refer to Section D**

For laboratory workers who are NOT radiation workers but work for a researcher who is an Authorized User (AU), it is the responsibility of the AU to provide appropriate training to these workers. The training should be commensurate with the worker's potential exposure to radiation. In some cases training may not be necessary (e.g., workers not required to work in any of the laboratories where radioactive material is authorized). On the Radiation Safety website the ***Radiation Instructions to Non-Radiation Laboratory Workers*** page provides some basic radiation information that the AU may wish to use (the AU may also contact Radiation Safety for assistance).

B. Authorized User (Non-Human Use)

An Authorized User (AU) is an individual who has been granted a radioactive material license by the UNMC Radiation Safety Committee that authorizes the use of radioactive materials. In accordance with the State of Nebraska regulations and conditions of the UNMC Broadscope radioactive material license an Authorized User must be UNMC faculty and meet the following training/experience requirements (Note: in certain circumstances the Radiation Safety Committee may approve a non-faculty individual for authorized use):

1. A college degree at the bachelor level, or equivalent training or experience, in the physical or biological sciences or in engineering.

2. One-hundred and sixty (160) hours experience in the safe handling of radioactive material. One hundred and sixty (160) hours experience is granted on a one hour for one hour basis. The name of the facility must be provided so that the Radiation Safety Office may verify the information.

3. Completion of the UNMC "Initial Radiation Worker Training." This training consists of:

a) Completion of an online self-study training module on the UNMC EHSA computer training system. This training covers various aspects of radiation health physics such as radioactive decay, biological effects, and regulatory dose limits. Contact Radiation Safety to enroll in this training.

b) Attending an "Initial UNMC Radiation Worker" training class offered by the Radiation Safety Office in which practical aspects of the UNMC radiation safety program (e.g., ordering radioactive material, waste disposal, surveys) are reviewed. Contact Radiation Safety to enroll in this classroom training.

4. At least forty (40) hours of formal instruction in:
   a) Radiation physics and instrumentation;
   b) Radiation protection;
   c) Mathematics pertaining to the use and measurement of radioactivity; and
   d) Biological effects of radiation.

   Forty hours of formal instruction is interpreted as 40 clock hours (actual hours spent on radiation related instruction). A course which is approved for three (3) credit hours is equivalent to 48 clock hours (1 credit hour = 16 clock hours). Also, any portion of an applicable course may be used. For example, if 5 clock hours of a 3 credit hour course is pertinent then 5 hours may be assigned. Refer to the following table which indicates the clock hours that have been approved for various classes by the State (Note that the Initial Radiation Worker Training is assigned eight (8) hours of training). Training must be documented by signature or by submitting transcripts, course outlines, certificates of completion, etc.

Table 1: Approved Clock Hours for Various Courses

Initial UNMC Radiation Safety Training = 8 hours (REQUIRED)	
Biochemistry = 10 hours	Radiobiology = 48 hours
General Chemistry = 10 hours	Physical Chemistry = 10 hours
Radioisotopic Methods = 48 hours	General Physics = 3 hours
Modern Physics = 15 hours	Calculus = 5 hours/course

If formal course work **cannot** be documented and the faculty member has at least 160 hours directly handling the type of radioactive material that is proposed, this individual may elect to enroll in a self-study program available from the Radiation Safety Office. These programs have been approved to meet the forty hour (40) State requirement.

To enroll in this option contact the Radiation Safety Office. The textbooks used for training are Basic Radiation Protection Technology (3rd Edition) by Daniel A. Gollnick, Ph.D., and/or Radioisotopic Methods for Biological and Medical Research by Herman W. Knoche, Ph.D. A review of the proposed use of radioactive material will determine which book is best suited for this training. These books may be checked out on loan from the Radiation Safety Office.

Tables 1 and 2 indicate the sections of reading and associated problem set for each textbook. Chapters are assigned by Radiation Safety and based upon the individual's previous training. A passing score of 80% is required.

Table 2: Gollnick, Basic Radiation Protection Technology, 3rd Edition

	Type of Training	Chapter (Pages)	Problem Set
a.	Principles & practice of radiation protection	Chapter 11 (426-443) Chapter 15 (632-665)	1,2,5,7,9,10,11,13,14 3,4,5,6,7,8,9,11,12

b. Radioactivity measurement standardization and monitoring techniques and instruments	Chapter 7 (233-281) Chapter 12 (472-497) Chapter S2 (726-729)	3,5,6,13,16,17,18 2,11,12,13,16,17,22 None
c. Mathematics and calculations basic to the use and measurement of radioactivity	Chapter 2 (24-47) Chapter 5 (114-129) Chapter 8 (282-296)	7,11,14,15,16 1,3,5,8,12,14 3,4,9
d. Biological effects of radiation	Chapter 4 (76-111) NRC Reg. Guide 8.29 NRC Reg. Guide 8.13	5,7,11,15,24 None None

Table 3: Knoche, Radioisotopic Methods for Medical Biological & Research

Type of Training	Chapter (Pages)	Problem Set
a. Principles & practice of radiation protection	Chapter 1 (3-11) Chapter 5 (79-99) Chapter 16 (357-376)	1,2,5,6,7 1,2,3,6,9,10,11 1,2,3,4,5,8,9,12
b. Radioactivity measurement standardization and monitoring techniques and instruments	Chapter 6(103-124) Chapter 8 (153-175) Chapter 9 (177-210) Chapter 10 (211-231) Chapter 12 (257-282)	2,3,8 2,7,8 1 1,2,3,5,7 1,3
c. Mathematics and calculations basic to the use and measurement of radioactivity	Chapter 2 (15-29) Chapter 3 (31-52) Chapter 4(53-77)	5,6 1,2,3,5,6,14 1,3,5,6,7,8,10,11,14
d. Biological effects of radiation	Chapter 14 (309-327) Chapter 15 (329-355) NRC Reg. Guide 8.29 NRC Reg. Guide 8.13	4,5,6,9,10,11,12,14,15 1,2,3,6-11,13,14,15

NOTE: NRC Reg. Guides 8.29 and 8.13 may be obtained from the Radiation Safety Office

C. Radiation Worker (Non-Human Use)

All individuals who work with radioactive material under the supervision of an Authorized User must have appropriate training. This training is

documented on the ***RSO-29 Training Qualifications for Radiation Workers*** form. The requirements for a radiation worker at UNMC are as follows:

1. Completion of the UNMC "Initial Radiation Worker Training". This training consists of:

    a) Completion of an online self-study training module on the UNMC EHSA computer training system. This training covers various aspects of radiation health physics such as radioactive decay, biological effects, and regulatory dose limits.

    b) Attending an "Initial UNMC Radiation Worker" training class offered by the Radiation Safety Office in which practical aspects of the UNMC radiation safety program (e.g., ordering, waste disposal, surveys) are reviewed.

    Contact the Radiation Safety Office to schedule this training.

2. At least twenty (20) hours of formal instruction in:

    a) Radiation physics and instrumentation;
    b) Radiation protection;
    c) Mathematics pertaining to the use and measurement of radioactivity; and
    d) Biological effects of radiation.

    Twenty hours of formal instruction is interpreted as 20 clock hours (actual hours spent on radiation related instruction). A course which is approved for three (3) credit hours is equivalent to 48 clock hours (1 credit hour = 16 clock hours). Also, any portion of an applicable course may be used. For example, if 5 clock hours of a 3 credit hour course is pertinent then 5 hours may be assigned. Refer Table 1 which indicates the clock hours that have been approved for various classes by the Nebraska Office of Radiological Health (Note that the

Initial Radiation Worker Training is assigned eight (8) hours of training). Training must be documented by signature or by submitting transcripts, course outlines, certificates of completion, etc.

If formal course work **cannot** be documented an individual may elect to enroll in a self-study program available from the Radiation Safety Office. These programs have been approved to meet the forty hour (40) State requirement. Radiation Safety will determine the training material to be assigned. To enroll in this option, contact the Radiation Safety Office.

The textbooks used for training are Basic Radiation Protection Techology (3rd Edition) by Daniel A. Gollnick, Ph.D., and/or Radioisotopic Methods for Biological and Medical Research by Herman W. Knoche, Ph.D. A review of the proposed use of radioactive material will determine which book is best suited for this training. These books may be checked out on loan from the Radiation Safety Office.

Tables 2 and 3 indicate the sections of reading and associated problem set for each textbook. Chapters are assigned by Radiation Safety and based upon the individual's previous training. A passing score of 80% is required.

3. Review of laboratory safety requirements with the Authorized User including the following topics:

   a. Sections of the Radiation Safety Manual pertinent to the types and quantities of radioactive material used.
   b. Discuss radioactive material license and conditions of used.
   c. Use of personnel monitoring (i.e., radiation badges). Contact the Radiation Safety Office if monitoring for a badge enrollment card (RSO-7).
   d. Discuss the contents of the three yellow Radiation Safety

posters found in the lab;

- Radiation Safety Rules to be Observed in the Laboratory
- Emergency Procedures for Incidents Involving Radioactive Material
- Notice to Employees

D. Irradiator Operators

There are two types of irradiators used on campus; irradiators that use radioactive material (i.e., Cs-137) to provide the radiation and irradiators that use an x-ray tube to provide the radiation. The requirements for the x-ray tube irradiator are discussed in Section D. To become an authorized operator of a Cs-137 irradiator, the following requirements must be met:

1. Must obtain permission of the irradiator's Authorized User (AU) to become an irradiator operator.
2. Must be a radiation worker.
3. Must be enrolled in the personnel monitoring program (i.e., radiation badge).
4. Must complete the training and experience requirements for operation for that irradiator. Contact the AU or Radiation Safety for further information.
5. All irradiator operators must undergo a "Trustworthy and Reliable" determination as required by the Nuclear Regulatory Commission (NRC). This determination will include a background check that includes fingerprinting and a FBI criminal history check. Contact Radiation Safety for further information.

After all the above criteria have been completed, the individual will be added to the AU's radioactive material license as an authorized irradiator operator.

E. Ancillary Personnel

Ancillary personnel consist of individuals who do not work directly with radioactive material or radiation, but due to the nature of their job may be required to enter rooms/areas where ionizing radiation may be used. Table 4 (at the end of the section) provides a summary of the initial/refresher training required by various ancillary groups. It should be noted that all employees receive training in new employee orientation to recognize where radiation/radioactive material can be used. Radiation Safety will also provide training upon request.

Table 4: Radiation Safety Training for Various Ancillary Groups

Department/ Category	Type & Description of Initial/Refresher Training
Environmental Services (ES)	ES Supervisor meets with the new employee and covers material provided in a handout prepared by Radiation Safety (supervisor maintains documentation).
Comparative Medicine	Radiation Safety provides training session annually to Comparative Medicine. Training consists of both refresher training and initial training (to those who have not had it). Radiation Safety will also provide initial training on an as needed basis.
Security/ Dispatch	Initial - Required to take an initial and annual radiation safety training on the Canvas computer training system. NOTE: Because certain Security personnel may be required to have unescorted access to rooms containing radionuclides in quantities of concern, these individuals must undergo a background check that includes fingerprinting/FBI criminal history check.
Maintenance	Initial - New personnel are required to take an initial radiation safety training module for maintenance personnel on the Canvas computer training system.

F. Annual Training/Instruction to Workers

All individuals who in the course of employment are likely to receive in a year an occupational dose in excess of 100 mrem (1 mSv) must be:

1. Kept informed of the storage, transfer, or use of radiation and/or radioactive material;
2. Instructed in the health protection problems associated with exposure to radiation and/or radioactive material, precautions or procedures to minimize exposure, and in the purposes and functions of protective devices employed;
3. Instructed in, and required to observe, to the extent within the worker's control, the applicable provisions of the regulations and licenses for the protection of personnel from exposures to radiation or radioactive material;
4. Instructed of their responsibility to report promptly to the licensee or registrant any condition which may lead to, constitute, or cause a violation of the regulations, and licenses or unnecessary exposure to radiation or radioactive material;
5. Instructed in the appropriate response to warnings made in the event of any unusual occurrence or malfunction that may involve exposure to radiation or radioactive material; and
6. Advised as to the radiation exposure reports which workers must be furnished pursuant to regulations.

In determining those individuals subject to the requirements the Radiation Safety Office will take into consideration assigned activities during normal and abnormal situations involving exposure to radiation and/or radioactive material which can reasonably be expected to occur during the life of a licensees or registrants facility. The extent of these instructions must be commensurate with potential radiological health protection problems present in the work place and must be performed annually.

Currently, annual radiation safety training is provided to Authorized Users, Radiation Workers, Irradiator (Cesium Source) Operators, Comparative Medicine, Security/Dispatch, Environmental Services, various X-ray users (refer to Section D), and individuals identified by the Radiation Safety Office or Radiation Safety Committee.

Section B-1
Control of Radioactive Material

A. How to Order Radioactive Material

All radioactive material is ordered through the Ariba online purchasing system used by the University of Nebraska. Each department should have a designated individual who is authorized to place orders through this system.

When ordering radioactive material ensure that the following information is entered:

1. The radioactive GL number (533102) must be used.

2. The radioactive material must be shipped to the Radiation Safety Office at the following address:

   UNMC Radiation Safety Office
   4367 Emile Street
   Omaha, NE 68105

3. The Authorized User must be indicated in the “unloading point”.

The order is sent to the Radiation Safety Office for approval. Radiation Safety will review the order to ensure that the Authorized User can receive that type and amount of radioactive material.

B. Receiving and Opening Radioactive Material Packages

All radioactive material packages must be received by the Radiation Safety Office. Radioactive material packages can only be received Monday through

Friday between 7:00 A.M. and 4:00 P.M. Special arrangements need to be made with Radiation Safety if these hours are inadequate.

1. Radiation Safety Procedure/Responsibilities

   a. Wear gloves to prevent hand contamination.

   b. Visually inspect the package for any sign of damage (e.g., crushed, punctured). If damage is noted, stop and notify the Radiation Safety Officer.

   c. Determine if the contents correspond to the requisition to ensure shipment does not exceed license possession limits.

   d. The following monitoring is required.

      i. Monitor the external surfaces of a DOT labeled (i.e., White I, Yellow II, or Yellow III) package for radioactive contamination unless the package contains only radioactive material in the form of a gas or in special form. Wipe all external surfaces (300 cm^2 recommended).
      NOTE: For DOT labeled packages containing H-3 Radiation will also monitor internal surfaces of package for contamination.

      The contamination action level is 22 dpm/cm^2 for beta/gamma and 2.2 dpm/cm^2 for alpha

      For a 300 cm^2 wipe area this corresponds to 6600 dpm and 660 dpm

      ii. Monitor the external surfaces of a DOT labeled (i.e., White I, Yellow II, or Yellow III) package for radiation levels unless the package contains quantities of radioactive material that are less than or equal to the Type A quantity (NOTE: It is unlikely package will contain greater than Type A quantity). Action levels are provided

in Title 180 NAC 13. If above action levels, contact RSO immediately.

iii. Monitor all packages known to contain radioactive material for radioactive contamination and radiation levels if there is evidence of degradation of package integrity, such as packages that are crushed, wet, or damaged. If above action levels, contact RSO immediately.

iv. The licensee must perform this as soon as practical after receipt of the package, but not later than three (3) hours after the package is received if it is received during normal working hours, or not later than three hours from the beginning of the next working day if it is received after working hours.

e. Open the outer package (following supplier's directions if provided) and verify contents (compare requisition, packing slip and label on the bottle or other container). Check integrity of the final source container (e.g., inspecting for breakage of seals or vials, loss of liquid, discoloration of packaging material, high count rate on smear). Check again that the shipment does not exceed license possession limits. If you find anything other than expected, stop and notify the RSO.

f. Notify the final carrier and by telephone, telegram, mailgram, or facsimile, and the State of Nebraska Office of Radiological Health if the removable radioactive surface contamination or radiation levels exceeds the applicable action levels.

g. Fill out the yellow RSO-8 form (“Radioactive Material Receipt and Disposal Record”) that will be used by the radiation workers to track radioactive material usage. The radioactive material will be assigned a unique tracking number (**RSO number**) that Radiation Safety will often times mark on the vial shielding container.

h. Survey the packing material and packages for contamination using an appropriate survey meter before discarding. If contamination is found, treat as radioactive waste. If no contamination is found, obliterate the radiation labels prior to discarding in the regular trash.

i. Maintain records of receipt, package survey, and wipe test results.

Deliver the package to the laboratory.

Only an Authorized User or Radiation Worker may sign for a radioactive material package.

2. Authorized User Responsibilities

a. When the package arrives, verify that the radioactive material is what you ordered and sign for the package.

b. Don gloves and move the package to a designated radioactive work area. When receiving volatile radioactive materials, handle the package in a vented hood.

c. Upon opening packaging examine inner container for possible contamination (e.g., leak, spill). If no contamination is suspected store the radioactive material in a secure storage area that is conspicuously posted for radioactive material. If contamination is suspected, wipe the inner vial for contamination.

i) If no contamination is found, store the radioactive material in a secure storage area that is conspicuously posted for radioactive material.

ii) If contamination is found, dispose of all contaminated shipping materials as radioactive waste and contact the Radiation Safety Office. If the radioactive material is still usable, clean the outside of the stock vial, and store in a

secure storage area that is conspicuously posted for radioactive material.
NOTE: If radioactive iodine packages are leaking, immediately request a thyroid bioassay from the Radiation Safety Office.

d. For DOT labeled packages (i.e., White I, Yellow II) use an appropriate survey meter to measure radiation levels of the outer shipping box and packaging. (NOTE: Not required for H-3 packaging which is swiped for contamination by Radiation Safety). If survey meter readings are at background levels deface or remove all radioactive symbols/markings and dispose as normal trash. If survey meter readings are above background levels dispose packaging as radioactive waste.

DOT White I Label

DOT Yellow II Label

C. Transferring and Shipping of Radioactive Material

1. Transferring Radioactive Material

Contact the Radiation Safety Office to obtain a "**Transfer Form**" to complete and submit to the RSO for approval and transfer of any radioactive material to another UNMC Authorized User (AU) or Authorized User off-campus. Radiation Safety will review all transfers to ensure that the AU receiving the material is licensed to receive the type and quantity of radioactive material requested.

When the transfer is completed, the AU must indicate the transfer of material on their RSO-8 form.

2. **Shipping of Radioactive Materials**

All Radioactive Material packages shipped off campus must meet the State of Nebraska Health and Human Services, Regulation and Licensure Regulations as well as the Department of Transportation (DOT) and International Air Transport Association (IATA) Regulations. **All shippers of radioactive material must be certified by the Radiation Safety Office**. Violation of DOT/IATA regulations can potentially result in large monetary fines. **For these reasons, the Radiation Safety Office will typically ship radioactive material for Authorized Users.**

D. Inventory Control

Each license specifies a maximum possession limit. This is the amount of radioactive material you may possess at any one time and includes material held in storage or in waste. Maximum possession limits are based on information submitted with the license application**.**

The **yellow RSO-8 form** serves to record receipt and use of each individual shipment of radioactive material. When the material is received in the Radiation Safety Office, it is assigned a unique identifier (RSO number which Radiation Safety will often write on the vial shield container) and entered in a computerized database under the Authorized User's license. Although the database decays the amount of radioactivity, the only way material can be deleted from the log is when the Radiation Safety Office receives the form RSO-8 indicating that the material has been disposed of or decayed, etc. If the form RSO-8 is not returned, the computerized inventory will continue to increase as new orders are received. If the radionuclide has a long half-life, the maximum possession limit could be approached, and further orders will not be approved.

An Authorized User should have on hand only RSO-8's for which material is present. This will ensure a correct inventory. Inventories are also reviewed during annual inspections and/or audits of the laboratory.

Helpful Hints for using the RSO-8 Form:

- Usage of radioactive material must be in units of radioactivity (e.g., µCi, mCi). Volume (µl) may be used if the conversion factor (µCi/µl) is readily available (e.g., marked on the RSO-8).
- Many workers find it convenient to tape active RSO-8 forms to the refrigerator or freezer where the material is being stored.
- The RSO-8 form may be sent into the Radiation Safety Office once all the material has been disposed of (do **NOT** need to wait for Radiation Safety to pick up the waste).

E. How is Radioactive Material Secured?

Licensees authorized to use radioactive material have the responsibility to maintain the security and accountability of the radioactive material in their possession. Events that have occurred over the past few years have put emphasis on security to prevent the malicious use of radioactive material with discouraging its beneficial use.

Stock material (e.g., the vial of radioactivity obtained from the manufacturer) will be secured at all times. Acceptable methods of securing radioactive material include:

1. Locked room

2. Locked storage unit such as a lockable refrigerator, freezer, cabinet, drawer, etc.

3. Using a lock box that is secured (e.g., container restrainer) within a refrigerator or freezer. If you typically frequent the refrigerator throughout the day and/or are in an open laboratory setting (e.g., several researchers in a large room) the lock box may be the more convenient method of securing material. Contact Radiation Safety if you would like more information regarding lock boxes.

Lock Box

Container Restraint

4. Direct Control: If radioactive material is unsecured (e.g., in use) an individual authorized to work with radioactive material must have **direct** control of the radioactive material.

F. Sealed Sources and Leak Tests

A sealed source is a known or estimated quantity of radioactive material that is encased in a capsule, sealed between layer(s) of non-radioactive material, designed to prevent leakage or escape of the radioactive material.

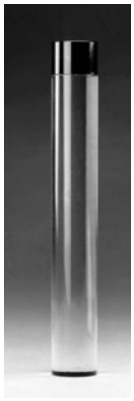
The amount of activity can vary significantly depending upon what the sealed source was designed to do. Rod (“stick”) or “button” sources contain small amounts of radioactivity and are used for calibration and operational checks of radiation measuring/detection equipment. Sealed sources in irradiators contain high amounts of radioactivity in order to deliver high radiation dose to specimens. Sealed sources containing higher amounts of radioactivity are routinely tested by Radiation Safety for leakage of radioactive contamination (“leak tests”). For sealed sources with greater than 100 microcuries of beta and/or gamma emitting material (excluding

gases, H-3, and radionuclides with half-lives less than 30 days), these leak tests are typically required every six months. If the test reveals any leakage greater than 0.005 microcuries, the source will be withdrawn from service and the regulation agency contacted.

Sealed sources containing radioactive material shall not be opened.

> Be aware that certain equipment such as liquid scintillation counters and gas chromatographs contain internal radioactive sealed sources – be sure to contact the Radiation Safety Office if this equipment is to be decommissioned or transferred.

Rod Source
(~ 3" Tall)



Button Source
(size ~ quarter)

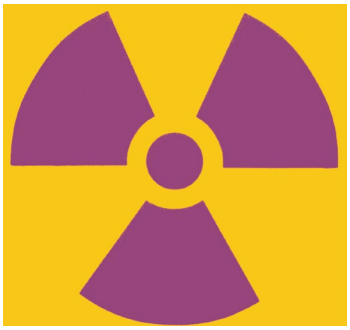
Procedure for Performing Leak Testing and Analysis

1. For each sealed source to be tested, list identifying information such as the sealed source serial number, manufacturer, model number, radionuclide, and activity.
2. Use a radiation survey meter to monitor exposure.
3. Prepare a separate wipe sample (e.g., cotton swab or filter paper) for each source. Number each wipe to correlate with identifying information for each source. Wipe the most accessible area where contamination would accumulate if the sealed source were leaking, but do not wipe the surface of a plated or foil source (see manufacturer's instructions).

4. Select instrumentation that is sensitive enough to detect 185 becquerels (0.005 microcurie) of the radionuclide contained in the sealed source. For gamma emitters a NaI well-counter or GeLi spectroscopy system is appropriate while for beta emitters liquid scintillation should be used (Note: Cs-137 leak tests may be counted using gamma spectroscopy or liquid scintillation).
5. The presence of 185 Bq (0.005 uCi) or more of removable contamination on any test sample must be considered evidence that the sealed source is leaking. The following steps must be followed is a sealed source is found to be leaking:
    a. The leaking source must be immediately withdrawn, and actions must be taken to prevent the spread of contamination. The leaking sealed must be repaired or disposed in accordance with Nebraska regulations (180 NAC 1).
    b. Reports of test results for leaking or contaminated sealed sources must be made in accordance with Nebraska regulations (180 NAC 4).

Section B-2
Caution Signs, Posting and Labels

Appropriate caution signs are required in all areas and on all containers where significant amounts of radiation or radioactive materials may be found. These must bear the three-bladed radioactive caution symbol (**tre-foil**) in magenta, purple, or black on a yellow background. The specific label to be used depends on the type and degree of hazard present.



What Types of Posting/Labels Are Required?

- All rooms authorized for radioactive material usage
- Freezers and refrigerators used to store radioactive material
- Equipment that is used for radioactive material (e.g., syringes, centrifuges)
- Radiation work areas (e.g., bench tops, fume hoods)
- Containers holding the radioactive material
- Radioactive waste containers
- Emergency Procedure (spills of radioactive material) posting
- Guidelines for Safe Use of Radioactive Material posting
- Notice to Employees posting
- Various X-Ray Producing Devices (Refer to Section D for Posting/Labeling)

The Radiation Safety Office will supply the signs and label rooms, hoods, work areas, refrigerators, etc. The Authorized User is responsible for the labeling of containers and bench top equipment (e.g., centrifuge). Contact the Radiation Safety Office for assistance.

A. When is a "Caution - Radioactive Material" Sign Required for a Room or Area?

Rooms or areas must be posted with a "Caution - Radioactive Material" sign

when the amount of radioactive material used or stored exceeds 10 times the quantity specified in Appendix 4-C of the state regulations (180 NAC 1). The activities corresponding to room posting for the most commonly used radionuclides are listed below:

Radionuclide	Posting Required
Calcium-45	1,000 µCi
Carbon-14	1,000 µCi
Chromium-51	10,000 µCi
Hydrogen-3	10,000 µCi
Iodine-125	10 µCi
Iodine-131	10 µCi
Phosphorus-32	100 µCi
Phosphorus-33	1,000 µCi
Sulfur-35	1,000 µCi
In-111	1,000 µCi
Lu-177	1,000 µCi
Technetium-99m	10,000 µCi

Typically, all rooms on an Authorized User's radioactive material license are posted with the "Caution – Radioactive Material" sign. This includes rooms used solely for liquid scintillation counting.

Exemptions to Posting:

1. A room or area is not required to be posted with a caution sign because of the presence of a sealed source, provided the radiation level thirty (30) centimeters (1 foot) from the surface of the source container or housing does not exceed five (5) millirem per hour (0.05 mSv/h).

2. Caution signs are not required to be posted in areas or rooms containing radioactive material for periods of less than eight (8) hours provided that;

a. The material is constantly attended during such periods by an individual who will take the precautions necessary to prevent the exposure of any individual to radiation or radioactive material in excess of the established dose limits, and

b. Such area or room is subject to the Authorized User's control.

3. Rooms or other areas in hospitals that are occupied by patients are not required to be posted with caution signs provided that the patient could be released from the hospital's control pursuant to the State of Nebraska patient release regulations (180 NAC 1).

B. How are Rooms Approved/Posted?

The Authorized User is responsible for notifying the Radiation Safety Office in writing (e.g., initial radioactive material license application, memo, email) of rooms and areas that will be used for radioactive material use.

Radiation Safety will arrange a time to conduct the posting of each authorized use location prior to approving that location for radioactive material use. A facilities posting checklist will be used to document postings.

C. When is a "Caution - Radioactive Material" Label Required on a Container?

A container having a quantity of radioactive material equal or greater than those amounts listed in Appendix 4-C of the state regulations (180 NAC 1) must bear a durable, clearly visible label bearing the radiation symbol and the words "Caution, Radioactive Material". The values for the most commonly used radionuclides are listed below in Table 1 (exemptions to labeling of containers are provided at the end of this section):

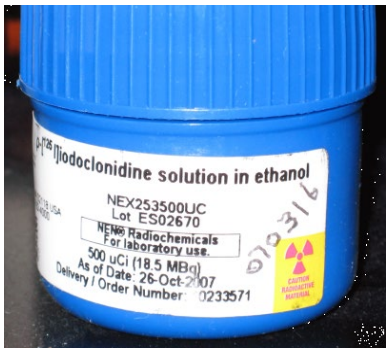
Table 1: Activity Levels for Container Labeling

Radionuclide	Activity in Container Container Required
I-125, I-131	1 µCi
P-32	10 µCi
C-14, Ca-45, P-33, S-35, Lu-177	100 µCi
H-3, Cr-51, Tc-99m	1000 µCi

The label (or container) should indicate the radionuclides present. The container labeling requirement is also applicable to radioactive waste containers. Examples of container labeling are shown in the figures below:

Radioactive "Sharps" Waste Container

Radioactive Waste Container



Shielding container for Radioactive material

Prior to removal or disposal of empty uncontaminated containers to unrestricted areas, the Authorized User must remove or deface the radioactive material label or otherwise clearly indicate that the container no longer contains radioactive materials.

Contact the Radiation Safety Office for questions regarding labeling of containers.

Exemptions to Container Labeling:

1. Containers holding licensed or registered material in concentrations less than those specified in Appendix 180 NAC 4-C.

2. Containers holding radioactive material in concentrations less than those specified in Table III of Appendix 180 NAC 4-B.

3. Containers attended by an individual who takes the precautions necessary to prevent the exposure of individuals in excess of the regulatory dose limits.

4. Containers when they are in transport and packaged and labeled in accordance with the regulations of the U.S. Department of Transportation (DOT).

5. Containers that are accessible only to individuals authorized to handle or use them, or to work in the vicinity of the containers, if the contents are identified to these individuals by a readily available written record. Examples of containers of this type are containers in locations such as water filled canals, storage vaults, or hot cells. The record shall be retained as long as the containers are in use for the purpose indicated on the record; or

6. Installed manufacturing or process equipment, such as piping and tanks.

D. Equipment Labels

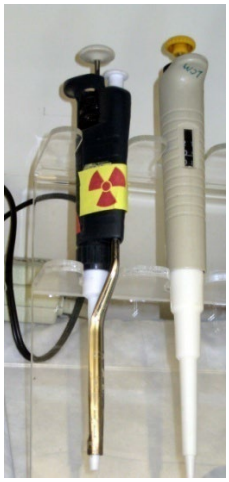
Within a lab authorized for radioactive material usage, equipment used for radioactive material should be clearly labeled to minimize contamination. Equipment that should be labeled includes:

- Refrigerators/freezers used to store radioactivity

- Bench tops and fume hoods where radioactivity is routinely used
- Syringes and other equipment (e.g., centrifuges, incubators) used for radioactive material
- "Hot" sinks (i.e., sinks designated to dispose of liquid radioactive waste)

Examples of these labels are provided in the figures below. Please contact Radiation Safety if you need any labels or assistance with labeling equipment.

NOTE: If equipment is no longer going to be used for radioactive material, the label may be removed if contamination wipes are performed and the results indicate that the equipment has levels less than 220 dpm/100 cm^2. The results from the wipe survey must be maintained.

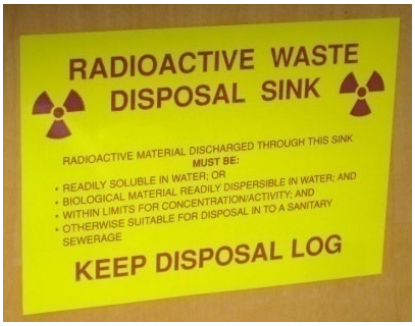


Equipment labels

Radioactive Waste Receptacles

Refrigerators & Freezers
Used to store radioactivity

Radioactive Work Areas

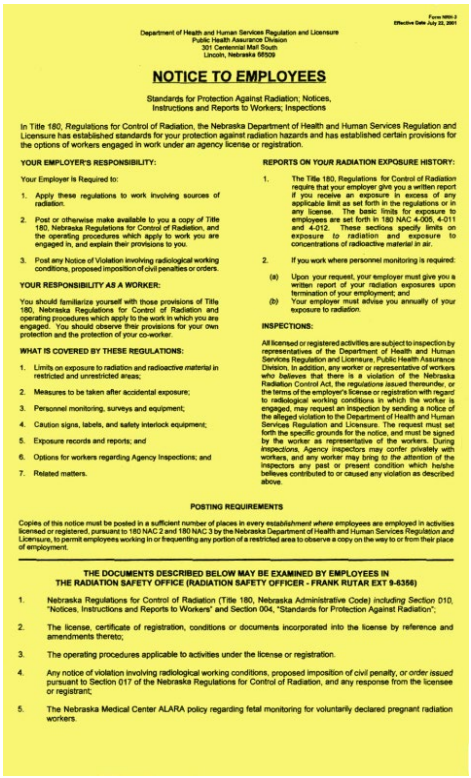


Radioactive Sinks

E. Notice to Employees

Each Authorized User has a yellow poster in the lab titled "Notice to Employees" that specifies:

1. Your Employer's Responsibility
2. Your Responsibility as a Worker
3. What is covered by these Regulations
4. Reports on your Radiation Exposure History
5. Inspections
6. Where documents (e.g., regulations, radioactive material license) may be found



Department of Health and Human Services Regulation and Licensure
Public Health Assurance Division
301 Centennial Mall South
Lincoln, Nebraska 68509

NOTICE TO EMPLOYEES

Standards for Protection Against Radiation; Notices, Instructions and Reports to Workers; Inspections

In Title 180, Regulations for Control of Radiation, the Nebraska Department of Health and Human Services Regulation and Licensure has established standards for your protection against radiation hazards and has established certain provisions for the options of workers engaged in work under an agency license or registration.

YOUR EMPLOYER'S RESPONSIBILITY:

Your Employer is Required to:

1. Apply these regulations to work involving sources of radiation.
2. Post or otherwise make available to you a copy of Title 180, Nebraska Regulations for Control of Radiation, and the operating procedures which apply to work you are engaged in, and explain their provisions to you.
3. Post any Notice of Violation involving radiological working conditions, proposed imposition of civil penalties or orders.

YOUR RESPONSIBILITY AS A WORKER:

You should familiarize yourself with those provisions of Title 180, Nebraska Regulations for Control of Radiation and operating procedures which apply to the work in which you are engaged. You should observe their provisions for your own protection and the protection of your co-worker.

WHAT IS COVERED BY THESE REGULATIONS:

1. Limits on exposure to radiation and radioactive material in restricted and unrestricted areas;
2. Measures to be taken after accidental exposure;
3. Personnel monitoring, surveys and equipment;
4. Caution signs, labels, and safety interlock equipment;
5. Exposure records and reports; and
6. Options for workers regarding Agency Inspections; and
7. Related matters.

REPORTS ON YOUR RADIATION EXPOSURE HISTORY:

1. The Title 180, Regulations for Control of Radiation require that your employer give you a written report if you receive an exposure in excess of any applicable limit as set forth in the regulations or in any license. The basic limits for exposure to employees are set forth in 180 NAC 4-005, 4-011 and 4-012. These sections specify limits on exposure to radiation and exposure to concentrations of radioactive material in air.
2. If you work where personnel monitoring is required:
   (a) Upon your request, your employer must give you a written report of your radiation exposures upon termination of your employment; and
   (b) Your employer must advise you annually of your exposure to radiation.

INSPECTIONS:

All licensed or registered activities are subject to inspection by representatives of the Department of Health and Human Services Regulation and Licensure, Public Health Assurance Division. In addition, any worker or representative of workers who believes that there is a violation of the Nebraska Radiation Control Act, the regulations issued thereunder, or the terms of the employer's license or registration with regard to radiological working conditions in which the worker is engaged, may request an inspection by sending a notice of the alleged violation to the Department of Health and Human Services Regulation and Licensure. The request must set forth the specific grounds for the notice, and must be signed by the worker as representative of the workers. During inspections, Agency inspectors may confer privately with workers, and any worker may bring to the attention of the inspectors any past or present condition which he/she believes contributed to or caused any violation as described above.

POSTING REQUIREMENTS

Copies of this notice must be posted in a sufficient number of places in every establishment where employees are employed in activities licensed or registered, pursuant to 180 NAC 2 and 180 NAC 3 by the Nebraska Department of Health and Human Services Regulation and Licensure, to permit employees working in or frequenting any portion of a restricted area to observe a copy on the way to or from their place of employment.

THE DOCUMENTS DESCRIBED BELOW MAY BE EXAMINED BY EMPLOYEES IN THE RADIATION SAFETY OFFICE (RADIATION SAFETY OFFICER - FRANK RUTAR EXT 9-6356)

1. Nebraska Regulations for Control of Radiation (Title 180, Nebraska Administrative Code) including Section 010, "Notices, Instructions and Reports to Workers" and Section 004, "Standards for Protection Against Radiation";
2. The license, certificate of registration, conditions or documents incorporated into the license by reference and amendments thereto;
3. The operating procedures applicable to activities under the license or registration.
4. Any notice of violation involving radiological working conditions, proposed imposition of civil penalty, or order issued pursuant to Section 017 of the Nebraska Regulations for Control of Radiation, and any response from the licensee or registrant;
5. The Nebraska Medical Center ALARA policy regarding fetal monitoring for voluntarily declared pregnant radiation workers.

Each individual should familiarize themselves with these provisions for their own protection and that of their co-workers.

F. Are Any Other Postings Required?

Radiation Area Postings

Additional postings are required if there is high enough radiation to cause a Radiation Area, High Radiation Area, or Very High Radiation Area. Below are some examples of these postings:

Radiation Area:
5 mrem/hr @ 30 cm from source

High Radiation Area:
100 mrem/hr @ 30 cm from source

The exemptions for Radiation Area postings are the same as those given for "Caution - Radioactive Material" postings (Section B). Contact Radiation Safety to verify all radiation areas and ensure proper controls are exercised.

What about Airborne Radioactivity?

If the activities you are engaged in are suspected to create airborne radioactivity (e.g., vapors, aerosols), the Radiation Safety Office can conduct appropriate surveys and calculations to determine if posting the area is required. If necessary, these areas will be posted with a "Caution-Airborne Radioactivity Area".

Safe Handling Practices and Emergency Procedures Posters

Each Authorized User is provided at least one of each of the following posters;

1. A yellow poster indicating the safety rules to be observed when working with radioactive material (refer to Section B-4) and
2. A yellow poster providing emergency procedures for incidents involving radioactive material (section.

G. What About Rooms that are No Longer Used for Radioactive Material (Deposting A Room)?

The Authorized User is responsible for notifying the Radiation Safety Office in writing (e.g., memo, email) of rooms that will no longer be used for radioactive material use. The Authorized User is responsible for ensuring that all radioactive material has been removed from the room and will perform a radioactive contamination survey to demonstrate that contamination levels at all selected monitoring points are below Contamination Action levels provided in Section B-6.

Radiation Safety will use a facilities termination checklist to document that appropriate labels and postings were removed.

H. What are the Consequences of Improper Postings and Labeling?

Inspectors from the State of Nebraska Office of Radiological Health will verify postings and labeling during University inspections. Improper radiation/radioactive material posting and labeling will result in items of non-compliance (i.e., violations).

Items will be reported to the Chancellor and the UNMC Radiation Safety Committee.

Section B-3
Safe Handling Practices for Radioactive Material

A. Radiation Safety Rules to Be Observed in The Laboratory

Each Authorized User has a yellow poster in the lab listing the safety rules to be observed in the lab. The verbiage on this poster is reproduced below:

1. Do not eat, drink, smoke or apply cosmetics in the laboratory.

2. Wear gloves and protective clothing (e.g., a lab coat) when working with radioactive material in any form other than a sealed source.

3. Never pipet radioactive solutions by mouth.

4. Do not expose open wounds to the possibility of radioactive contamination.

5. Do not store food or drink in the same storage location (e.g., refrigerators) as radioactive material.

6. Clearly label containers holding radioactive materials with the words “Caution: Radioactive Material” and the radiation symbol.

7. Work with radioactive materials over absorbent paper and/or trays to contain contamination.

8. Work with radioactive materials that could become airborne in a ventilated enclosure such as a fume hood.

9. Use appropriate shielding to keep the dose rate as low as reasonably achievable.

10. Wear badge or another specified personnel monitor (except for H-3, C-14, and S-35).

11. Monitor during and after procedure to ensure that exposure rates are kept low, and that work area has not become contaminated. Decontaminate any contaminated areas.

12. Monitor the entire person after performing a radioactive procedure and before leaving the laboratory. Notify Radiation Safety if any contamination is not easily removable.

13. Monitor equipment or other materials before removing from a restricted area. Decontaminate as necessary.

14. Dispose of radioactive waste in accordance with the methods approved by the Radiation Safety Office.

15. Notify the Radiation Safety Office immediately if radioactive material has been or is suspected to have been inhaled, ingested into a person.

16. Never leave radioactive material unattended unless it has been secured against unauthorized removal.

17. Record details of contamination events for the Radiation Safety Office review.

B. Specific Guidelines for The Safe Use of Commonly Used Radionuclides

Certain radionuclides exhibit physical, chemical or biological properties which require special handling to ensure user safety and regulatory compliance.

The Radiation Safety Committee has developed guidelines for the safe use of radionuclides commonly used at UNMC. These are provided in **Section C** and include the following radionuclides:

Appendix 1:	H-3	Appendix 8:	Ca-45
Appendix 2:	C-14	Appendix 9:	P-33
Appendix 3:	P-32	Appendix 10:	Tc-99m
Appendix 4:	S-35	Appendix 11:	Lu-177
Appendix 5:	I-125	Appendix 12:	In-111
Appendix 6:	Cr-51	Appendix 13:	Ac-225
Appendix 7:	I-131		

These guidelines are not intended to be all inclusive, but they do represent many years of experience and can assist the Authorized User in keeping personnel exposures and environmental releases as low as reasonably achievable (ALARA).

Section B-4

Emergency Procedures for Incidents Involving Radioactive Materials/Radiation

A. What is the Call List for Radiation Emergencies?

Security Dispatch: (402) 559-5555
Radiation Safety Office: (402) 559-6356

Be prepared to state:

- Your name and location
- The Radionuclide and quantities involved
- Brief Description of Incidence
- A call back number where you may be reached

B. Spills

The following instructions apply only to the radiation aspects of an incident. If injuries occur, the procedures must be coordinated with appropriate first aid measures and priorities assigned to providing necessary medical care. Spills involving radioactive material are classified as either Minor or Major. Initiate a minor or major spill procedure by estimating the amount of radioactivity spilled and applying it to the table below. Spills below these millicurie amounts are considered minor and any spills involving greater activity amounts are considered major.

Radionuclide	Minor Spill Limit
Alpha Emitters	$\leq$ 0.1 mCi
P-32, I-125, I-131, Y-90	$\leq$ 1 mCi
C-14, S-34, Ca-35, , In-111, Lu-177	$\leq$ 10 mCi
H-3, F-18, Cr-51, Tc-99m,	$\leq$ 100 mCi

Reference: NUREG-1556, Vol. 9, Rev 3, App. N

For contamination control individuals using unsealed forms of radioactive material must wear gloves and appropriate protective clothing. In addition, absorbent covering (e.g., blue pads, blotter paper) should be used on counter surfaces when working with radioactive material.

> If radioactivity ends up strictly on the absorbent covering, it is not considered a spill and does NOT need to be reported or documented.

C. What Procedures to Follow for Minor Spills

Each Authorized User has a yellow poster in the laboratory titled "Emergency Procedures for Incidents Involving Radioactive Material". This poster contains the step by step procedure and is reproduced below:

> For minor spills, the individual who caused the spill is responsible for clean-up and decontamination. Contact Radiation Safety if any assistance is needed.

Minor Spills Involving Minimal External Radiation Hazard to Personnel

1. Notify all persons in room at once. Only permit the minimum number of persons necessary to deal with the spill into the area. For minor spills, the individual who caused the spill is responsible of clean-up and decontamination.

2. Permit only the minimum number of persons necessary to deal with the spill into the area. Don disposable gloves and confine the spill immediately.

3. If assistance is required, contact Radiation Safety Office (402 559-6356).

4. Don disposable gloves and decontaminate.

   i. Liquid Spills: Drop absorbent material (e.g., paper towels) on spill. Typically, water can be used to decontaminate the contaminated area.

   ii. Solid Spills: Dampen thoroughly, taking care not to spread the contamination.

5. Monitor all persons involved in the spill and cleaning.

6. Permit no persons to resume work in the area until a survey has confirmed the area has been decontaminated. Confirmation can be determined using either an appropriate survey meter (measured levels are less than twice background levels) or a contamination wipe less than the contamination action level for that radionuclide (< 1000 dpm/100 cm^2 for most beta/gamma emitters, < 200 dpm/100 cm^2 for I-131 or I-125).

7. The incident should be documented either by memo/email to the Radiation Safety Office or on the monthly laboratory contamination form.

Remember, if radioactivity ends up strictly on the absorbent covering, it is not considered a spill and does NOT need to be reported or documented.

D. Major Spills

Each Authorized User has a yellow poster in the laboratory titled "Emergency Procedures for Incidents Involving Radioactive Material". This poster contains the step by step procedures and is reproduced below:

For major spills, the Radiation Safety Office should be notified immediately. The Radiation Safety staff will supervise the clean-up and decontamination. The Radiation Safety Office will complete the necessary documentation.

Major Spills Involving External Radiation Hazard to Personnel

1. Notify all persons not involved in the spill to vacate the room at once.
2. If the spill is liquid, and the hands are protected, right the container.
3. If the spill is on the skin, flush thoroughly.
4. If the spill is on clothing, discard outer or protective clothing at once.
5. Switch off all fans.
6. Vacate the room and prohibit entrance to contaminated area.
7. Immediately contact Security Dispatch (9-5555) or Radiation Safety (402 559-6356) and indicate there is radiation spill.
8. Decontaminate skin and/or hair as advised by Radiation Safety Office. Any person who might have been involved must remain near area to be monitored by Radiation Safety.
9. Decontaminate the area only as directed by the Radiation Safety Office.
10. Permit no person to enter the area until a survey is made and approval of the Radiation Safety Office is secured.

11. Prepare a complete history of the accident and subsequent activity related thereto for the laboratory records.

E. Other Incidents Involving Radioactive Material (e.g., Fires, Explosions)

For any other type of incident involving release of radioactivity, the following guidance should be observed:

1. Notify all persons in the area to leave immediately.
2. Provide life-saving first aid, if applicable.
3. Confine the material to the extent possible without jeopardizing your personal safety.
4. Notify the Radiation Safety Office immediately at 9-6356 or 9-5555.
5. Instruct all persons who may have been contaminated or exposed to remain in a safe location until released by the Radiation Safety Office.

F. Personnel Decontamination

Overview of Personnel Decontamination

For contamination not involving personal injury (e.g., no open wounds, cuts, etc.), the theory of decontamination is relatively simple. Most radioactive contamination on intact skin behaves like loose dirt and may be removed by routine washing. The effectiveness of decontamination procedures for beta, gamma emitting radionuclides are easily monitored by a Geiger counter. For low energy beta emitters (e.g., H-3) swipes using absorbent material (e.g., filter paper or q-tips) can easily locate external contamination. Radionuclides on the intact skin surface rarely, if ever, cause a high enough gamma radiation dose to be a hazard if decontamination is promptly initiated. The intact skin is a very effective

barrier to internal contamination. Internal contamination may be a hazard depending upon activity and residence time within parts of the body.

Since the main hazard of external contamination is the possibility of internal contamination, external decontamination procedures are designed to:

(1) Minimize or prevent internal contamination and
(2) Decrease the external contamination which is present.

All efforts are made to clean the contamination from the skin, but occasionally it may be fixed or imbedded in the skin. The skin barrier must be preserved so that procedures such as shaving or harsh scrubbing are not done. If hair needs to be removed, clipping is effective. Warm water, not hot, is used for washing so that a hyperemia is not induced which may increase absorption of any contaminants through the skin. Cold water is not used since it would tend to close skin pores and trap radioactive contamination. Decontamination is performed by progressive cleansing, starting with mild agents such as soap and water and working up to somewhat more involved procedures.

Procedure for Personnel Decontamination:

For contamination involving personal injury (e.g., open wounds, cuts):

a. Provide first aid and medical stabilization to the extent possible.

b. Contact Security/Dispatch (9-5555) immediately.

1. Remove any contaminated clothing.

2. Wash affected body areas thoroughly for 2 or 3 minutes, repeatedly soaping and rinsing. Use a mild soap or lukewarm water and/or decontamination fluid (e.g., RadiacWash or Count-Off).

3. Notify the Authorized User immediately after the event.

4. Avoid prolonged use of any one decontamination procedure as irritation of the skin may impede the success of a more suitable procedure.

5. **The decontamination end point is reached when:**

   a. No further decrease occurs as determined by monitoring (e.g., using appropriate survey meter);

   b. The contamination is considered low enough to no longer be a significant hazard (e.g., an appropriate survey meter indicates less than twice background levels) or;

   c. When further decontamination would be more harmful than helpful.

If these measures are not immediately and completely effective, notify the Radiation Safety Office (402 559-6356).

G. Decontamination of Facilities and Equipment

1. As with personnel decontamination, the theory of decontamination of facilities and/or equipment is simple. Normally the areas of contamination may be cleaned by routine washing, using soap and water. Consideration can also be given to the chemistry of the contaminant in an attempt to find a suitable dissolving or chelation agent. Preparations for decontamination should begin promptly and begin with the area of least contamination progressing to the area of greatest contamination.

2. When performing decontamination, ensure that disposable gloves are worn. Monitor hands occasionally to determine if gloves should be changed out.

3. If contamination is “fixed” to a surface it may be necessary to remove

the surface and place it in the radiological waste. For "fixed" contamination involving radionuclides with short half-lives (where the external dose rate is not a personnel hazard) the area may be covered, marked as a contaminated area and left to decay down to background levels.

4. The internal surfaces of some laboratory equipment may be contaminated during normal use. If these surfaces are impractical to clean, the equipment should be labeled to indicate internal contamination.

5. **The decontamination end point is reached when:**

a) All removable contamination is cleaned to levels as low as reasonably achievable (ALARA). An uncontrolled area may not be released until the removable contamination is less contamination action level for the radionuclide of concern.

Radionuclide/Emission	Contamination Wipe Action Level*
Beta-gamma emitters (nuclides with decay modes other than alpha emission)	1000 dpm 100 cm^2
I-131	200 dpm 100 cm^2
Any alpha emitters	100 dpm 100 cm^2
I-125	20 dpm 100 cm^2

*Above background levels

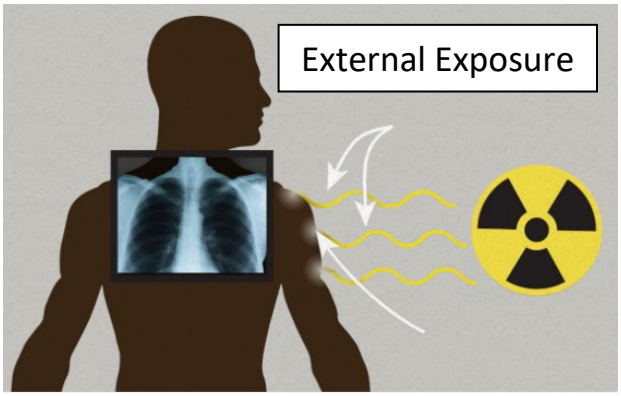
b) For "fixed" contamination, where the external exposure rate is not significant and the half-life is short, the affected area is covered and labeled.

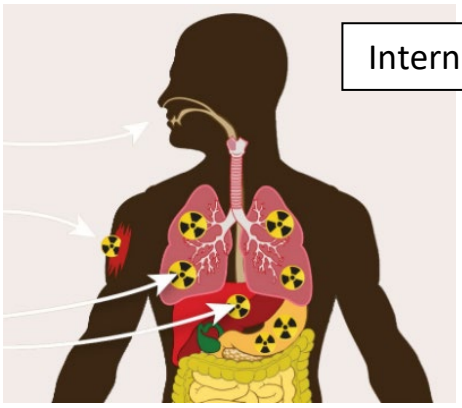
c) For "fixed" contamination where the external exposure may present a personnel hazard or the half-life is long, the surfaces are removed and placed in radiological waste or properly shielded and labeled to indicate contamination.

d) For surfaces not accessible to personnel (e.g., internals), the equipment is properly labeled to indicate contamination.

Section B-5
Personnel Monitoring

Individuals working with ionizing radiation can receive radiation dose either externally (e.g., radiation emitted from radioactive material or a device outside the body) or internally (from radioactivity deposited within the body due to ingestion, inhalation, or absorption of radioactive material). To determine the external radiation dose personnel monitoring devices (dosimeters or "**radiation badges**") are used, while **bioassays** are used to determine internal radiation dose.





A. External Monitoring

1. Who Must be Monitored?

Radiation dosimeters (e.g., "badges") monitor radiation exposure from external sources of radiation and radioactive material. State regulations require that the licensee (e.g., UNMC) must monitor exposures to radiation and radioactive material at levels sufficient to demonstrate compliance with the occupational regulatory dose limits. At a minimum, the following individuals must be monitored:

a. Adult workers likely to receive an external radiation dose, in

one year, in excess of 10% of the occupational dose limits, summarized in the table below:

Radiation Dose	Monitoring Required if Annual Dose Exceeds:	Annual Dose Limit
Whole Body Dose (DDE)	500 mrem	5000 mrem
Lens of Eye (LDE)	1500 mrem	15,000 mrem
Extremity (SDE-ME)	5000 mrem	50,000 mrem
Skin (SDE-WB)	5000 mrem	50,000 mrem

b. Declared Pregnant Worker (DPW), a woman who has voluntarily declared in writing of her pregnancy, likely to receive during the entire pregnancy, from radiation doses external to the body, a deep dose equivalent in excess of 100 mrem.

c. Minors (< 18 years old) are required to be monitored if likely to receive in one year from external sources, a DDE in excess of 100 mrem, LDE in excess of 150 mrem, or a SDE (skin or extremity) in excess of 5000 mrem. **NOTE:** Nebraska law does not allow minors to work in “hazardous” jobs which include work with radioactive material.

d. Various users/operators of x-ray producing devices (refer to Section D).

Historical data shows that most UNMC radiation workers never approach values which require personnel monitoring. The majority of the researcher workers receive less than 10 mrem annually and very few exceed 100 mrem. Although not required, it is recommended that all individuals working with radioactive material wear dosimetry. The exception is work solely with very low energy beta emitters (beta

emitters with a maximum energy less than 250 keV, such as H-3, C-14, S-35, cannot penetrate the dead layer of the skin) or the use of very low amounts of radioactivity.

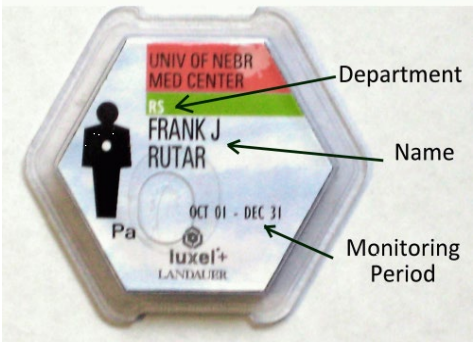
Non-Radiation Workers
Non-radiation workers may also request monitoring if they have a concern regarding radiation exposure

2. Types of Radiation Badges

UNMC utilizes Landauer, Inc., an accredited dosimetry company to provide and process radiation dosimeters. It is important to remember that dosimetry only measures external radiation exposure and offers no protection from radiation.

a. Whole Body Dosimeter (Whole Body Badge)

To monitor exposure at UNMC workers are issued a whole body dosimeter (often referred to as a "radiation badge"). At UNMC, the Luxel OSL (Optically Stimulated Luminescence) Whole Body Dosimeter is used. This dosimeter utilizes a high purity aluminum oxide crystal that has higher sensitivity and environmental stability over other types of radiation badges used. The Luxel dosimeter can measure gamma/x-ray doses down to 1 mrem and beta exposures down to 10 mrem.



The badge utilizes filters to measure the following dose quantities simultaneously:

Deep Dose Equivalent (DDE) is the dose at a tissue depth of 1 cm and is basically the whole body dose the worker is receiving from external radiation. Because most workers do not receive any internal radiation exposure, the DDE is essentially the worker's TEDE (annual limit of 5000 mrem).

Lens Dose Equivalent (LDE), which is the dose at tissue depth of 0.3 cm and is used to estimate the dose to the lens of the eye (annual limit of 50,000 mrem).

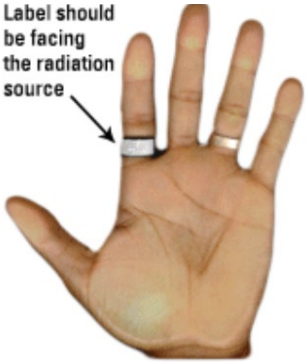
Shallow Dose Equivalent to the Whole Body (SDE-WB) is the dose at a tissue depth of 0.007 cm and is used to estimate the dose to the skin (annual limit of 50,000 mrem).

The whole body radiation badge is worn on the front trunk section of the body and should be worn anytime working with or near radiation sources. It can be worn inside or outside your lab coat. If a lead apron is worn, the badge is worn on the collar area on the outside of the apron. Radiation badges are exchanged semi-annually (Jan. 1st and July 1st) or quarterly (Jan. 1st, April 1st, July 1st, Oct. 1st) depending upon expected radiation exposure.

Because the exposure measured with this badge is your official record of radiation dose, it is important to keep the following in mind:

- Do NOT wear another person's badge.
- Do NOT store your radiation badge near radiation sources.
- If you lose your badge, immediately contact Radiation Safety.
- If your badge becomes damaged, contaminated (e.g., radioactivity is spilled on the badge) or is inadvertently exposed to radiation (e.g., left in an x-ray room), immediately contact Radiation Safety.

b. Extremity Dosimeter ("Ring Badge")



The extremity dosimeter (often referred to as a "ring badge") measures the radiation exposure to the extremities, i.e., the hands. Instead of an OSL, the ring badge uses a TLD (thermoluminescent dosimeter that utilizes a LiF crystal) to measure exposure. It can read doses down to 30 mrem.

It is recommended that a ring badge be used when working with more than 1 millicurie of radioactive higher energy beta, or x/gamma ray emitters (e.g., P-32, P-33, Cr-51, I-131, I-125). The ring badge should be worn on the hand that is likely to receive the highest exposure and comes in a range of sizes (S, M, and L). To avoid contamination, wear the badge inside with the label on the palm side under gloves.

c. Fetal Badge

Any female worker who voluntarily enrolls in the Fetal Monitoring Program will be provided a fetal badge in addition to her regular whole body badge. The badge is identical to the whole body badge except that only the Deep Dose Equivalent (DDE) is measured. The fetal badge is to be worn on the front of the abdomen. If a lead apron is used, the fetal badge should be placed under the apron while the standard whole body badge is worn on the collar outside the apron.

Because of the lower dose limit for fetal exposure, **both the worker's fetal and regular whole body badges are exchanged on a monthly basis.**

3. How to Enroll in the Radiation Badging Program

Each department has a badge coordinator who has information relevant to enrolling in the badge program (contact the Radiation Safety Office if you do not know the badge coordinator for your department). You must first complete the UNMC Radiation Dosimeter Request Form, which is available electronically on the EH&S Radiation Website. Alternatively, you may contact your department's badge coordinator or Radiation Safety for a paper copy of the form.

All individuals must provide a dose history to the Radiation Safety Office if they are likely to receive in excess of 10% of any applicable annual limit. Additionally, any individual who had been badged (or is badged) at another facility during the current calendar year must provide the Radiation Safety Office with pertinent exposure data. This exposure data will allow adjustments to be made so that none of the annual limits are exceeded.

It is each individual's responsibility to notify the badge coordinator or Radiation Safety Office when they terminate work involving radiation exposure or no longer require a radiation badge. If requested, a

termination report will be forwarded.

How to Enroll in the Fetal Monitoring Program

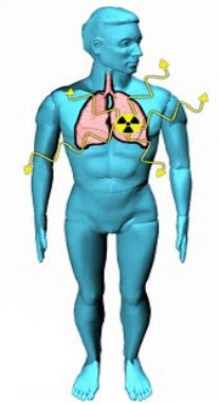
Any pregnant female radiation worker who wishes to voluntarily enroll in the Fetal Monitoring Program needs to complete the Declaration of Pregnancy/Fetal Monitoring form which is available on the EH&S Radiation Safety website. Alternatively, a paper copy of the form can be obtained from the department badge coordinator or Radiation Safety. The form must be signed by both the DPW and her immediate supervisor. The information on this form will allow Radiation Safety Office to calculate the dose received from the date of conception until the date of declaration. Exposure limits for the remaining allowable dose will be set at that time.

A Declared Pregnant Woman (DPW) is limited to **500 mrem for the entire gestation period**. If the dose equivalent to the embryo/fetus is found to be 450 mrem or more when the pregnancy is declared, the DPW is allowed 50 mrem for the remainder of the pregnancy.

The exposure levels for fetal monitoring badges will be evaluated throughout the entire gestation period by the Radiation Safety Office. A fetal ALARA (As Low As Reasonably Achievable) level has been set by the Radiation Safety Office at an exposure of **40 mrem/month**. Should this level be exceeded, the DPW will receive immediate notification.

At the end of the pregnancy, the DPW will contact the Radiation Safety Office to discontinue the fetal monitoring badge. If requested, a Fetal Exposure final report will be generated.

B. Internal Monitoring (Bioassays)



Internal monitoring is conducted to assess the potential intake (ingestion, inhalation, or absorption) of radioactive material into the body. **Bioassays** (direct measurement of radioactive material in the body) is the method of internal monitoring used at UNMC. The bioassay measurements are used to confirm the adequacy of radiological controls and to determine compliance with the occupational dose limits.

There are various types of bioassays that can be used to quantify the amount of activity of a radionuclide internally, including:

a. **Thyroid Bioassay**: Historically, this has been the most commonly performed bioassay at UNMC. Because iodine concentrates in the thyroid, this bioassay is used for individuals working with radioactive forms of Iodine, specifically I-125 and I-131. The gamma radiation emitted by the thyroid is used to estimate the uptake of radioiodine.

b. **Gamma Measurements**: Similar to the thyroid bioassay, a nuclear medicine gamma camera or whole body gamma counter can be used to measure the internal radioactivity in the body if the radionuclide emits gamma radiation in its radioactive decay process.

c. **Excreta Bioassay**: Radioactivity taken up internally will be excreted in the urine or feces. The amount of radioactivity in excreta can be measured using various counters such as a liquid scintillation counter or gamma spectroscopy system.

The type of bioassay and requirements for requiring a bioassay depends upon a number of factors including the radionuclide, chemical form, amount of activity used, and the experimental procedure.

Two separate categories of bioassay measurements determine the frequency and scope of measurements. These are routine measurements

and special monitoring.

1. Routine Bioassays

Routine Measurements include baseline measurements, periodic measurements, and termination measurements. These measurements should be conducted to confirm that appropriate controls exist and to assess dose.

Baseline Measurements

A baseline measurement of radioactive material within the body may be conducted prior to initial work activities that involve work with radioactive material that has the potential of internal contamination or the individual has performed similar type work with that radionuclide.

Periodic Measurements

Depending upon the radionuclide, physical/chemical form (e.g., volatility), and the protocol on how the radioactive material will be used, periodic measurements may be required to demonstrate compliance.

Termination Measurements

When an individual is no longer subject to the bioassay program, because of termination of employment or change in employment status, termination bioassay measurements should be made, when practicable, to ensure that any unknown intakes are quantified.

2. Special Monitoring

Because of uncertainty in the time of intakes and the absence of other data related to the exposure (e.g., physical and chemical forms, exposure duration), correlating positive results to actual intakes for routine measurements can sometimes be difficult. Abnormal and

inadvertent intakes from situations such as inadequate engineering controls, inadvertent ingestion, contamination of a wound, or skin absorption should be evaluated on a case-by-case basis. Circumstances that should be considered when determining whether potential intakes should be evaluated include:

1. The presence of unusually elevated levels of facial and/or nasal contamination.

2. Entry into airborne radioactivity areas without appropriate exposure controls.

3. Operational events with a reasonable likelihood that a worker was exposed to unknown quantities of airborne radioactive material (e.g., loss of system or container integrity).

4. Known or suspected incidents of a worker ingesting radioactive material.

5. Incidents that result in contamination of wounds or other skin absorption.

6. Evidence of damage to or failure of a respiratory protective device.

3. Action Levels for Bioassays

There are two action levels for bioassays: an Evaluation Level and Investigational Level. These action levels are based upon the radionuclide's ALI (Annual Limit of Intake) which is the **intake** (the amount of radioactivity initially taken into the body) that would result in a regulatory dose limit for occupational radiation workers (e.g., Committed Effective Dose Equivalent of 5 rem or Committed Dose Equivalent of 50 rem). The intake is typically calculated by dividing the **uptake** (the amount of radioactivity measured at the

time after initial intake) by the Intake Retention Factor given in NUREG/CR-4884. The intake could also be calculated by determining the effective elimination clearance from several bioassay measurements.

The Evaluation Level is set at an intake of 0.02 ALI and Investigation Level is set at an intake of 0.1 ALI.

If the **Evaluation Level** is exceeded the following actions should be taken:

i. An investigation of the operations involved, including air and other in-facility surveys, should be conducted to determine the causes of exposure and to evaluate the potential for further exposures.

ii. Corrective actions that will eliminate or lower the potential for further exposures should be implemented.

iii. A repeat bioassay should be performed within 24 hours of the last measurement, in order to confirm the presence of intake.

If the **Investigation Level** is exceeded the following actions should be taken;

i. Conduct all the steps for an Evaluation Level.

ii. As soon as possible, refer the case to appropriate medical consultation for recommendations regarding therapeutic procedures that may be conducted to accelerate removal of radioactive material from the body. For radioiodines, this should be done within 2-3 hours after exposure when the time of exposure is known so that any prescribed thyroid-blocking agent may be effective. NCRP Report 161 and the Radiation Emergency Assistance Center/Training Site (REAC/TS) can provide guidance for emergency treatment if a severe intake of radioiodine, or another radionuclide, were to occur.

iii. Conduct repeated measurements as determined by the Radiation Safety Office. The frequency and duration of performing bioassays will be dependent upon the radionuclide's effective half-life in the body. For example, for I-125 or I-131 bioassays should be conducted at approximately 1-week intervals until the thyroid content is less than 1 µCi (37 kBq). If there is a possibility of radioiodine retention in certain parts of the body that requires evaluation, continue bioassay as long as necessary to ensure that appreciable exposures do not go undetected.

iv. If the investigation indicates that further work in the area might result in exposure of a worker to concentrations that would cause the worker to exceed a regulatory dose limit, the worker will be restricted from further work until the source of the exposure is found and corrected.

4. Thyroid Bioassays for I-125 and I-131

Thyroid bioassays are used to assess the intake of I-125 and I-131 compounds that tend to concentrate in the thyroid gland.

Thyroid bioassays are typically performed at the Radiation Safety Office (Shackleford Hall). The procedure involves using a NaI scintillation probe to measure the amount of radioactive iodine in your thyroid (see figure to the right). The procedure normally takes a few minutes to perform. Radiation Safety personnel is available to assist you if needed.

a. Activity at which Thyroid Bioassays are Required

1. A baseline thyroid bioassay should be performed prior

to handling or observing work with volatile radioiodine for the first time.

2. The activity levels at which bioassays are required are given in the table provided on the **Table I** in this section. These quantities apply to both the single quantity handled at any one time or integrated as the total amount of activity introduced into a process over any **three (3) month period**.

3. It should be noted that the table indicates the minimum requirement for performing a thyroid bioassay is recommended that a thyroid bioassay be performed anytime 1 mCi or more of radioiodine is put into process. The bioassay should be performed **6 to 72 hours** after handling to ensure adequate uptake by the thyroid.

4. Individuals may request a bioassay at any time. Bioassays should be performed after spills, contamination events or any abnormal occurrence involving radioioidine.

5. An individual no longer subject to the bioassay program, because of termination of employment or change in employment status should perform a termination bioassay to ensure that any unknown intakes are quantified.

b. Action Levels for Thyroid Bioassays

The limiting ALI's are 60 µCi for I-125 and 50 µCi for I-131. For simplicity, I-131's slightly more conservative ALI will be used for I-125 action levels.

Action Category	Bioassay Action Level for I-125 or I-131
Evaluation Level	Intake = 1 µCi
Investigation Level	Intake = 5 µCi

c. How is the Intake & Thyroid Dose Determined?

The thyroid bioassay is a measurement of the **uptake** in the thyroid, which is the amount of activity measured in the thyroid at some time after the initial intake. The **intake** is calculated by dividing the uptake, by the Intake Retention Factor (NUREG/CR-4884). For I-125 and I-131 the following uptakes correspond to action level intakes:

Uptakes Corresponding to Action Levels		
Time of Bioassay (Hours after Intake)	Evaluation Level (Thyroid Intake = 1 uCi)	Investigation Level (Thyroid Intake = 5 uCi)
6 hrs	**I-125 = 0.0586 uCi I-131= 0.055 uCi**	**I-125 = 0.293 uCi I-131= 0.275 uCi**
12 hrs	**I-125 = 0.0952 uCi I-131= 0.096 uCi**	**I-125 = 0.476 uCi I-131= 0.480 uCi**
24 hrs	**I-125 = 0.141 uCi I-131= 0.133 uCi**	**I-125 = 0.705 uCi I-131= 0.665 uCi**
72 hrs	**I-125 = 0.175 uCi I-131= 0.142 uCi**	**I-125 = 0.875 uCi I-131= 0.710 uCi**
45 days	**I-125 = 0.0823 uCi I-131= 0.0028 uCi**	**I-125 = 0.412 uCi I-131= 0.140 uCi**

The thyroid dose can be calculated by assuming an intake equal to 1 ALI corresponds to a Committed Dose Equivalent to the Thyroid of 50 rem. The non-stochastic ALI for I-125 is 60 uCi and for I-131 the ALI is 50 uCi.

TABLE I Activity Levels Requiring Bioassay for I-125/I-131		
	**Activity Handled in Unsealed Form Making Bioassay Necessary	
Type of Operation	**Volatile Forms (e.g., compounds where radioiodine is normally bound & are known to release radioiodine when the material is in process)** **Example: NaI Liquid**	**Non-volatile Forms (e.g., activity in process is always chemically bound & processed in such a manner that the iodine remains in a non-volatile form)** **Example: Radioimmunoassay (RIA) kits**
Open Room or Bench	**0.1 mCi**	**1.0 mCi**
Fume Hood	**1.0 mCi**	**10.0 mCi**
Glove Box	**10.0 mCi**	**100.0 mCi**

1. **In operations where reagent containers are opened indoors for simple operations such as pouring liquid solutions, the above table does not apply; bioassays should be performed whenever an individual employee handles in open form (e.g., an open bottle or container) more than 50 mCi of I-125 or I-131 at any one time.**

2. **Operations involving the routine use of I-125 or I-131 in an open room or bench should be discouraged. Whenever practicable, sealed bottles or containers holding more than 0.1 mCi of I-125 or I-131 should be opened at least initially within fume hoods recommended fact velocity or 125 lfpm).**

Example: **If a researcher uses a total of 1 mCi of I-125 NaI (assumed to be volatile) over a three-month period and performs all the work in a fume hood, they would be required to perform a thyroid bioassay.**

5. Urine Bioassays for H-3

Urine bioassays are used to assess the intake of radionuclides that do not exhibit uptake within a particular organ. These compounds are typically cleared from the blood via the kidneys and can be measured in the urine for a finite period following the intake. The most likely scenario would involve substantial amounts of tritium (H-3). Urine bioassays have historically not been required at UNMC.

For tritium, analysis of urine for tritium content has proven to be the most reliable method for determining the concentration of tritium in the body. In most cases, after H-3 will enter the body, it will distribute into body water and will not concentrate. It is eliminated with a biological half-life of 10 to 15 days due to normal turnover of body water.

a. When does a Urine Bioassay Need to be Performed?

1. The activity amounts of H-3 requiring a urine bioassay is provided in the Table II. Contact the Radiation Safety Office if you plan to work with a cumulative H-3 activity of 100 mCi (0.1 Ci) or more in a one-month period. It is recommended prior to working with substantial amounts of H-3 that require a urine bioassay.

2. Urine bioassays may be requested at any time and may also be required following spills, personnel contamination, or other abnormal occurrences.

3. To ensure distribution, a urine bioassay is normally performed 24 hours after handling H-3. The frequency for other radionuclides will be determined by the Radiation Safety Office.

b. Bioassay Action Levels

The ALI for Tritium is 80,000 uCi (80 mCi) which is the intake amount that would result in a Committed Effective Dose Equivalent of 5 rem.

Action Category	Action Level	H-3 Intake
Evaluation Level	Intake = 0.02 ALI	1600 uCi
Investigation Level	Intake = 0.10 ALI	8000 uCi

c. How is the Intake & Dose Determined?

The urine bioassay is a measurement of the **uptake** in body, which is the amount of activity remaining in the body sometime after the initial intake. The **intake** is calculated by dividing the uptake by the Intake Retention Factor (NUREG/CR-4884). For H-3, the following uptakes correspond to action level intakes:

Urine Uptakes Corresponding to Action Levels		
Time of Bioassay (Hrs after Intake)	Evaluation Level (0.02 ALI; 1 Rem CEDE)	Investigation Level (0.10 ALI; 5 Rem to CEDE)
1 Day	H-3 = 61.6 uCi	H-3 = 308 uCi
2 Days	H-3 = 60.2 uCi	H-3 = 300 uCi
10 Days	H-3 = 34.6 uCi	H-3 = 172 uCi

5. Bioassays for Other Radionuclides

Bioassay requirements for other radionuclides will be determined by the Radiation Safety Office on a case-by-case basis.

a. A urine bioassay would be necessary when large activity amounts (> 100 mCi) of methionine, cysteine or trans-labeled sulfur-35 are put into process since these compounds have the potential to be slightly volatile.

b. Urine or fecal bioassays are likely to be used when working with alpha emitting radionuclides. The Intake Retention Factor (NUREG/CR-4884) can be used to estimate the intake and subsequent radiation dose.

c. If there is a useful gamma emitting photon in the radionuclide's decay scheme (including daughter products), the use of a gamma camera in Nuclear Medicine or a whole body counter (e.g., used commonly at Nuclear Power facilities) may be helpful in determining the uptake and effective clearance rate in the body. These parameters can then be used to calculate the internal radiation dose to the individual.

C. Results of Monitoring

All personnel who are provided monitoring (external and/or internal) may contact the Radiation Safety Office at any time to get their radiation exposure history or most current badge readings. In addition, UNMC provides the following exposure history reports:

1. Annual Reports

Each worker who is required to be monitored for radiation dose by regulation is furnished annually a written report of the worker's dose. This written report must include:

a) The deep dose equivalent to the whole body, lens dose equivalent, and shallow dose equivalent to the skin. These doses are typically measured with the worker's whole body badge (e.g., DDE, LDE, SDE).

b) The shallow dose equivalent to the extremities which is typically measured with an extremity ("ring") badge.
c) Any intake of radioactive material and the corresponding radiation dose (committed effective dose equivalent) from this intake. This is determined by performing a bioassay (e.g., thyroid bioassay).
d) The TEDE (Total Effective Dose Equivalent) which is the sum of the effective dose equivalent from external and internal exposures. Typically, this is the DDE from the worker's radiation badge plus the dose from any intake of radioactive material.

Exposure histories at UNMC indicate that UNMC radiation workers are well below the values requiring monitoring and therefore, these annual reports are not required by regulation. However, UNMC currently provides this annual report to each worker who provided a radiation badge. Workers who terminate employment with UNMC will be mailed this annual report if a forwarding address is provided to the Radiation Safety Office or Human Resources.

2. Termination Reports

At the request of a worker who is required by regulation to be monitored and is terminating employment (or has terminated employment), UNMC will provide a termination report regarding the radiation dose received by that worker for the current year. If the most recent results are not available at the time, a written estimate will be provided with a clear indication that this is an estimate. If a worker requests a written report of their doses, it will be provided within 30 days after it is received from the company providing the dosimetry services.

TABLE II
Activity Levels Requiring Bioassay for Tritium (H-3)

Type of Operation[a]	Activity Handled in Unsealed Form Making Bioassay Necessary		
	HTO[b] and Other Tritiated Compounds (Including Nucleotide Precursors)	Tritium (HT or T_2)[c] Gas in Sealed Process Vessels[d]	HTO Mixed with More Than 10 kg of Inert H_20 (e.g., in Reactor Coolant)[e]
Processes in open room or bench with possible escape of tritium from process vessels	0.1 Ci	100 Ci	0.01 Ci/kg
Processes with possible escape of tritium conducted within a fume hood of adequate design, face velocity, and performance reliability	1 Ci	1,000 Ci	0.1 Ci/kg
Processes conducted within glove boxes that are ordinarily closed but with possible release of tritium from process vessels and occasional exposure to contaminated box and leakage	10 Ci	10,000 Ci	1 Ci/kg

a Quantities (<10 kg) of substances containing tritium that are present during operations may be considered to be either the amount processed by an individual at any one time (when accidental intake is more likely) or the amount of activity that entered into the process (throughout) during any one month (when routine handling of repeated batches is the more likely source of exposure).

b HTO is a symbol for a water molecule in which a tritium atom (T) is present in place of a normal hydrogen atom (H).

c A molecule of hydrogen gas contains two hydrogen atoms. Either one of these atoms may be replaced with T to form HT, or two T atoms may combine to form T_2 gas.

d This assumes that adequate air monitoring has established that there is no tritium leakage or that no significant amount of tritium gas can be converted to HTO before intake.

e This column is applicable in place of the previous two columns in cases where tritium can be identified at measurable concentrations in substantial amounts of water or other substances, such as a nuclear power plant. A baseline urine bioassay is required prior to participation in most radiation safety protocol activities. If a urine bioassay is required by the protocol, a second urine bioassay will be requested after the initial experiment.

Section B-6
Laboratory Surveys

A. Types of Surveys

Surveys are performed in all areas where radiation is used to identify any potential radiation problems and ensure that radiation doses to individuals working in or around these areas are kept as low as reasonably achievable (ALARA). There are five types of surveys which may be performed depending on the types and quantities of radioactive material being used.

1. **General Use Survey:** This is a visual check of the lab areas to ensure appropriate warning signs, labels, alarms, notices and procedures are being used.

2. **Instrument Survey**: This is using a survey instrument to locate fixed and removable contamination on surfaces, equipment, personnel and clothing. At a minimum, an instrument survey should be performed at the end of each working day.

3. **Wipe Survey**: This is using absorbent material (e.g., filter paper, q-tip) wipe to locate and quantify (in dpm) removable contamination on surfaces, equipment, personnel and clothing. Depending upon the radionuclide and the amount of radioactivity used, wipe surveys may be required to be performed daily, weekly, or monthly.

4. **Exposure Rate Survey**: This is using an ion chamber to determine exposure rates (in mR/hr) for compliance to regulatory limits. Radiation Safety will typically perform these surveys.

5. **Air Concentration Survey**: This is using air sampling equipment to determine the airborne concentration of radioactive material in a room or area. Radiation Safety will perform this survey if necessary.

B. General Use Survey

When working in a radioactive material laboratory the following items should be checked and maintained. The Radiation Safety Office will also check these items during audits and will report any deficiencies to the Authorized User for correction.

1. Proper posting of radiation uses and storage areas with the “Caution - Radioactive Material” sign.

2. Use of proper radioactive waste containers. Containers must be conspicuously labeled with the radiation symbol and the “Caution - Radioactive Material” warning. The use of unauthorized containers (e.g., coffee cans) to store radioactive material is prohibited unless the original container labels are defaced or removed.

3. Ensure that radiation waste is not being deposited in the normal trash.

4. Ensure that food and drink are not stored in refrigerators or other devices (e.g., cold rooms) containing radioactive material.

5. Ensure that laboratory glassware is not being used for food or drink purposes, and that food and drink containers are not being used for radioactive materials unless labeled “Radioactive Material”.

6. Ensure that food and drink is neither prepared nor consumed in any laboratory/area used radioactive material.

The laboratory is responsible for correcting any deficiencies noted above.

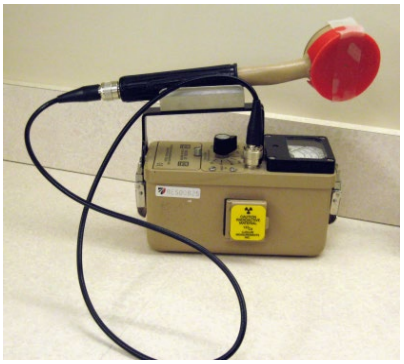
C. Instrument Surveys

1. When Does an Instrument Survey Need to be Performed?

At a minimum, instrument surveys are to be performed at the end of each working day, when a spill occurs or anytime an individual or area is believed to be contaminated. This survey is used for an immediate indication of a problem or to detect contamination prior to a wipe survey.

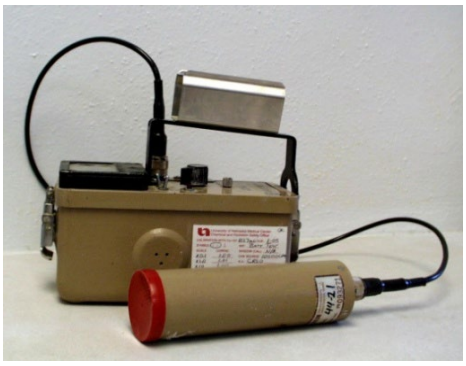
2. What Type of Instrument Should be Used?

This depends on the nuclide being detected. For most radionuclides a survey meter equipped with a pancake Geiger-Mueller (G-M) probe or thin end window G-M probe is appropriate for most radionuclides used at UNMC.



Survey meter with GM Pancake probe

GM end window probe



Survey meter with NaI probe for low energy gammas

NOTE 1 : Tritium (H-3) cannot be detected with a survey meter due to very low energy. A wipe test counted on a liquid scintillation counter must be used to determine any H-3 contamination.

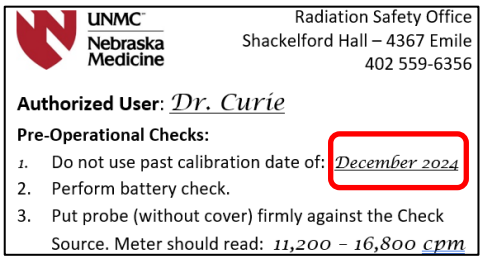
NOTE 2: For I-125 a low energy NaI probe (e.g., Ludlum 44-3) should be used.

NOTE 3: Many survey meters have a “F” or “S” (fast or slow) response setting. The slow response setting will give a more accurate reading but takes around 20 seconds to equilibrate. The fast setting will equilibrate within a few seconds but will show more fluctuation. In most cases the fast response setting is acceptable and **preferred**.

2. How is an Instrument Survey Performed?

a. Perform an operation check to ensure that the meter is operating correctly. The operation check consists of the following three steps which are given on the calibration sticker adhered to the survey meter:

i. **Check calibration date**. Make sure the today's date is not past the calibration due date.

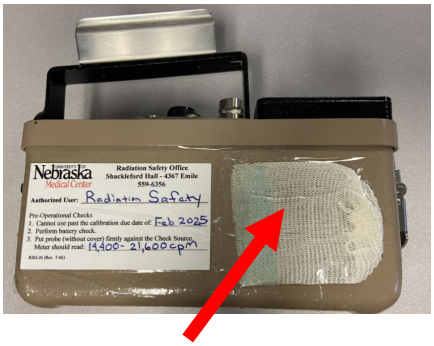


Example calibration sticker used on a survey meter.

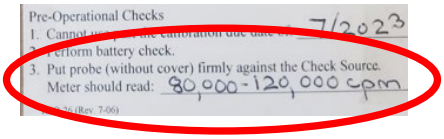
ii. **Perform a battery check**.
Depending upon the meter you will either turn the toggle on the meter to "Batt" or move the range selector from the "OFF" position and press down on the BAT button. If the batteries are good the needle will go into the "Batt OK" or "Batt Test" region. If batteries are low, you may change out the batteries yourself…it does **NOT** require recalibration.

iii. **Perform a function check**. For survey meters this typically involves placing the probe against a radioactive check source (often a gas mantel or button source adhered to the meter) and ensuring the meter reading falls within the acceptable range indicated on the calibration sticker.

Button Check Source
(Typically, Cesium-137)



Gas Mantel Check Source
(Low amounts of Thorium)



For this meter the check source should read between 80,000 – 120,000cpm)

b. Go to an area with a low background level and measure background radiation level (typically, you just need to hold the probe up in the air away from the meter check source). For a Ludlum survey meter equipped with a GM probe, the background level is typically 40 - 100 cpm (Note: if set on the fast response, there will be considerable fluctuation in this range).

c. Slowly scan the area (or items) with the probe approximately 1 centimeter away. Remember to survey yourself (starting with your hands) to ensure that you are not contaminated.

d. **ACTION LEVEL: If radiation levels are greater than 2 times background levels, decontaminate** (Often times, paper towels and water can adequately decontaminate surfaces).

e. After decontamination, a second survey is performed to ensure that contamination has been removed. If still above 2 times background, decontaminate again. If still above the action level,

you are required to perform a contamination wipe to measure non-fixed contamination.

D. Wipe Surveys

A wipe survey is used to determine the amount of removable contamination present. It is recommended that an instrument survey be performed prior to a wipe survey to minimize the chance of inadvertently spreading contamination and also to identify the areas requiring greater attention in wipe sampling.

1. When & Where do Wipe Surveys Need to be Performed?

The frequency of wipe surveys is determined by the radionuclide and activity put into process and is specified in the ***Removable Contamination Survey Frequency for Research Laboratories*** Table B1. Depending upon the radionuclide, its ALI (Annual Limit of Intake), and quantity put into process, contamination wipes surveys may need to be performed daily, weekly or monthly. The wipe survey is required to be performed for all locations and equipment where radioactive material was placed into process.

a. What About Rooms Used ONLY to Store Radioactivity?

If the radioactive material that was stored in the room was put into process, then wipe(s) are required in that room. If the material was not put into process wipe surveys are NOT required. However, it is good practice to take a wipe in these storage areas (e.g., floor by freezer, freezer shelf) whenever you are performing surveys.

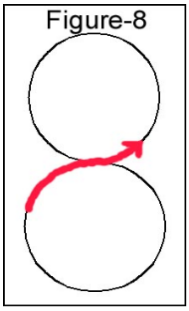
b. How about Rooms that only have Liquid Scintillation and/or Gamma Counters?

If you use a liquid scintillation or gamma counter to count radioactive samples, you must perform a contamination wipe survey.

2. How is a Wipe Survey Performed?

a. Wear disposable gloves.

b. Use dry filter paper or some other absorbent material (e.g., q-tip) and apply light pressure over the surface being surveyed. An area of approximately 100 square centimeters should be covered with each wipe. This area can be approximated by making a figure-8 over the area of a dollar bill.



c. Analyze the sample by using an appropriate counter for the radionuclide being counted. Liquid scintillation counters (LSC) are commonly used. Gamma counters can be used if appropriate gamma rays are emitted. The counting instrument must be sufficiently sensitive to detect below the contamination wipe action level for that radionuclide.

d. **The Action Level for Contamination Wipe Surveys:** The Action Level for contamination wipes is dependent upon the radionuclide/emission and is provided in the following table:

Radionuclide/Emission	Contamination Wipe Action Level*
Beta-gamma emitters (nuclides with decay modes other than alpha emission)	1000 dpm 100 cm^2
I-131	200 dpm 100 cm^2
Any alpha emitters	100 dpm 100 cm^2
I-125	20 dpm 100 cm^2

*Above background levels

e. Any wipes over the action level must be decontaminated (typically using water or radioactive decontamination solution, such as Radiac Wash, with paper towels) and the area must be re-swiped and counted.

3. Documentation Required for Wipe Surveys

The regulations require that each lab must have a copy of the survey results recorded in dpm keyed to a room map (e.g., a laboratory diagram indicating where the wipes were taken).

a. Room Maps

Radiation Safety will assist you in creating a laboratory diagram (room map) of each room where radioactive material is used or stored. Instead of making a new room map for each survey, most labs use a "master" set of room maps indicating where wipes are to be taken each time. It is recommended that these maps be stored in the survey section of your Radioactive Material Records book.

b. Wipe Survey Results Documentation

For many laboratories using radioactive material, contamination wipes are required monthly. Each month the Radiation Safety Office sends out a ***Laboratory Contamination Survey*** form to document contamination wipe surveys. On each form is the Authorized User's name, the Action Level and wipe frequency/action level for each of the radionuclides authorized on their license, and all the rooms that are on their radioactive material license. If a daily or weekly wipe are required that month, that survey can count as the monthly wipe survey. For labs that are required to do more than one survey in a month (e.g., several daily and/or weekly wipes) contact Radiation Safety on how best to document wipe surveys (some labs sent in a copy of the wipe results each time they perform a wipe).

After completing the Laboratory Contamination Survey form, file the form **and survey results (including surveys after decontamination).** The survey results can be the actual printout of the counter (e.g., from the liquid scintillation counter) or a log where the contamination wipe results are documented. It is recommended that these documents be filed in the survey section of the Radioactive Material Records book. Radiation Safety requests that a copy of the Laboratory Contamination Survey form and wipe results be sent to the Radiation Safety Office for tracking purposes.

E. Exposure Rate Survey

NOTE: Research laboratories typically do not need to perform exposure surveys. The Radiation Safety Office will perform exposure surveys when necessary.

An ion chamber (shown in the figure to the right) is specifically designed and calibrated to measure external radiation levels in air and is typically used for exposure surveys since it will provide a true reading of the exposure rate. Geiger Mueller (GM) survey meters can also be used for exposure rate survey (most survey meters have dual scales displaying both cpm and mR/hr), but GM meters tend to over or under-respond depending upon the radionuclide.

1. Exposure surveys are performed on large quantities of high energy gamma emitting radionuclides, such as I-131, and Cs-137. These surveys are also performed on packages or waste drums prepared for shipment, and to determine radiation area classification (e.g., Radiation Area, High Radiation Area, Very High Radiation Area).

2. **ACTION LEVEL**:

Action levels are variable and determined by the regulatory limits. However, a few of the exposure limits are provided below:

Non-restricted Area:
This is an area that is not controlled by the licensee (e.g., UNMC) for radiation safety purposes and, therefore, individuals of the general public may be present. The total effective dose equivalent cannot exceed 2 mrem in any one hour and 100 mrem annually in these areas. Because any public radiation exposure is most likely to be external, an exposure survey is used to determine compliance.

Radiation Area:
Areas where an individual might receive a deep dose equivalent of 5 mrem in one hour at 30 cm (1 ft) from the source of radiation or from any surface that the radiation penetrates. These areas are required to be posted as "Caution, Radiation Area".

High Radiation Area:
Areas where an individual might receive a deep dose equivalent of 100 mrem in one hour at 30 cm (1 ft) from the source of radiation or from any surface that the radiation penetrates. These areas are required to be posted as "Caution, High Radiation Area".

Very High Radiation Area:
Areas in which an individual may encounter dose rates of 500 rad in one hour at 1 meter from a source of radiation or any surface through which the radiation penetrates. These areas are required to be posted as "Grave Danger, Very High Radiation Area" or "Caution, Very High Radiation Area".

F. Air Concentration Surveys

Air concentration surveys can be performed when it is suspected that radioactive material is airborne, and personnel are being exposed via inhalation. The Radiation Safety Office will perform air sampling when necessary.

Airborne radioactive iodines (I-125, I-131) are measured by drawing a known volume of air through activated charcoal filters. Airborne dust which may contain radioactive particles are measured by drawing the air through a pre-filter.

Action levels are variable and determined by the regulatory limits.

Table I; Removable Contamination Survey Frequency for Research Laboratories Using Normal Chemical Operations (e.g., analysis, simple chemical preparations)

The frequency of removable contamination surveys (e.g., "wipes") for **unsealed sources** (e.g., liquid, gas) is dependent upon the radionuclide, its Annual Limit of Intake (ALI) and the amount placed into process. The following table provides the contamination wipe survey frequency:

Activity Put into Process	< 0.1 ALI	≥0.1 ALI < 1 ALI	≥1 ALI
Frequency	Monthly	Weekly	Daily

"Placed into process" means the amount being used in the actual chemical operation(s). For example, if a 20 mCi vial is opened briefly to take a 5 mCi aliquot out, then 5 mCi is considered placed into process. If a 20 mCi vial is sitting in storage and isn't opened, then no radioactivity was placed into process. Daily contamination surveys are required anytime an alpha emitter is put into process. Below is the table indicating the contamination survey frequency for some of the common radionuclides used at UNMC:

	Activity Put into Process (Note: low activities highlighted)		
Isotope	**Monthly**	**Weekly**	**Daily**
Ac-225, At-211	Daily survey anytime activity is put into process		
C-14	≤ 0.2 mCi	> 0.2 to 2 mCi	> 2 mCi
Cr-51	≤ 2 mCi	> 2 to 20 mCi	> 20 mCi
Cu-64	≤ 1 mCi	> 1 to 10 mCi	> 10 mCi
F-18	≤ 5 mCi	> 5 to 50 mCi	> 50 mCi
H-3	≤ 8 mCi	> 8 to 80 mCi	> 80 mCi
I-125	≤ 4 uCi	> 4 to 40 uCi	> 40 uCi
I-131	≤ 3 uCi	> 3 to 30 uCi	> 30 uCi
Lu-177	≤ 0.2 mCi	> 0.2 to 2 mCi	> 2 mCi
P-32	≤ 60 uCi	> 60 to 600 uCi	> 600 uCi
P-33	≤ 600 uCi	> 600 to 6000 uCi	> 6000 uCi
Pb-212	≤ 3 uCi	> 3 to 30 uCi	> 30 uCi
S-35	≤ 1 mCi	> 1 to 10 mCi	> 10 mCi
Tc-99m	≤ 2 mCi	> 2 to 20 mCi	> 20 mCi

References: Appendix L NUREG 1556, Vol. 11, Revision 1 and Appendix B to 10 CFR Part 20

Note 1: The amounts listed are based upon simple chemical operations. For other operations, contact Radiation Safety. **Table II- Modifying Factors** below will be used to determine contamination wipe frequency.

Note 2: No surveys are required for areas less than exempt quantity of a selected radionuclide.

Note 3: No surveys required in storage areas for closed containers of radioactive material which were **not** put into process (i.e., freezers). Before a storage area can be released for unrestricted use, a contamination survey must be performed.

Note 4: Remember to survey the room used to count the contamination wipes.

TABLE II

Modifying Factors for Other Than Normal Operations

Multiply these factors by the activity in Table I to determine contamination survey frequency.

Operation (Note: For operations not listed contact Radiation Safety)	Factor
Simple storage	x 100
Very simple wet operations (e.g., preparation of aliquots of stock solutions)	x 10
Complex wet operations (e.g., multiple operations, or operations with complex glass apparatus)	x 0.1
Simple dry operations (e.g., manipulation of powders) and work with volatile radioactive compounds	x 0.1
Potential exposure of non-occupational persons	x 0.1
Dry and dusty operations (e.g., grinding)	x 0.01

Example: If the daily frequency for I-131 during normal operations is >10 mCi, then the daily frequency for I-131 for simple wet operations is >100 mCi (e.g., 10 mCi x 10).

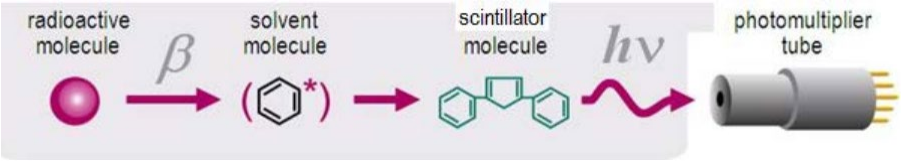
Reference: Appendix U NUREG 1556, Vol. 11 1998

Section B-7
Instrumentation

At UNMC the two major types of instrumentation used in radioactive material work in research laboratories are the survey meter and the liquid scintillation counter (LSC).

A survey meter is a portable, handheld, electronic instrument used to detect ionizing radiation. A survey meter consists of a detector (usually a probe) that converts the radiation into an electronic signal. This electronic signal is then converted to a visual indication of the radiation intensity (analog or digital). The survey meter is used primarily to determine if any radioactive contamination is present (e.g., surveying hands and the area of use after working with radioactivity). Survey meters are required to be calibrated annually. The Radiation Safety Office performs the calibration of most survey meters used on campus.

The liquid scintillation counter (LSC) is used for measuring and quantifying the radiation from a beta-emitting radionuclide. Samples to be counted are dissolved in a "cocktail" solution that contains small amounts of fluors (scintillators). 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 counter has two photomultiplier tubes which measure the light and quantify the energy emitted by the sample. The LSC is the most commonly used instrument to perform required contamination wipe surveys and is discussed at the end of this section.



A. What Type of Survey Meter Should I Use?

A survey meter equipped with a GM probe is recommended for most research labs at UNMC. The only exceptions are I-125 which requires a low energy NaI probe and alpha emitting radionuclides where an alpha probe (e.g., ZnS) might be used (depending upon the alpha emitter, it may emit beta-gamma radiation which is detectable with the GM probe). While there are several types of GM probes available (pancake, end-window, side window), the pancake probe is recommended because its large probe face is useful in surveying for contamination.

Survey meter with Ludlum 44-9 GM Pancake probe

Low Energy NaI Probe (e.g., Ludlum 44-3)

ZnS alpha probe (e.g., Ludlum 43-90)

NOTE: A survey meter cannot be used for the detection of Tritium (H-3); its beta particles are so low in energy they are unable to penetrate into the probe. To survey for H-3 contamination, you must perform wipe surveys and count on a liquid scintillation counter.

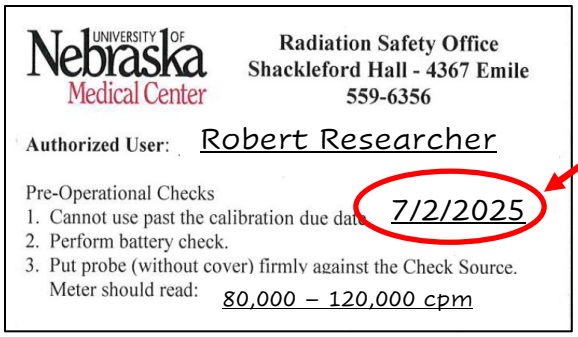
B. How to Use a Survey Meter

1. First Step – Pre-Operational Check

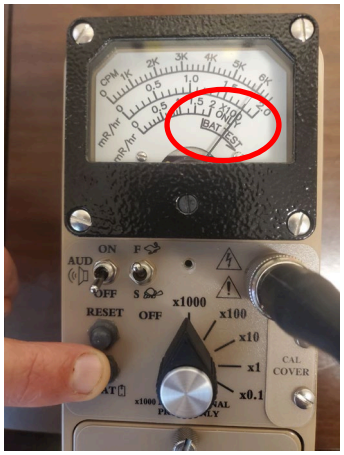
Prior to using a survey meter, it must be checked for proper operation. The calibration sticker taped on the meter (see figure

below) provides the 3 steps necessary to perform this "pre-operational check". The 3 steps are as follows:

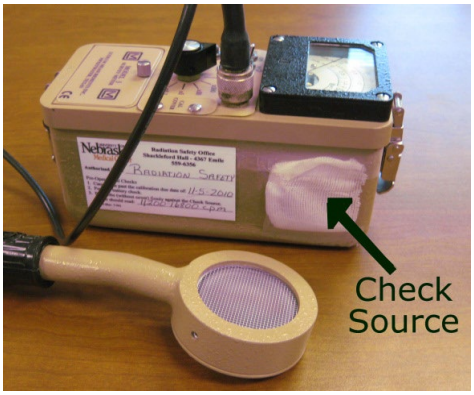
1) Make sure that the meter isn't past its calibration due date.


Nebraska Medical Center
Radiation Safety Office
Shackleford Hall - 4367 Emile
559-6356
Authorized User: Robert Researcher
Pre-Operational Checks
1. Cannot use past the calibration due date: 7/2/2025
2. Perform battery check.
3. Put probe (without cover) firmly against the Check Source.
Meter should read: 80,000 – 120,000 cpm
Check calibration due date

2) Perform a battery check. This typically involves turning the meter toggle to "BAT" (or similar verbiage) or pressing the "BAT" button and ensuring that the meter needle goes into the "BAT TEST" region (or similar verbiage). If the needle does not go into this region, the batteries need to be changed out. **You may change out the batteries yourself – the survey meter does NOT need to be recalibrated following a battery change.**



1) Put the probe (without its cover if it has one) against the check source. Typically, the check source is a small plastic disk source or a gas mantel that is adhered to the side of the meter. Make sure that the meter reads within the cpm range indicated on the calibration sticker. If it is outside the range indicated, contact Radiation Safety.



2. Using the Survey Meter

Radiation Readings:
The meter face on many survey meters reads in both CPM (counts per minute) and mR/hr (see figure). The cpm scale is typically the appropriate scale for surveying because the meters are usually calibrated using this scale.

Range Settings:
Most meters have several range settings. For the meter shown in the figure, the range can be set to X0.1, X1, X10, X100. To obtain the correct radiation reading you must multiply the cpm reading displayed by the range setting the meter is toggled at.
Example: If the needle is at 2K cpm (2000 cpm) and the toggle is at X0.1, then the correct radiation reading is 200 cpm.

Audio Setting:
Setting the audio (AUD) to "ON" will provide an audio indication of the radiation in addition to the visual needle reading. The higher radiation level, the more frequent the "clicks".

Response Setting (F or S):
The response setting of the meter can be set to Fast (F) or Slow (S). The slow setting will give a more accurate reading of the radiation, but it takes approximately 20 seconds to equilibrate. For most surveys, the fast (F) setting, which takes 4 to 5 seconds to equilibrate, is appropriate.

Performing a Survey Using the Survey Meter:
1) Before surveying, determine the background radiation levels. Typical background levels are around 40 - 100 cpm.
2) Proceed to survey placing the probe close to the surface (e.g., 0.5 to 1 cm). Avoid touching the surfaces to avoid contaminating the probe.

3) **The Action Level for instrument surveys are readings that are twice above background levels**. If the instrument survey reading is greater than twice background, the area/item should be decontaminated followed by another instrument survey. If the reading is still above background, a contamination wipe survey needs to be performed (contact Radiation Safety if assistance is required).

C. Calibration of Survey Meters

Radiation survey meters must be calibrated at least annually and after servicing (battery changes are NOT considered servicing). Radiation Safety calibrates most of the survey meters used here on campus and will contact the Authorized User (AU) prior to the meter's calibration due date, which is indicated on the calibration sticker taped to the meter.

The AU is responsible for delivering the survey meter to the Radiation Safety Office. If a survey meter is needed while the instrument is being calibrated, a loaner survey meter can be checked out at the Radiation Safety Office. Radiation Safety will contact the AU when the meter is calibrated and ready to be picked up. The documentation of the calibration is maintained by Radiation Safety.

Survey meters will be calibrated with a radiation source and/or an electronic pulser. When an electronic calibration (pulser) is performed, the instrument will be checked for response using a radiation source.

1. Radiation Safety Procedure for Calibrating Instruments Reading in mR/hr

1) The source must be approximately a point source when calibrating instruments reading in mR/hr or mrem/hr.

2) The exposure rate at a given distance will be traceable by documented measurements to a standard certified within 5 percent accuracy by the National Institute of Standards and Technology (NIST).

3) The source will be of sufficient strength to give an exposure rate of about 30 mR/hr at 100 cm. This corresponds to minimum activities of 85 millicurie for Cs-137 or 21 millicurie for Co-60.

4) The inverse square law, transmission factors, and the radioactive decay law will be used to correct for change in an exposure rate due to changes in distance, attenuation, or source decay.

5) A record will be made of each survey meter calibration.

6) A single point on a survey meter scale may be considered satisfactorily calibrated if the indicated exposure rate differs from the calculated exposure rate by less than 10 percent. If readings are between 10% and 20%, correction factors must be provided.

7) Three kinds of scales are frequently used on survey meters:

   a. Meters on which the user selects a linear scale must be calibrated at no less than two (2) points on each scale. The points should be at approximately 1/3 and 2/3 of full scale.

   b. Meters that have a multi-decade logarithmic scale must be calibrated at no less than one point on each decade and no less than two (2) points on one of the decades. Those points should be at approximately 1/3 and 2/3 of the decade.

c. Meters that have an automatically ranging digital display device for indicating rates must be calibrated at not less than one point on each decade and at no less than two (2) points on one of the decades. Those points should be approximately 1/3 and 2/3 of the decade.

8) Readings above 1,000 mR/hr need not be calibrated. However, such scales should be checked for operation and approximate correct response.

9) At the time of calibration, the apparent exposure rate from a built-in or owner-supplied check source will be determined and recorded.

10) The report of the survey meter calibration will indicate the data obtained. This will include:

a. The Authorized User;

b. A description of the instrument that includes manufacturer, model number, serial number, and type of detector;

c. For each calibration point, the expected exposure rate, the measured exposure rate, and the scale selected of the instrument;

d. The angle between the radiation flux field and the detector (for external cylindrical GM or ionization-type detectors, this will usually be “parallel” or “perpendicular” indication photon traveling either parallel with or perpendicular to the central axis of the detector; for instruments with internal detectors, this should be the angle between the flux field and a specified surface of the instrument);

e. For detectors with removable shielding, an indication of

whether the shielding was in place or removed during the calibration procedure;

f. The apparent reading from the check source; and

g. The name of the person who performed the calibration and the date on which the calibration was performed.

11) The following information will be attached to the instrument as a calibration sticker:

a. The source that was used to calibrate the instrument;

b. The proper deflection in the battery check mode (unless this is clearly indicated on the instrument);

c. For each scale or decade, one of the following as appropriate;

d. The average correction factor (if factor < 10%, indication that the factor < 10%),

e. A graph or graphs from which the correction factor for each scale or decade may be deduced, or

f. An indication that the scale was checked for function but not calibrated or an indication that the scale was inoperative;

g. The angle between the radiation flux and the detector during the calibration; and

h. The apparent exposure rate from the check source.

NOTE: *One-word reminders or symbols that are explained on the Survey Meter Calibration Report may be used on the calibration sticker.*

2. Radiation Safety Procedure for Calibrating Instruments With a Pulser

1) An electronic pulser will be used which has the proper voltage and frequency response for the instrument being calibrated.

2) The pulser will be calibrated annually to ensure proper operation.

3) The pulser will be capable of covering the entire ranges indicated on the instrument.

4) A record will be made of each survey meter calibration.

5) A single point on a survey meter scale may be considered satisfactorily calibrated if the indicated count rate differs from the known count rate by less than 10 percent. If readings are between 10% and 20% correction factors must be provided.

6) Three kinds of scales are frequently used on survey meters:

   a. Meters on which the user selects a linear scale must be calibrated at no less than two points on each scale. The points should be at approximately 1/3 and 2/3 of full scale.

   b. Meters that have a multidecade logarithmic scale must be calibrated at no less than one point on each decade and no less than two points on one of the decades. Those points should be at approximately 1/3 and 2/3 of the decade.

   c. Meters that have an automatically ranging digital display device for indicating rates must be calibrated at not less than one point on each decade and at no less than two points on one of the decades. Those points should be

approximately 1/3 and 2/3 of the decade.

7) At the time of calibration, the apparent count rate from a built-in or owner-supplied check source will be determined and recorded. In order to determine the radiation emitted from the check source, the probe must be attached and functional. A conversion factor relating cpm to mrem/hr will be determined as required. The orientation of the probe to the check source will also be indicated.

NOTE: *Instruments used to measure exposure or dose rate for regulatory compliance (e.g., mR/hr) must be fully calibrated using the Radiation Safety procedure for calibrating instruments in mR/hr.*

8) The report of the survey meter calibration will indicate the data obtained. This will include:

   a. The Authorized User;

   b. A description of the instrument that includes manufacturer, model number, serial number, and type of detector;

   c. For each calibration point, the expected count rate, the measured count rate, and the scale selected of the instrument;

   d. The apparent reading from the check source; and

   e. The name of the person who performed the calibration and the date on which the calibration was performed.

9) The following information will be attached to the instrument as a calibration sticker:

   a. The Authorized User;

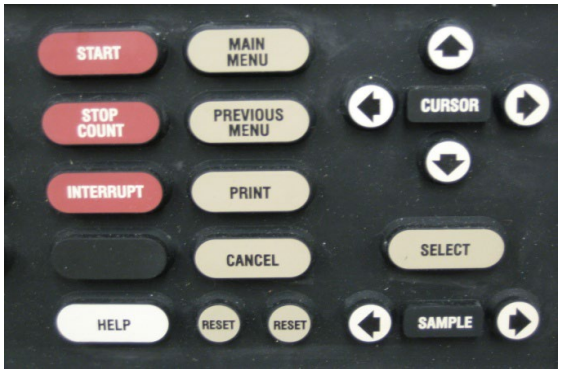
b. Calibration due date;
c. Perform battery check (unless this is clearly indicated on the instrument);
d. The acceptable reading range from the check source;

NOTE: *One-word reminders or symbols that are explained on the Survey Meter Calibration Report may be used on the calibration sticker.*

D. Using the Beckman Liquid Scintillation Counter (LSC)

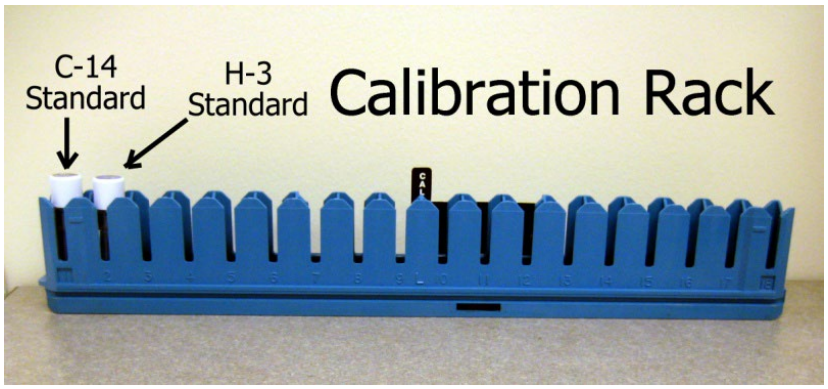
1. Auto Calibration (Beckman)

The Auto Calibration protocol should be performed at the beginning of each day of use to ensure that the unit is functioning properly. Note that the operating and keyboard controls are located on the front of the LSC unit. Below is a picture of a Beckman LS 6500 unit.



Operating controls for LS 6500; use cursor to move about on a screen display; use the SELECT button to select an entry.

1) Each LSC comes with unquenched standards (blank, H-3, C-14) In the rack with the “CAL” command flag; place the C-14 standard in position #1 and the H-3 standard is position #2.



2) Place the rack in the LSC counter on the right side of the unit (the racks are moved counterclockwise) with the position numbers facing towards you.

3) Place the rack with the **HALT** flag in the LSC counter after the calibration rack (this tells the counter to quit counting).

4) Go to Main Menu display (just press **MAIN MENU** on LSC controls), scroll with cursor arrow keys to Automatic Counting and press the **SELECT** key).

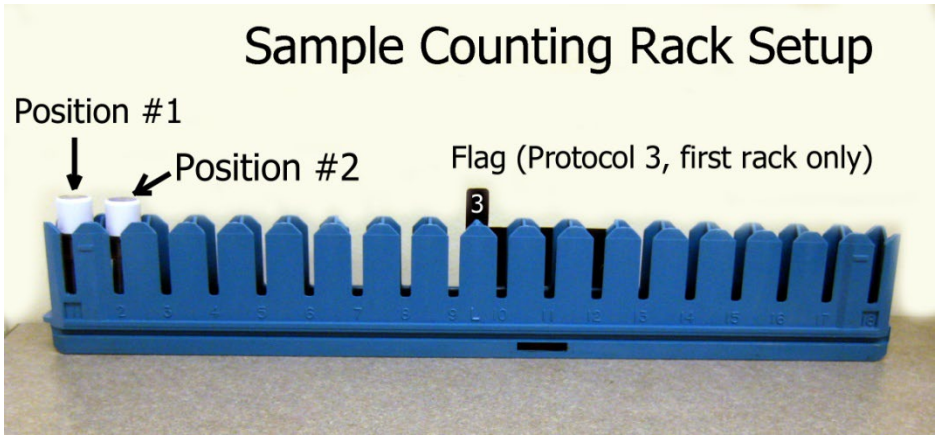
5) The LSC display will prompt you to press the **START** key to begin the calibration. When calibration is complete, the following message will be printed out indicating a successful calibration;

```
INSTRUMENT CALIBRATION:  Mini (Date & Time)
Calibration successful
```

2. Sample Counting (Beckman)

1) The samples to be counted in the LSC are placed in the 7 ml or 20 ml LSC vials.

2) Place vials in the LSC counting racks. The counting positions are given on the front of the rack with position #1 (first sample to be counted) on your left as you are facing the rack. The first rack must have the **command** flag corresponding to the counting protocol you wish to use. If you fill up the rack, use additional racks, without any flags, filling counting positions from left to right. Shown below is a figure counting with a protocol 3.



3) LSC cocktail fluid is dispensed into each vial. For the 7 ml samples, add enough fluid to cover the sample (e.g., 5 or 6 ml) and then cap the vial. For the 20 ml vials typically 10 ml of cocktail is appropriate.

   NOTE: Only LSC cocktail containing non-hazardous chemicals are allowed at UNMC. If a LSC cocktail containing hazardous chemicals (e.g., toluene, xylene is required, contact Radiation Safety.

4) A background sample is often used to determine the counts

from background radiation. The sample should be physically/chemically the same as the samples being counted (e.g., if filter paper is being used for contamination wipes, place a piece of filter paper in the background vial). Add the background sample to a LSC vial and add cocktail. Place in position #1.

5) As a function check for the LSC, a standard can be counted with the samples. For example, the unquenched C-14 standard that comes with the LSC can be used. Place this standard in the rack (e.g., last position). After the LSC run is completed view the cpm or dpm of the standard to determine if it is consistent with previous results.

6) Place the racks into the LSC counter. The LSC moves the racks in a counterclockwise position so place the first rack (with the Command flag) on the right side towards the back (position #'s should face towards the front). Place additional racks in after the first rack.

7) Place the red rack with the **HALT** flag in the LSC counter after the last rack to be counted (this tells the counter to quit counting).

8) Go to the Main Menu (press the **MAIN MENU** control button) and use the cursor keys to move to **Automatic Counting** and press the **SELECT** key. The LSC will count each of the samples

and print out the results. Subtract the background results from the sample results to get the net reading (cpm or dpm). If the results are in counts per minute (cpm) and you need the actual activity, i.e., in disintegrations per minute (dpm), go to Section F, “Converting LSC cpm to dpm).

9) Disposal of liquid scintillation vials is discussed in Section B-8, “Radioactive Waste General Guidelines” of the Radiation Safety Manual.

E. How to Use the Perkin Elmer/Packard Liquid Scintillation Counter (LSC)

NOTE: Perkin Elmer has incorporated Packard so both types of liquid scintillation counters work similar.

1. Synchronization (Perkin Elmer/Packard)

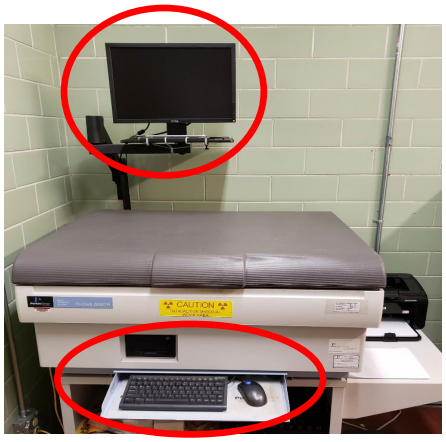
Note: The synchronization protocol takes approximately an hour to run so you may want to run this protocol the night before counting the samples.

1) Each LSC comes with three unquenched standards (C-14 H-3, Background). Place the C-14 standard in rack position 1, H-3 in position 2, and the background standard in position 3. Place the SNC command flag in the rack (make sure tab is pushed out to the left).

Make sure that the tab on the command flag is pushed out so the LSC recognizes it.

2) Open the LSC cover and place the rack on the on the right side (racks are moved counterclockwise).

3) The computer keyboard and monitor screen are used to select the protocol and operation of the Perkin Elmer/Packard LSCs.



Keyboard & Computer Monitor used to operate the Perkin Elmer/Packard LSCs

4) Use the keyboard and monitor to start the protocol. The output will indicate any problems with the LSC.

2. Sample Counting (Perkin Elmer/Packard)

1) Place the sample in a LSC vial. The vials come in 7 ml or 20 ml vials that are either glass or plastic (most commonly used are 20 ml glass vials).

2) Add counting cocktail to the vial (Note: alternatively, could add the sample to a vial prefilled with the cocktail). For 20 ml vial, typically 10 ml of cocktail is added. For 7 ml vials, fill vial until sample is covered (typically 5 – 6 ml).

   NOTE: Only LSC cocktail containing non-hazardous chemicals are allowed at UNMC. If a LSC cocktail containing hazardous chemicals (e.g., toluene, xylene) is required, contact Radiation Safety.

3) A background sample is often used to determine the counts from background radiation. The sample should be physically/chemically the same as the samples being counted (e.g., if filter paper is being used for contamination wipes, use a piece of filter paper for the background). Add the background sample to a LSC vial and add cocktail.

4) Place the samples in the LSC counting rack(s). The background sample is placed in the Position #1 (sample numbers go from left to right on the rack).

5) On the first rack, place the command flag corresponding to the counting protocol to be used. Make sure the tab on the flag is pushed out to the left so that the LSC can recognize the protocol.

Place background vial in position #1. Make sure the tab on the command flag is pushed out to the far left so LSC can recognize the protocol.

6) Place the first rack on the right side of the LSC. If there are more than one rack place these racks behind the first rack. The LSC moves the racks in a counterclockwise direction.

7) As a function check for the LSC, a standard can be counted with the samples. For example, the unquenched C-14 standard that comes with the LSC can be used. Place this standard in second position of the rack or at the very last position of the sample run. After the LSC run is completed, view the cpm or dpm of the standard to determine if it is consistent with previous results.

8) Run the LSC (computer screen will list operation selections).

9) The LSC will count each of the samples and print out the results. Subtract the background results from the sample results to get the net reading (cpm or dpm). If the results are in counts per minute (cpm) and you need the actual activity, i.e., in disintegrations per minute (dpm), go to Section F, "Converting LSC cpm to dpm).

10) Disposal of liquid scintillation vials is discussed in Section B-8, "Radioactive Waste General Guidelines" of the Radiation Safety Manual.

F. Converting LSC cpm results to dpm

Direct DPM protocols will use quench correction factors to determine counting efficiency and display results in disintegrations per minute or dpm. Otherwise, results will be in counts per minute or cpm. To convert cpm to dpm, divide the net cpm by the counting efficiency for that radionuclide, i.e.,

$$DPM = (\text{Net cpm}) \div (\text{Counter Efficiency})$$

If the LSC doesn't subtract the background cpm then the use the following:

$$\text{Net cpm} = \text{Sample cpm} - \text{Background cpm.}$$

The efficiency can be found by counting a sample with known activity or can be approximated using counting efficiencies provided by the manufacturer. Perkin Elmer has provided the following counting efficiencies which can also be used for Beckman LSCs);

Radionuclide	Typical Efficiency
C-14, P-32, P-33, S-35, I-131, Ca-45, Y-90, Lu-177	> 95% (0.95)
I-125	78% (0.78)
H-3	60% (0.60)
Cr-51	35% (0.35)

G. Annual Calibration of the Liquid Scintillation Counters (LSCs)

Annually, Radiation Safety checks each liquid scintillation counter for operation as follows:

1. The self-normalization (Perkin Elmer/Packard) or auto calibration (Beckman) protocol is performed on the unit.
2. Radiation Safety counts three unquenched LSC standards (Blank, H-3, C-14). For the Perkin Elmer/Packard the Direct DPM protocol is run. For the Beckman, the counting protocol that is most commonly used for that LSC is used (e.g., single label, dual label, open spectrum).
3. Radiation Safety will review the efficiency of the H-3 and C-14 standards compared to that of the Radiation Safety Office's liquid scintillation counter as well as efficiencies measured from other years. Manufacturer information indicates that the counting efficiency for H-3 should be in the 50 – 60% range while for C-14 a counting efficiency of 90% is expected.
4. For LSC's with poor counting efficiencies Radiation Safety will immediately notify the Authorized User for that LSC.

Section B-8
Radioactive Waste General Guidelines

A. General Guidelines

1. No radioactive waste may be disposed of by conventional methods. Specifically;

    a. Solid radioactive wastes may not be placed in standard waste containers to be collected by environmental services (e.g., trash cans).

    b. Liquid radioactive waste must be segregated from non-radioactive liquid waste.

    c. Radioactive carcasses must be disposed by Radiation Safety.

2. No solid waste may contain free standing liquid.

3. No radioactive waste shall be released from the laboratory area for pickup and disposal prior to autoclaving or other suitable deactivation of infectious agents.

4. Waste that is non-radioactive should never be mixed with radioactive waste. For example, the shipping packaging that the radioactive material arrives in is typically non-radioactive. Except for H-3, most radionuclides can be detected in waste with an appropriate survey instrument. Prior to placing in radioactive waste, monitor the waste as follows:

    a. Check your radiation detection survey meter for proper operation.

    b. Plan to monitor in a low-level radiation area (less than 100 cpm with a survey meter with a GM probe).

c. Remove any shielding from around the item and monitor all surfaces of each individual item.

d. Any waste that that cannot be distinguished from background can be treated as normal waste (NOTE: Deface or remove any labels/markings that indicate radiation or radioactivity).

Remove or deface any radioactive labels/markings prior to placing into normal trash

e. Items that can be distinguished from background radiation levels must be treated as radioactive waste.

5. Disposal of radioactive material (e.g., placed in a radioactive waste container) must be documented on the RSO-8 radioactive material tracking form.

6. Any waste which contains both radioactivity and hazardous material is classified as **"mixed" waste**. Mixed waste must meet the requirements of both the Radiation Safety Office and the Chemical Safety Office and is often costly to dispose of. **Please contact one of these offices if you are expecting to generate mixed waste**.

7. Due to the ultimate method of disposal by the RSO, radioactive waste must be segregated by radionuclide whenever possible. (Note: in some circumstances Radiation Safety will allow C-14 and H-3 waste to be comingled).

8. In all cases of waste management consider the entire impact of various available disposal routes. Consider occupational and public

exposure to radiation, other hazards associated with the material (e.g., toxicity, carcinogenicity, pathogenicity flammability), and disposal costs.

9. A reasonable attempt should be made to secure radioactive waste. When waste containing a large amount of activity is generated, the waste needs to be secured (e.g., lockable cabinet) or you need to contact Radiation Safety to come and immediately to pick up the waste. Radioactive waste can only be stored in a room authorized for radioactive material use on the license.

B. Managing Solid Radioactive Waste

1. Storage of Solid Radioactive Waste

The Radiation Safety Office (RSO) will provide waste buckets and plastic liner bags for storing solid radwaste. Other types of containers (e.g., Lucite containers for storing high energy beta emitters such as P-32) are also acceptable.

Containers should be labeled “Caution Radioactive Material” and the radionuclide should be indicated on the container (labels available from RSO).

5 Gallon Radwaste Bucket Lined with Plastic Bag

Radionuclide Indicated

Sharps Container

Lucite waste box for high energy beta waste

Sharp items such as syringes, pipettes, broken vials, etc., shall **NOT** be placed in the waste bucket. These shall be placed in a cardboard box or a suitable "sharps" container (RSO can provide sharps containers).

Radioactive animal carcasses, viscera and blood should be sealed in double plastic bags and kept in cold storage (e.g., freezer) prior to pick up).

2. Disposal of Solid Radioactive Waste

For solid radioactive waste, the following two options are available; a) Contact the Radiation Safety Office (RSO) for a waste pickup or b) Dispose the waste using the Decay in Storage (DIS) method.

NOTE: Because of the regulatory requirements associated with Decay-In-Storage (DIS), it is recommended that research labs have Radiation Safety pick up their solid radioactive waste for disposal instead of disposing waste using the DIS method themselves.

a. Waste Pickup by RSO

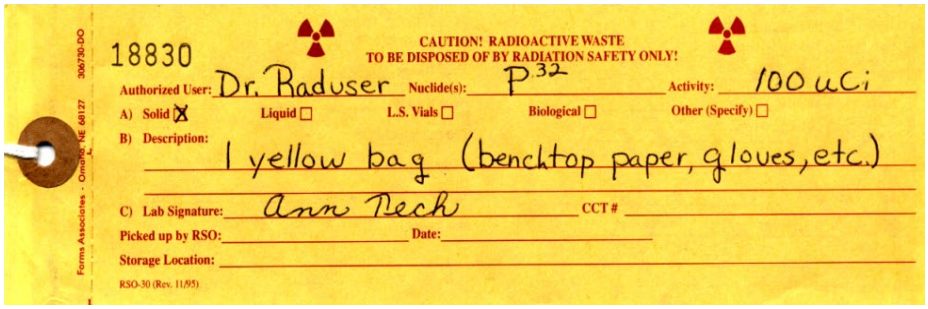
This is the preferred method of disposal of solid radioactive waste. The following steps are used to have solid waste picked up by the RSO:

i. Secure bag opening using a tie-wrap, tape, etc.

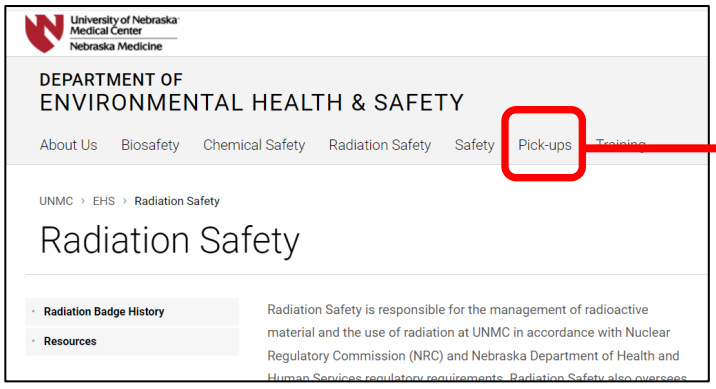
NOTE 1: Radioactive animal carcasses, viscera and blood should be sealed in double plastic bags and kept in cold storage (e.g., freezer) prior to pick up.

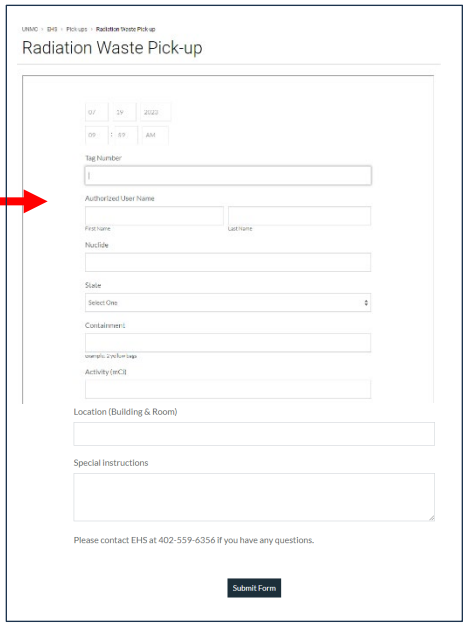
Note 2: Sharps containers are NOT to be bagged.

ii. Fill out a waste tag (see figure below) and attach to the bag or sharps container. Each bag of animal carcasses should have its own waste tag. Tags may be obtained from Radiation Safety.



iii. Request a pickup via the Radiation Safety website:





This is also a good time to request additional yellow radioactive waste bags, sharps container, tags, etc., if needed (enter request in the Special Instructions).

iv. Radiation Safety will leave one copy of the waste tag in the lab to indicate that the waste was picked up. It is recommended that the laboratory holds onto the waste tag to demonstrate that the waste was picked up.

B. Decay in Storage (DIS) Disposal Method

Waste with a radiological half-life less than 120 days may be disposed using Decay-in-Storage (DIS) as follows:

i. The waste must be stored (decay) at least 10 half-lives AND surface level readings on the waste (e.g., bag) are at background levels. If more than one radionuclide is present in the waste, the longest half-life must be used.

ii. After at least 10 half-lives of the longest lived radionuclide in the waste, monitor all surfaces with an appropriate survey meter. A survey meter equipped with a GM probe is appropriate for most radionuclides, except I-125, which requires a low energy NaI probe. Waste may be released as normal waste if all readings are at background radiation levels and all radiation labels/markings are removed or defaced (NOTE: If in a radwaste bag…you may just remove/deface any radiation verbiage/symbols on the outside of the bag).

iii. For radioactive waste that is decayed in storage and disposed, a record of each disposal must be maintained. This record must include;
- Date of disposal

- Date on which the radioactive material went into storage
- Radionuclide(s) disposed
- Model and serial number of the survey instrument used
- Background dose rate
- Radiation dose rate measured at the surface of each waste container
- Name of the individual performing the disposal

Because of these documentation and storage requirements, in most situations it is recommended that Radiation Safety picks up solid waste and performs the decay-in-storage method.

C. Managing Liquid Radioactive Waste

1. Storage of Liquid Radioactive Waste

a. Waste liquid may be collected in metal, glass or plastic jugs depending on the chemical profile of the waste. Secondary containment (e.g., plastic tray or tub) is recommended in case the container should leak.

b. Container must be closed except when adding waste.

c. Do not fill liquid containers beyond 3/4 full.

d. Containers should be labeled “Caution Radioactive Material” and the radionuclide should be indicated on the container (labels available from RSO). Chemical Safety also requires that the full name of the hazardous chemical be listed on the container.

e. Radioactive waste can only be stored in a room authorized for

radioactive material use on the license. A reasonable attempt should be made to secure radioactive waste. When waste containing a large amount of activity is generated, the waste containers need to be secured (e.g., lockable cabinet) or you need to contact Radiation Safety to come immediately to pick up the waste.

2. Disposal of Liquid Radioactive Waste

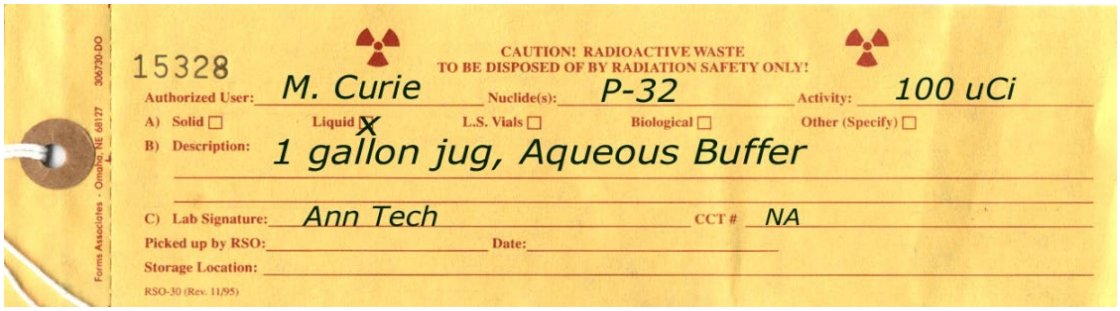
For liquid radioactive waste, the following three options are available;

a) Contact the Radiation Safety Office (RSO) for a waste pickup
b) Dispose via the sanitary sewer or
c) Dispose the waste using the Decay in Storage (DIS) method.

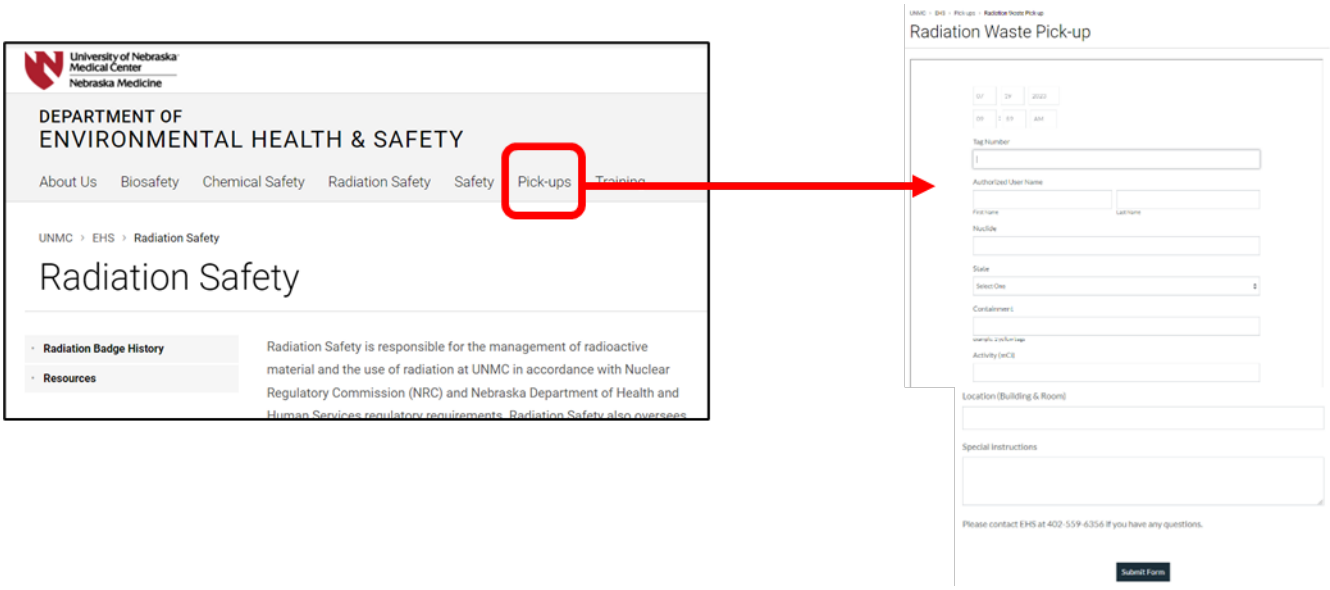
NOTE: Because of the regulatory requirements associated with Decay-In-Storage (DIS), it is recommended that research labs either dispose liquid radioactive waste via the sanitary sewer or have Radiation Safety pick up the waste for disposal.

a. Waste Pickup by RSO

i. Fill out a waste tag and attach to the container (see figure below). Tags may be obtained from Radiation Safety.



ii. Contact Radiation Safety to schedule a waste pickup. Either call the Radiation Safety Office (402 559 6356) or send a request via the Radiation Safety website as follows:



This is also a good time to request additional yellow radioactive waste bags, sharps container, tags, etc., if needed (enter request in the Special Instructions).

iii. Radiation Safety will leave one copy of the waste tag in the lab to indicate that the waste was picked up. It is recommended that the laboratory holds onto the waste tag to demonstrate that the waste was picked up.

iv. Radiation Safety will leave one copy of the waste tag in the lab to indicate that the waste was picked up. It is recommended that the laboratory holds onto the waste tag to demonstrate that the waste was picked up.

b. Release to the Sanitary Sewer

Liquid radioactive waste may be discharged into the sanitary sewer provided;

a. It is readily soluble or dispersible in water and does not contain hazardous materials.

b. It is discharged into a properly labeled “hot” sink followed by sufficient flushing to ensure that material clears the sink trap and enters the system.

c. The quantity released per day does not exceed the following (contact Radiation Safety for radionuclides not listed):

Radionuclide	Daily Limit to Sewer
Cr-51, Cu-64, F-18, H-3, Tc-99m	10,000 uCi
C-14, Ca-45, Co-57, Ga-67, I-123, In-111, Lu-177, P-33, Pb-203, S-35,	1000 uCi
At-211, Fe-59, Na-22, P-32, Pb-212, Sr-89, Y-90	100 uCi
Ac-225, I-125, I-131, Sr-90	10 uCi

Note 1: If the daily limits above are approached on a frequent basis (e.g., weekly), contact the RSO to ensure the monthly and annual limits for the University are not exceeded.

Note 2: These limits may be increased based on the dilution factor in your area. To increase the limit for any radionuclide, approval must first be obtained from the Radiation Safety Office.

All sewer disposals are required to be recorded on the RSO-8 tracking form. Disposals must be recorded in µCi or mCi or a conversion factor (e.g., µCi/µl) must be provided if disposals are recorded in volume (e.g., µl).

D. Managing Waste Liquid Scintillation Vials

Only Liquid Scintillation Vials (LSVs) containing biodegradable liquid scintillation fluid may be used unless written approval from the Radiation Safety Committee is obtained.

Due to ultimate method of disposal by the RSO, waste liquid scintillation vials must be segregated by radionuclide.

Disposal of biodegradable liquid scintillation fluid may be accomplished in two ways:

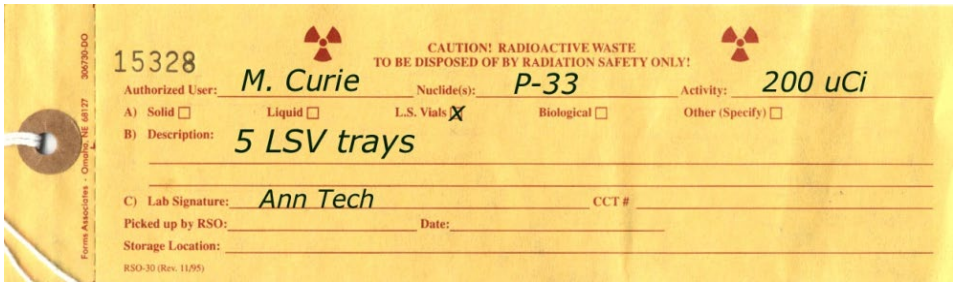
1. **Release to the Sanitary Sewer**: The fluid (cocktail) may be emptied directly into the sanitary sewer (in a designated hot sink). The vials are then triple rinsed and disposed of as normal trash. Radioactivity is accounted for on the yellow RSO-8 inventory form. Because the radioactivity levels for contamination wipes is so low, it is recommended that labs disposal of these vials through this option (Note: unless wipes counts are extremely high, e.g., thousands of dpm, sewer disposal does NOT need to be recorded on the RSO-8).

2. **Waste Pickup by Radiation Safety Office**:

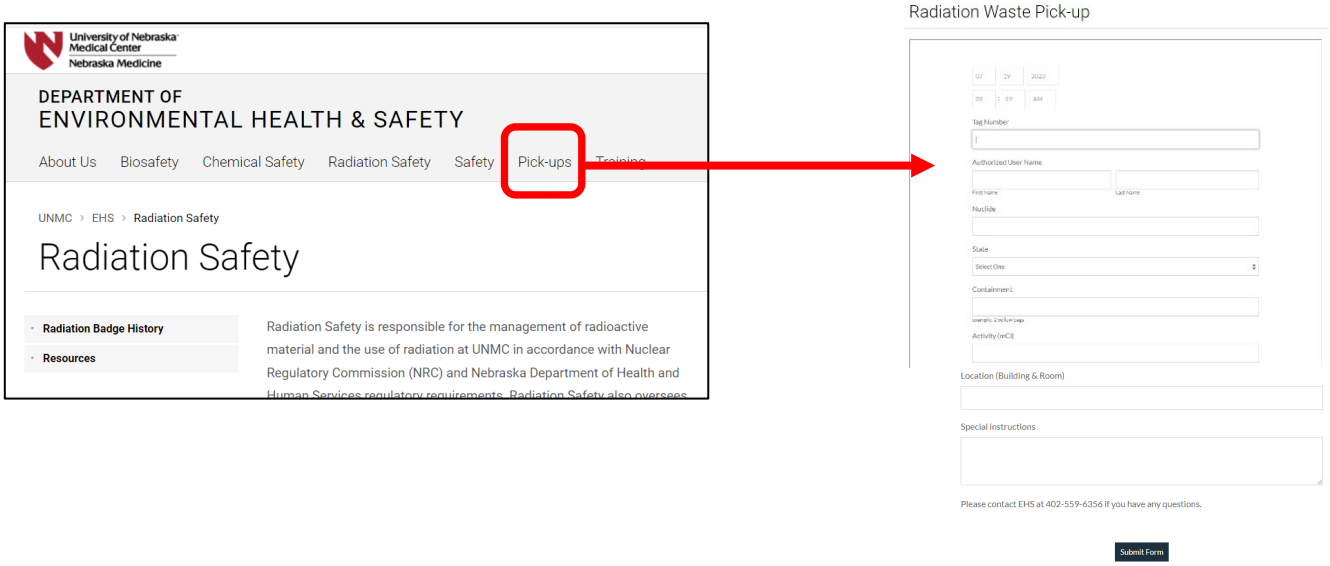
   a. LSVs must be segregated by radionuclide and from all other wastes. Screwcaps must be tightened. Waste LSVs should be placed in cardboard trays (e.g., the trays the vials were originally packed in, see figure below) and the trays in cardboard cases. If trays are not available, double bag the LSVs in plastic and seal the bags (separate bag for each radionuclide).

Tray of LSVs

b. Fill out a waste tag and attach to the container (see figure below). One tag may be used for several trays of the same radionuclide. Tags may be obtained from Radiation Safety.



c. Contact the Radiation Safety to schedule a waste pickup. Either call the Radiation Safety Office (402 559 6356) or send a request via the Radiation Safety website as follows:



d. Radiation Safety will leave one copy of the waste tag in the lab to indicate that the waste was picked up. It is recommended that the laboratory maintain the waste tag to demonstrate that the waste was picked up.

E. Exempt Waste

In accordance with the State Regulations (180 Nebraska Administrative Code) the following licensed material may be disposed of as if it were not radioactive:

1. 1.85 kBq (0.05 uCi), or less of H-3, C-14, or I-125 per gram of medium used for liquid scintillation counting or in-vitro clinical or in-vivo laboratory testing.

2. 1.85 kBq (0.05 uCi), or less of H-3, C-14, or I-125 per gram of animal tissue average over the weight of the entire animal, provided the tissue could not be used as food for human or animal feed.

Nothing in this section relieves the user from complying with disposal requirements concerning the chemical, biological, or infectious aspects of this waste. Contact the Radiation Safety Office prior to disposing of these to ensure compliance.

F. Managing Gaseous Effluents

1. Limits on maximum permissible concentrations in effluents to restricted areas (areas controlled by UNMC for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials) are contained in the State Regulations (180 Nebraska Administrative Code).

2. Limits on maximum permissible concentrations in effluents to unrestricted areas are contained in the State Regulations (180 Nebraska Administrative Code).

3. To ensure compliance with these regulations, contact the Radiation Safety Office if airborne activity is suspected. The RSO has available air monitoring and detection equipment.

G. Shipment of Radioactive Waste

Shipment of radioactive waste by a licensed commercial vendor is only performed by the Radiation Safety Office staff who have been DOT trained to ship radioactive material/waste.

Radionuclide Safety Data Sheet

PHYSICAL DATA

Radionuclide:	Hydrogen-3 (H-3), aka “Tritium”
Decay Mode:	Beta (100% abundance)
Beta Energy:	18.6 keV (maximum); 5.7 keV (average)
Physical Half-Life:	12.3 years
Biological Half-Life:	10 - 12 days
Effective Half-Life:	10 - 12 days *
	* Forcing liquids to tolerance (3-4 liters/day) will reduce the effective half-life of H-3 by a factor of 2 or 3 (relatively easy to flush out of system with fluids).
Specific Activity:	9650 curies / gram
Maximum Beta Range in Air:	5 mm = 0.5 cm = 1/4"
Maximum Beta Range in Water:	0.005 mm = 0.0005 cm = 3/10,000"
Penetrability of Beta Particle in Tissue:	Insignificant (cannot penetrate dead layer of skin)

RADIOLOGICAL DATA

Least radiohazardous of all radionuclides

Critical Organ:	Body Water or Tissue
Routes of Intake:	Ingestion, Inhalation, Puncture, Wound, Skin Contamination (Absorption)
Exposure Concerns:	Internal exposure & contamination are primary concerns; EXTERNAL EXPOSURE NOT A CONCERN
Committed Effective Dose Equivalent (CEDE):	Tritiated Water: 64 mrem/mCi Organic Compounds: 160 mrem/mCi
Annual Limit on Intake (ALI):	80 mCi (ingestion or inhalation) (1 ALI = 5,000 mrem CEDE)
Skin Contamination Exposure Rate (0.007 cm):	0 mrad/hr per 1.0 mCi (cannot penetrate dead layer of skin)

SHIELDING/LABELING

Shielding: None Required

Labeling: Container with $\geq$ 1 mCi must be labeled “Caution, Radioactive Material”

SURVEY INSTRUMENTATION

H-3 CANNOT be detected using a G-M or NaI survey meter
Must use wipes/smears and count a liquid scintillation counter to detect H-3 contamination. Counting efficiency on a Perkin Elmer liquid scintillation counter is approximately 60%.

PERSONAL RADIATION MONITORING DOSIMETERS

Personnel dosimetry (whole body & ring badges) are **NOT** needed (H-3 beta energy is too weak).

BIOASSAY REQURIEMENTS

For HTO (Tritiated Water) and other Tritiated compounds (including nucleotide precursors), the following activities if handled at any one time or processed in a month period require a bioassay:

100 mCi in an open room or bench
1000 mCi in a certified hood

If bioassay required, at least 100 ml of urine must be collected within 72 hours of use
Rule of Thumb: About 0.001 uCi/liter of H-3 in urine sample is indicative of a total integrated whole body dose of approximately 10 millirem (average person) if no treatment is instituted (flush with fluids) [NCRP-65 / 1980]

DOSIMETRY

Millicurie quantities of tritium do not present an external exposure hazard because the low energy betas emitted cannot penetrate the outer dead layer of skin. The critical organ for tritium uptake is the whole body water. Three to four hours after intake, tritiated water is uniformly distributed in all body water. On average, tritiated water is eliminated with a ten-day biological half-life. Elimination rates may be increased by increasing water intake.

RADIOACTIVE WASTE

Isolate waste from other radionuclides in clearly labeled containers. H-3 waste may be mixed with C-14 waste if approved by Radiation Safety.

Sanitary sewer disposal limit is 10 mCi in any one day via a designated “hot” sink provided it is readily soluble, dispersible in water, and contains no hazardous materials. A sewer log must be maintained.

GENERAL RADIOLOGICAL SAFETY INFORMATION (H-3)

(Permission from University of Michigan Radiation Safety Office)

- Inherent Volatility (at STP): SUBSTANTIAL
- Experimental uses include total body water measurements & in-vivo labeling of proliferatory cells by injection of tritium-labeled compounds (ie: thymidine). Tritium labeling is also used in a variety of metabolic studies.
- Many tritium compounds readily penetrate gloves and skin; handle such compounds remotely and wear double gloves, changing out gloves frequently (every 20 – 30 minutes)
- Oxidation of H-3 gas in air is usually slow (< 1% per day)

- Absorption of H-3 inhaled in air is much less when it is present as elemental H-3 than as tritiated water (HTO).
- Tritium penetrates the skin, lungs, and GI tract either as tritiated water or in the gaseous form.
- As gaseous hydrogen, H-3 is not significantly absorbed into the body and does NOT exchange significantly with hydrogen in the body compounds.
- As water (HTO), the H-3 entering the lung or GI tract is completely absorbed and is rapidly dispersed throughout the body.
- Some H-3 is incorporated into cellular components and has a long turnover rate. Forcing fluid reduces internal exposures from H-3.
- Monitor for H-3 contamination using only smears, swabs, swipes, or wipe testing (bench tops, floors, refrigerator/freezer handles, phone, etc).
- Always wear a lab coat & disposable gloves when handling H-3.
- Skin contamination, ingestion, inhalation, and punctures involving H-3 are primary radiological concerns (internal doses).
- Tritiated water, taken into the body by inhalation, ingestion, or absorption through the skin is assumed to be completely and instantaneously absorbed and rapidly mixed with total body water.
- The volume of total body water (standard man) is 42,000 ml.
- The concentration of H-3 (uCi/ml) in urine is assumed to be the same as that in total body water. (urine concentration = body concentration)).
- For a continuous inhalation exposure at a rate of 1/365 of an ALI per day, the equilibrium concentration of H-3 in urine is 0.073 uCi/ml. (NOTE: 1/365 of 80 mCi (ALI) = 219 uCi)
- The predicted concentration activity normalized to unit intake from inhalation is 2.204 E-5 uCi/ml per uCi of H-3 intake.
- Tritiated thymidine, if not catabolized, is taken up only by the nuclei of those cells synthesizing DNA.
- The ingestion ALI of tritiated thymidine is likely to be approximately 1/10 of that for tritiated water.
- The ALI for tritiated thymidine might be as much as 50-times smaller than the ALi for tritiated water.
- Ingested tritiated water is assumed to be completely and instantaneously absorbed from the GI tract and to mix rapidly with the total body water so that, at all times following ingestion, the concentration in sweat, urine, sputum, blood, insensible perspiration, and expired water vapor is the same.
- Tritiated water is instantaneously distributed uniformly among all the soft tissues of the body after inhalation.
- Organic compounds of H-3 are not very volatile under normal circumstances and the probability of their being inhaled as vapors is, therefore, small.

Radionuclide Safety Data Sheet

PHYSICAL DATA

Radionuclide:	Carbon-14 (C-14)
Decay Mode:	Beta (100% abundance)
Beta Energy:	156.4 keV (maximum); 49.5 keV (average)
Physical Half-Life:	5730 years
Biological Half-Life:	10 days (Whole body)
Effective Half-Life:	10 days (Bound/Whole body)
	40 days (Unbound/Whole body)
Specific Activity:	4460 millicuries / gram
Maximum Beta Range in Air:	25.4 cm = 10"
Maximum Beta Range in Water/Tissue:	0.030 cm = 0.012”
	(~ 1% of C-14 betas transmitted through dead layer of skin)
Maximum Beta Range in Lucite/Plastic:	0.025 cm = 0.01”

RADIOLOGICAL DATA

Critical Organ:	Fat Tissue (most labeled compounds)
	Bone (for some labeled carbonates)
Routes of Intake:	Ingestion, Inhalation, Puncture, Wound, Skin Contamination (Absorption)
Exposure Concerns:	Internal exposure & contamination; EXTERNAL EXPOSURE IS NOT A CONCERN
Committed Effective Dose Equivalent (CEDE):	2.09 mrem/uCi (ingestion/inhaled)
Annual Limit on Intake (ALI):	2 mCi (ingestion/inhalation - labeled organic compound)
	2000 mCi (inhalation; carbon monoxide)
	200 mCi (inhalation; carbon dioxide)
	(1 ALI = 5,000 mrem CEDE)

SHIELDING/LABELING

Shielding: None Required (< 3mm plexiglass)

Labeling: Container with $\geq$ 100 uCi must be labeled “Caution, Radioactive Material”

SURVEY INSTRUMENTATION

C-14 can be detected with a survey meter equipped with a GM pancake probe (15.5 cm^2 surface area), but probe must be at a close distance (< 1 inch)

Counting efficiency of C-14 with GM survey meters is about 3%

Wipes/smears should be counted on a liquid scintillation counter to detect C-14 contamination. Counting efficiency on a Perkin Elmer liquid scintillation counter is approximately 95%.

PERSONAL RADIATION MONITORING DOSIMETERS

Personnel dosimetry (whole body & ring badges) are **NOT** needed (C-14 beta energy is too weak).

BIOASSAY REQURIEMENTS

Not normally required. Notify Radiation Safety if an intake of C-14 is suspected

DOSIMETRY

Millicurie quantities of C-14 do not present a significant external exposure hazard because the low energy betas emitted barely penetrate the horny outer skin layer. The critical organ for uptake of many C-14 labeled carbonates is the bone. The critical organ for uptake of many other C-14 labeled compounds is the fat of the whole body. Most C-14 labeled compounds are rapidly metabolized and the radionuclide is exhaled as $^{14}CO_2$. Some compounds and their metabolites are eliminated via the urine. Biological half-lives vary from a few minutes to 35 days. Ten (10) days being a conservative value for most compounds.

RADIOACTIVE WASTE

Isolate waste from other radionuclides in clearly labeled containers. H-3 waste may be mixed with C-14 waste if approved by Radiation Safety.

Sanitary sewer disposal limit is 1 mCi in any one day via a designated “hot” sink provided it is readily soluble, dispersible in water, and contains no hazardous materials. A sewer log must be maintained.

GENERAL RADIOLOGICAL SAFETY INFORMATION (C-14)

(Permission from University of Michigan Radiation Safety Office)

- Inherent Volatility (STP): Not Significant
- Many C-14 compounds readily penetrate gloves and skin. Handle such compounds remotely and wear double gloves, changing the outer pair at least every 20 minutes.
- Care should be taken NOT to generate CO_2 gas that could be inhaled.
- Skin contamination, ingestion, inhalation, and puncture are primary concerns (potential internal doses).
- Always wear a lab coat and disposable gloves when working with C-14.
- Slowly monitor your hands, shoes, clothing and work area using a G-M survey meter for gross C-14 contamination (3% counting efficiency).
- Monitor for surface contamination by smearing, swabbing, swiping, or wipe testing where used and counting in a liquid scintillation counter.
- Typical liquid scintillation counter counting efficiency for C-14 ~ 95%.
- The concentration of carbon in adipose tissue, including the yellow marrow, is about 3-times the average whole body concentration. No other organ or tissue of the body concentrates stable carbon to any significant extent.

- The fractional absorption of dietary carbon (uptake to blood) is usually in excess of 0.90.
- ^{14}C-thymidine are specifically incorporated into the DNA of dividing cells and tissues are irradiated much more uniformly from C-14 incorporated into DNA than they are from ^{3}H incorporated into DNA.
- There are three main classes of carbon compounds which may be inhaled: organic compounds, gases (CO or CO_2), and aerosols of carbon containing compounds such as carbonates and carbides.

Organic Compounds - most organic compounds are NOT very volatile under normal circumstances and the probability of these being inhaled as vapors is therefore small. In circumstances where such substances are inhaled it would be prudent to assume that once they enter the respiratory system they are instantaneously and completely translocated to the systemic circulation without changing their chemical form.

Gases - the inhalation of CO and its retention in body tissues has been studied extensively. Since gas has a relatively low solubility in tissue water, doses due to absorbed gas in tissues are insignificant in comparison with doses due to the retention of CO bound to hemoglobin. CO_2 in the blood exists mainly as a bicarbonate.

Carbonates & Carbides - It is assumed that inhaled or ingested C-14 labeled compounds are instantaneously and uniformly distributed throughout all organs & tissues of the body where they are retained with a biological half-life of 40 days.

Radionuclide Safety Data Sheet

PHYSICAL DATA

Radionuclide:	Phosphorous-32 (P-32)
Decay Mode:	Beta (100% abundance)
Beta Energy:	1710 keV (maximum); 694 keV (average)
Physical Half-Life:	14.3 days
Biological Half-Life:	1155 days (Bone)/ 257 days (Whole Body)
Effective Half-Life:	14.1 days (Bone)/13.5 days (Whole Body)
Specific Activity:	285,518 curies / gram
Maximum Beta Range in Air:	610 cm = 20 feet
Maximum Beta Range in Water/Tissue:	0.76 cm = 1/3” - Energy > 795 keV can penetrate lens of the eye (0.3 cm) - Energy > 70 keV required to penetrate dead layer of skin; 95% of P-32 particles penetrate dead layer (0.007 cm)
Maximum Beta Range in Lucite/Plastic:	0.61 cm = 3/8”

RADIOLOGICAL DATA

Critical Organ:	Bone (soluble P-32), Lung (inhalation) and GI Tract/LLI (ingestion for insoluble forms and non-transportable P-32 compounds
Routes of Intake:	Ingestion, Inhalation, Puncture, Skin Contamination (Absorption)
Exposure Concerns:	Internal & external exposure and contamination
Committed Dose Equivalent (CDE):	Inhalation: 95 mrem/uCi (Lung) Ingestion: 30 mrem/uCi (Marrow)
Committed Effective Dose Equivalent (CEDE):	Inhalation: 16 mrem/uCi Ingestion: 8.8 mrem/uCi
Annual Limit on Intake (ALI):	600 uCi (ingestion / all compounds) 900 uCi (inhalation / except phosphates) 400 uCi (inhalation / phosphates) (1 ALI = 5,000 mrem CEDE)

SKIN CONTAMINATION:

VERY HIGH LOCALIZED DOSE IF P-32 CONTAMINATION REMAINS ON SKIN

Skin Contamination Dose Rate (0.007 cm tissue depth): 7030 mrem/hour per 1 uCi/cm^2

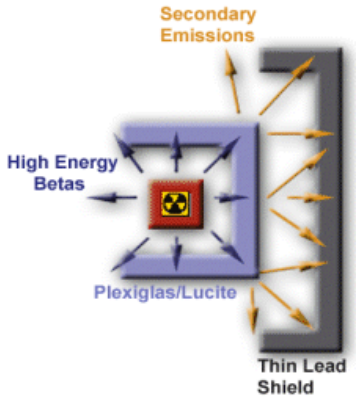
SURVEY INSTRUMENTATION:

P-32 can be detected with a survey meter equipped with a GM probe (pancake probe preferable)
Counting efficiency of P-32 with GM survey meters is about 25%
Low energy NaI probe should be used only to detect bremsstrahlung x-rays
Wipes/smears should be counted on a liquid scintillation counter to detect P-32 contamination. Counting efficiency on a Perkin Elmer liquid scintillation counter is approximately 98%.

SHIELDING/LABELING

Shielding : > 3/8" thick plexiglass, acrylic, Lucite, plastic or wood will completely shield P-32
Do NOT shield soley with lead because bremsstrahlung x-rays will be produced with P-32 high energy beta particles
May use lead AFTER the low Z material (e.g., Lucite, plastic) if Bremsstrahlung radiation is present

Labeling: Container with $\geq$ 10 uCi must be labeled "Caution, Radioactive Material"



PERSONAL RADIATION MONITORING DOSIMETERS

Personnel dosimetry (whole body & ring badges) are required in working with millicurie amounts of P-32

BIOASSAY REQURIEMENTS

Not normally required. Notify Radiation Safety if an intake of P-32 is suspected

DOSIMETRY

The bone is the critical organ for intake of transportable compounds of P-32 (bones receives about 20% of dose ingested). Phosphorus metabolism is complex; 30% is rapidly eliminated from the body, 40% possesses a 19-day biological half-life, and the remaining 30% is reduced by radioactive decay. If ingested, 60% of P-32 is excreted in the first 24 hours; only about 1% is excreted after the 2nd or 3rd day. The lung and large intestine are the critical organs for inhalation and indigestion, respectively, of non-transportable P-32 compounds. The high energy beta emissions can present a substantial skin dose hazard. For example, 1 uCi of P-32 on a 1 cm^2 area of bare skin can produce a dose rate of 7 to 8 rem/hr to the skin. Multi millicurie quantities of P-32 can produce a significant secondary radiation (bremsstrahlung x-rays) presenting an external exposure hazard.

RADIOACTIVE WASTE

Isolate waste from other radionuclides in clearly labeled containers.
Sanitary sewer disposal limit is 100 uCi in any one day via a designated "hot" sink provided it is readily soluble, dispersible in water, and contains no hazardous materials. A sewer log must be maintained.

GENERAL RADIOLOGICAL SAFETY INFORMATION (P-32)

(Permission from University of Michigan Radiation Safety Office)

- Inherent Volatility (STP): Insignificant / Negligible; P-32 is not volatile, even when heated, and can be ignored as an airborne contaminant unless aerosolized.
- White vinegar can be an effective decontamination solvent for this nuclide in most forms.
- P-32 is used as a tracer to study phosphorus-containing processes (nucleotide biochemistry).
- Skin (0.007 cm) & lens of the eye (0.3 cm) are primary dose concerns.
- Skin contamination (skin dose), lens of the eye dose, ingestion, inhalation, puncture, absorption through skin, and area contamination are primary radiological concerns.
- Drying can cause airborne P-32 dust contamination.
- Rapid boiling can cause airborne P-32 contamination.
- Expelling P-32 solutions through syringe needles and pipette tips can generate airborne aerosols.
- Never work directly over an open container of P-32. Avoid direct eye exposure from penetrating P-32 beta particles.
- Always wear a lab coat and disposable gloves when handling P-32.
- Monitor your hands, shoes, lab coat, work areas, and floors using a survey meter equipped with a thin-window G-M probe for gross contamination. Preferably, use a sensitive G-M pancake / frisker probe (15.5 cm^2 monitoring area).
- Monitor for removable surface contamination by smearing, swiping, swabbing, or wipe testing where P-32 is used. Count smears or swabs in a liquid scintillation counter (LSC).
- Use low-atomic (low Z) shielding material to shield P-32 and reduce the generation of bremsstrahlung x-rays. The following materials are low Z materials: plexiglass, acrylic, lucite, plastic, wood, or water.
- DO NOT use only lead foil, lead sheets, or other high-density (high atomic number) materials to shield P-32 directly. Penetrating bremsstrahlung x-rays will be generated in lead and other high density shielding material May use lead AFTER the low Z material (e.g., Lucite, plastic) if Bremsstrahlung radiation is present..
- Percent of incident P-32 betas converted to bremsstrahlung x-rays: 4.8% (lead), 0.5% (lucite), and 0.3% (wood).
- Safety glasses or goggles are recommended when working with multi millicurie amounts of P-32.

Radionuclide Safety Data Sheet

PHYSICAL DATA

Radionuclide:	Sulfur-35 (S-35)
Decay Mode:	Beta (100% abundance)
Beta Energy:	167 keV (maximum); 49 keV (average)
Physical Half-Life:	87.44 days
Biological Half-Life:	90 days (unbound S-35); 623 days (bound S-35 in Testes)
Effective Half-Life:	44 - 76 days
Specific Activity:	42,710 curies / gram
Maximum Beta Range in Air:	26 cm = 10.5"
Maximum Beta Range in Water/Tissue*:	0.32 cm = 0.015”
Maximum Beta Range in Lucite/Plastic:	0.25 cm = 0.01”

RADIOLOGICAL DATA

Critical Organ:	Testes
Routes of Intake:	Ingestion, Inhalation, Puncture, Wound, Skin Contamination (Absorption)
Exposure Concerns:	Internal exposure & contamination are primary concerns; EXTERNAL EXPOSURE NOT A CONCERN

Annual Limit on Intake (ALI):

Form	Ingestion	Inhalation
Elemental sulfur, sulfides of Sr, Ba, Ge, Sn, Pb, As, Sb, Bi, Cu, Ag, Au, Zn, Cd, Hg, W, Mo and sulfates of Ca, Sr, Ba, Ra, As, Sb, Bi	6 mCi	2 mCi
All other sulfides and sulfates	10 mCi (8 mCi LLI Wall)	20 mCi
Vapor	NA	10 mCi

SHIELDING/LABELING

Shielding: None Required (< 3mm plexiglass)

Labeling: Container with $\geq$ 100 uCi must be labeled “Caution, Radioactive Material”

SURVEY INSTRUMENTATION

S-35 can be detected with a survey meter equipped with a GM pancake probe (15.5 cm^2 surface area), but probe must be at a close distance (< 1 inch)

Counting efficiency of S-35 with GM survey meters is about 4%

Wipes/smears should be counted on a liquid scintillation counter to detect S-35 contamination. Counting efficiency on a Perkin Elmer liquid scintillation counter is approximately 95%.

PERSONAL RADIATION MONITORING DOSIMETERS

Personnel dosimetry (whole body & ring badges) are **NOT** needed (S-35 beta energy is too weak).

BIOASSAY REQURIEMENTS

Not normally required. Notify Radiation Safety if an intake of S-35 is suspected

DOSIMETRY

Millicurie quantities of S-35 do not present a significant external exposure hazard because the low energy emissions barely penetrate the horny outer skin layer. The critical organ for S-35 is the whole body. The elimination rate of S-35 depends on the chemical form. Most S-35 labeled compounds are eliminated via the urine. Ninety days is a conservative biological half-life.

RADIOACTIVE WASTE

Isolate waste from other radionuclides in clearly labeled containers.
Sanitary sewer disposal limit is 1 mCi in any one day via a designated "hot" sink provided it is readily soluble, dispersible in water, and contains no hazardous materials. A sewer log must be maintained.

GENERAL RADIOLOGICAL SAFETY INFORMATION (S-35)

(Permission from University of Michigan Radiation Safety Office)

- Inherent volatility (STP): **SIGNIFICANT** for S-35 methionine & cysteine
- Many S-35 compounds and metabolites are slightly volatile and may create contamination problems if not sealed or otherwise controlled. This occurs particularly when S-35 amino acids are thawed, and then they are added to cell culture media & incubated. Therefore vent thawing S-35 vials in a hood by inserting a needle of a charcoal packed syringe through the septum seal and vent incubated S-35 labeled tissue culture through a charcoal impregnated filter paper.
- Radiolysis of S-35 amino acids (cysteine & methionine) during storage & use may lead to the release of S-35 labeled volatile impurities. Volatile impurities are small (≤ 0.05%).
- Metabolic behavior of organic compounds of sulfur (cysteine & methionine) differs considerably from the metabolic behavior of inorganic compounds.
- Organic compounds of sulfur (cysteine & methionine) become incorporated into various metabolites. Thus, sulfur entering the body as an organic compound is often tenaciously retained.
- The fractional absorption of sulfur from the gastrointestinal tract is typically > 60% for organic compounds of sulfur. Elemental sulfur is less well absorbed from the GI tract than are inorganic compounds of the element (80% for all inorganic compounds of sulfur and 10% for sulfur in its elemental form). Elemental sulfur is an NRC inhalation Class W.
- Inhalation of the gases SO_2, COS, H_2S, and CS_2 must be considered. Sulfur entering the lungs in these forms is completely and instantaneously translocated to the transfer compartment and from there its metabolism is the

same as that of sulfur entering the transfer compartment following ingestion or inhalation of any other organic compound of sulfur.

- Contamination of internal surfaces of storage and reaction vessels may occur (rubber o-rings).
- Vials of S-35 labeled amino acids (cysteine & methionine) should be opened and used in ventilated enclosures (exhaust hoods). In addition, S-35 vapors may be released when opening vials containing labeled S-35 amino acids, during any incubating of culture cells containing S-35, and the storage of S-35 contaminated wastes.
- The volatile components of S-35 labeled cysteine & methionine are presumed to be hydrogen sulfide (H_2S) and methyl mercaptan (CH_3SH), respectively.
- Excessive contamination can be noted on the inside surfaces and in water reservoirs of incubators used for S-35 work. Most notable surface contamination can be found on rubber seals of incubators & centrifuges.
- Radiolytic breakdown may also occur during freezing process, releasing as much as 1.0 uCi of S-35 per 8 mCi vial of S-35 amino acid during the thawing process.
- S-35 labeled amino acids work should be conducted in an exhaust hood designated for radiolytic work.
- Vent S-35 amino acid stock vials with an open-ended charcoal-filled disposable syringe. Activated charcoal has a high affinity for S-35 vapors.
- Place an activated carbon or charcoal canister, absorbent sheet, or tray (50-100 grams of granules evenly distributed in a tray or dish) into an incubator to passively absorb S-35 vapors. Discard absorbers which exhibit survey meter readings of > 10-times facility background levels.
- Always wear a lab coat and disposable gloves when handling S-35.
- Monitor personnel (hands, clothing, shoes, etc), work areas, and floors using a G-M survey meter equipped with a G-M pancake / frisker probe for gross contamination.
- Monitor for removable surface contamination by smearing, swiping, swabbing, or wipe testing where S-35 is used. Count smears or swabs in a liquid scintillation counter (LSC).
- Research personnel must maintain a current inventory of S-35 sources at all times.
- Expelling S-35 solutions through syringe needles and pipette tips can generate airborne aerosols.
- Drying can cause airborne S-35 dust contamination and rapid boiling can volatilize S-35 or cause airborne S-35 aerosol contamination.
- Skin contamination (dose), ingestion, inhalation, puncture/injection, absorption through skin, and area contamination are primary radiological safety concerns.

Radionuclide Safety Data Sheet

PHYSICAL DATA

Radionuclide:	Iodine-125 (I-125)
Decay Mode:	Electron Capture
Gamma Energy:	Gamma = 35 .5 keV (6.5%)
	K x-ray = 27 keV (112.5%)
	K x-ray = 31 keV (25.4%)
Gamma Constant:	0.27 mR/hr per mCi at 1 meter
Physical Half-Life:	60.14 days
Biological Half-Life:	120 – 138 days(unbound iodine)
Effective Half-Life:	42 days (unbound iodine in thyroid)
Specific Activity:	17,353 curies / gram
Half-value Layer (HVL) lead:	0.0018 cm = 0.02 mm
Half-value Layer (HVL) Water/tissue:	1.7 cm = 2/3”
Half-value Layer (HVL) concrete:	0.21 cm

RADIOLOGICAL DATA

Critical Organ:	Thyroid
Routes of Intake:	Ingestion, Inhalation, Puncture, Wound, Skin Contamination (Absorption)
Exposure Concerns:	External & Internal exposure & contamination
Committed Dose Equivalent (CDE):	1273 mrem/ uCi I-125 ingested (Thyroid)
	799 mrem/ uCi I-125 inhaled (Thyroid)
Committed Effective Dose Equivalent (CEDE):	50 mrem/ uCi I-125 ingested (WB)
	25 mrem/ uCi I-125 inhaled (WB)
Annual Limit on Intake (ALI):	40 uCi (Thyroid from ingestion)
	60 uCi (Thyroid from inhalation)
	1 ALI = 50,000 mrem CDE to the Thyroid

SHIELDING/LABELING

Shielding:	Lead foil or sheets (1/32” – 1/16” thick)
	0.152 mm lead foil will reduce exposure rate by 99%
	7.2 mm lead impregnated plastic or acrylic shield will reduce exposure rate >> 99.9%
Labeling:	Container with $\geq$ 1 uCi must be labeled “Caution, Radioactive Material”

SURVEY INSTRUMENTATION

Survey meter equipped with a low-energy NaI scintillation probe (1" crystal) is preferred for the detection of I-125
Low-energy NaI probe efficiency for I-125 ~ 13%.
Survey meter equipped with G-M pancake/frisker (15.5 cm^2 area) is very inefficient for detection of the low energy I-125 gamma/x-rays (G-M efficiency ~ 0.5% at 1 cm).
Wipes/smears should be counted on a liquid scintillation counter or gamma well detector to detect I-125 contamination.
Counting efficiency on a Perkin Elmer liquid scintillation counter is approximately 78%
Counting efficiency of a COBRA well detector is 82% (2" NaI crystal) and 83% (3" NaI crystal)

PERSONAL RADIATION MONITORING DOSIMETERS

Personnel dosimetry (whole body & ring badges) recommended when working with I-125
Dose rates from an unshielded 1 millicurie point source of I-125:

1 cm = 2750 mrem/hr 10 cm = 27.5 mrem/hr 100 cm = 0.27 mrem/hr

BIOASSAYS

The following activities if handled at any one time or processed in a three (3) month period require a thyroid bioassay:

Open room or bench:	0.1 mCi (volatile); 1 mCi (non-volatile)
Certified Hood:	1 mCi (volatile); 10 mCi (non-volatile)

When required, bioassays must be performed at a minimum on a quarterly basis. If more frequent monitoring is desired, it must be performed within 6 to 72 hours after suspected intake.

DOSIMETRY

The thyroid is the critical organ for I-125 uptake. Individual uptake and metabolism vary over a wide range. The thyroid may be assumed to accumulate 30% of soluble radioiodine uptake to the body and retain iodine with a 138 day biological half-life. All radioiodine in the body can be assessed to be eliminated via the urine.

RADIOACTIVE WASTE

Isolate waste from other radionuclides in clearly labeled containers.
Sanitary sewer disposal limit is 10 uCi in any one day via a designated "hot" sink provided it is readily soluble, dispersible in water, and contains no hazardous materials. A sewer log must be maintained.

GENERAL RADIOLOGICAL SAFETY INFORMATION (I-125)

(Permission from University of Michigan Radiation Safety Office)

- Inherent Volatility (STP): "SUBSTANTIAL" [volatilization is a very significant concern with I-125 especially in disassociated (free) form or in acidic solutions]
- Caution should be used when making low pH (acidic) solutions of I-125 (volatilization)

- Internal exposure and contamination represent the primary hazards for most I-125 applications. Iodine-125 is easily shielded using 1/32 – 1/16" lead sheets to reduce external radiation exposures.
- Acidic and frozen solutions enhance radioiodine volatility.
- Soluble iodide ion is oxidized to elemental (free) iodine which has low solubility in water and high vapor pressure. Acidic solutions enhance the oxidation of sodium iodide to elemental (free) iodine; thereby, increasing volatility.
- Alkaline sodium thiosulfate should be used to chemically stabilize I-125 prior to initiating decontamination of an I-125 spill (0.1 M NaI, 0.1 M NaOH, and 0.1 M Na2S2O3).
- Store at room temperature: DO NOT FREEZE (whenever possible)
- Radioiodine labeled compounds should be assumed to be potentially volatile since radiolytic decomposition can give rise to free iodine in solution. Radiolytic decomposition is minimized by maintaining solutions at low (dilute) concentrations.
- Addition of antioxidants (sodium thiosulfate) to either labeled or NaI solutions of I-125 will help reduce both decomposition & volatilization.
- Regulatory limits on personal intake and environmental releases of I-125 are quite restrictive because of the relatively high radiotoxicity relative to other common university-related radionuclides.
- The urinary excretion rate decreases by about two orders of magnitude during the first 5-days after intake. Thus, uncertainties in interpretation of urinary excretion that arise because of the unknown time of intake in routine monitoring may be large.

Radionuclide Safety Data Sheet

PHYSICAL DATA

Radionuclide:	Chromium-51 (Cr-51)
Decay Mode:	Electron Capture
Gamma Energies (primary):	320 keV (9.8% abundance)
	5 keV (22% abundance)
Auger Electron:	4 keV (66.9% abundance)
Gamma Constant:	0.018 mR/hr per mCi at 1 meter
	(180 mR/hr per mCi at 1 cm)
Physical Half-Life:	27.7 days
Biological Half-Life:	616 days
Effective Half-Life:	26.6 days
Specific Activity:	9.24 E4 curies / gram

RADIOLOGICAL DATA

Critical Organ:	Lower Large Intestine (LLI)
External & Internal exposure & contamination are primary radiological concerns	
Committed Dose Equivalent (CEDE):	0.145 mrem/ uCi (ingestion)
	0.334 mrem/ uCi (inhalation for oxides & hydroxides)
Annual Limit on Intake (ALI):	40 mCi (ingestion)
	20 mCi (inhalation)
	1 ALI = 5000 mrem CEDE (Whole Body)

SHIELDING/LABELING

Shielding: 1/4" – 1/2 " lead shielding is adequate shielding for Cr-51

Half-Value Layer (HVL / Lead):	1.7 mm = 0.7”
Half-Value Layer (HVL / Water or Tissue):	5.7 cm = 2.24”
Half-Value Layer (HVL / Plexiglass):	4.8 cm = 1.9”

Labeling: Container with $\geq$ 1 mCi must be labeled “Caution, Radioactive Material”

SURVEY INSTRUMENTATION

A survey meter equipped with a NaI scintillation probe is suitable for detection of the Cr-51 gammas. Typical detection for thick crystal NaI scintillation efficiency is 1%-3%

A survey meter equipped with a G-M pancake or thin-window probe is NOT recommended for detecting Cr-51. Typical efficiency for a G-M survey meter is < 1% (although it can be used to detect gross contamination)
Indirect counting using a liquid scintillation counter (LSC) or gamma counter should be used to detect removable Cr-51 contamination on smears, swabs, or swipes
Efficiency on a Perkin Elmer (Packard) LSC is 35%. Efficiencies for gamma well counters (2"- 3" NaI crystal) ~5 to 6%

PERSONAL RADIATION MONITORING DOSIMETERS

Personnel dosimetry (whole body & ring badges) recommended when working with Cr-51
Dose rates from an unshielded 1 millicurie point source of Cr-51:

1 cm = 180 mrem/hr 10 cm = 1.8 mrem/hr 100 cm = 0.0.18 mrem/hr

Skin Contamination Dose Rate (Basal Cells): 56 millirad/hour per uCi/cm^2

BIOASSAYS

Not normally required. Notify Radiation Safety if an intake of Cr-51 is suspected.

DOSIMETRY

The lower large intestine is the critical organ for intake of soluble Cr-51 compounds and ingestion of insoluble compounds. An uptake of Cr-51 is slowly eliminated from the body equally via urine and feces with a biological half-life of 616 days. The dose committed is reduced by the short physical half-life of Cr-51.

RADIOACTIVE WASTE

Isolate waste from other radionuclides in clearly labeled containers.
Sanitary sewer disposal limit is 10 mCi in any one day via a designated "hot" sink provided it is readily soluble, dispersible in water, and contains no hazardous materials. A sewer log must be maintained.

GENERAL RADIOLOGICAL SAFETY INFORMATION (Cr-51)

Inherent Volatility (STP): Insignificant / Negligible

- Store millicurie amounts of Cr-51 (including waste) behind lead shielding (¼ - ½ inch thick);
- Use shielding to minimize exposure while handling Cr-51
- Use tools to handle Cr-51 sources and contaminated objects; avoid direct hand contact
- Always wear a lab coat and disposable gloves when handling Cr-51.
- Monitor personnel, work areas, and floors using a survey meter equipped with a 1" x 1" or a low-energy NaI scintillation probe for Cr-51 contamination. A survey meter equipped with a G-M pancake/frisker probe (15.5 cm^2 surface area) can be used for the detection of gross Cr-51 contamination.
- Monitor for removable surface contamination by smearing, swiping, swabbing, or wipe-testing where Cr-51 is used. Count smears or swabs in a liquid scintillation counter (LSC) or a gamma counter.

Radionuclide Safety Data Sheet

PHYSICAL DATA

Radionuclide:	Iodine-131 (I-131)
Decay Mode:	Beta (followed by gamma/IC)
Beta Energies (primary):	192 keV (89% abundance / average) 606 keV (89% abundance / maximum)
Gamma Energies(primary):	364 keV (82% abundance) 637 keV (7% abundance) 284 keV (6% abundance) 723 keV (2% abundance) 80 keV (3% abundance) 29-34 keV (4.5% / x-rays)
Gamma Constant:	0.22 mR/hr per mCi at 1 meter
Physical Half-Life:	8.05 days
Biological Half-Life:	138 days (unbound)
Effective Half-Life:	7.6 days (unbound)
Specific Activity:	124,068 curies / gram
Half-value Layer (HVL) lead:	0.23 cm = 0.09”
Half-value Layer (HVL) Water/tissue:	6.3 cm = 2.5”
Maximum Beta Range in Water:	2 mm = 0.20 cm = 0.08”
Maximum Beta Range in Air:	165 cm = 65” = 5.4 ft

RADIOLOGICAL DATA

Critical Organ:	Thyroid
Routes of Intake:	Ingestion, Inhalation, Puncture, Wound, Skin Contamination (Absorption)
Radiological Concerns:	External & Internal exposure & contamination
Committed Dose Equivalent (CDE):	1761 mrem/ uCi I-125 ingested (Thyroid) 1080 mrem/ uCi I-125 inhaled (Thyroid)
Annual Limit on Intake (ALI):	30 uCi (Thyroid from ingestion) 50 uCi (Thyroid from inhalation) 1 ALI = 50,000 mrem CDE to the Thyroid

SHIELDING/LABELING

Shielding : Half-value Layer (HVL) lead: 0.23 cm = 0.09”
Half-value Layer (HVL) Water/tissue: 6.3 cm = 2.5”
Tenth-value Layer (TVL) lead: 0.7 cm = 0.28”
NOTE - Plexiglass, acrylic, plastic, wood, or other low-density material will NOT shield I-131 gamma; use lead bricks.

Labeling: Container with $\geq$ 1 uCi must be labeled “Caution, Radioactive Material”

SURVEY INSTRUMENTATION

Survey meter equipped with a GM probe (preferably a GM pancake with 15.5 cm^2 surface area) or NaI probe should be used to survey for I-131
GM probe efficiency for I-131 ~ 8%.
Wipes/smears should be counted on a liquid scintillation counter or gamma well detector to detect I-131 contamination.
Counting efficiency on a Perkin Elmer liquid scintillation counter is approximately 98%
Counting efficiency of a COBRA well detector is 60% (2” NaI crystal) and 70% (3” NaI crystal)

PERSONAL RADIATION MONITORING DOSIMETERS

Personnel dosimetry (whole body & ring badges) recommended when working with I-131
Dose rates from an unshielded 1 millicurie point source of I-131:

1 cm = 2200 mrem/hr 10 cm = 22 mrem/hr 100 cm = 0.22 mrem/hr

BIOASSAYS

The following activities if handled at any one time or processed in a three (3) month period require a thyroid bioassay:

Open room or bench: 0.1 mCi (volatile); 1 mCi (non-volatile)
Certified Hood: 1 mCi (volatile); 10 mCi (non-volatile)

When required, bioassays must be performed at a minimum on a quarterly basis. If more frequent monitoring is desired, it must be performed within 6 to 72 hours after suspected intake.

DOSIMETRY

The thyroid is the critical organ for I-131 uptake. Individual uptake and metabolism vary over a wide range. The thyroid may be assumed to accumulate 30% of soluble radioiodine uptake to the body and retain iodine with a 138 day biological half-life. All radioiodine in the body can be assumed to be eliminated via the urine.

RADIOACTIVE WASTE

Isolate waste from other radionuclides in clearly labeled containers.
Sanitary sewer disposal limit is 10 uCi in any one day via a designated “hot” sink provided it is readily soluble, dispersible in water, and contains no hazardous materials. A sewer log must be maintained.

GENERAL RADIOLOGICAL SAFETY INFORMATION (I-131)

(Permission from University of Michigan Radiation Safety Office)

- Inherent Volatility (STP): SIGNIFICANT [volatilization is a very significant concern with I-131 especially in a disassociated (free) form or acidic solutions]
- Acidic and frozen solutions enhance radioiodine volatility.
- Store at room temperature: DO NOT FREEZE (whenever possible)
- Radioiodine labeled compounds should be assumed to be potentially volatile because decomposition can give rise to free iodine in solution. Maintaining radioiodine solutions at low (dilute) concentration minimizes radiolytic decomposition.
- Soluble iodide ion is oxidized to elemental (free) iodine that has low solubility in water and a high vapor pressure. Acidic solutions enhance the oxidation of sodium iodide to elemental (free) iodine; thereby, increasing volatility.
- Regulatory limits on personal intakes and environmental releases of I-131 are quite restricted because of the relatively high radiotoxicity relative to other common university-related radionuclides.
- Addition of antioxidants (sodium thiosulfate) to either labeled or sodium iodine solutions of I-131 will help reduce both decomposition and volatilization. Alkaline sodium thiosulfate should be used to chemically stabilize I-131 prior to initiating decontamination of an I-131 spill (0.1 M NaI, 0.1 M NaOH, and 0.1 $Na_2S_2O_3$).
- Drying can form airborne I-131 contamination.
- Radioiodine in the body is eliminated quite rapidly via the urine.
- Most radioiodine accidents are in a soluble form and will be rapidly absorbed via inhalation, ingestion, absorption through the skin, or any combination of these routes.
- Due to its volatile character and ease of absorption, potentially exposed individuals should be monitored after any accident or spill either by in-vivo (thyroid count) or in-vitro (urine) analysis.
- Thyroid counts made within 12-hours after a suspected intake of I-131 often may be unreliable due to skin contamination.
- Of the iodine entering the transfer compartment of the body, approximately 30% is taken up by the thyroid and the remainder (70%) is assumed to be excreted in the urine (ICRP 54).
- Iodine is lost from the thyroid in the form of organic iodine. This organic iodine uniformly distributes among all organs & tissues of the body, other than the thyroid, and is retained with a biological half-life of 12 days. 90% of the organic iodine lost from the thyroid is returned to the transfer compartment and the rest is excreted via the feces.
- The administration of stable iodine (KI or Lugals Solution) blocks the transfer of radioiodine to the thyroid. The onset of inhibition (thyroid blocking) occurs rapidly after administration of stable iodine.
- NOTE: The use of stable iodine blocking agents is a personal choice.
- The urinary excretion rate decreases by more than two orders of magnitude within 5 days after intake. Thus, uncertainties in interpretation of urinary excretion that arise because of the unknown time of intake in routine monitoring may be large unless exposure is avoided for 5 days before sampling.
- Expelling I-131 solutions through syringe needles and pipette tips can generate airborne aerosols.
- Always wear a lab coat and disposable gloves (preferably, two pairs) when handling I-131.
- Monitor hands, lab coat, shoes, work areas, and floors using a G-M survey meter equipped with a pancake/frisker probe for gross contamination.

- Monitor for removable surface contamination by smearing, swiping, swabbing, or wipe testing where I-131 is used. Count smears or swabs in a liquid scintillation counter (LSC) or gamma counter
- Iodinations are to be conducted in an approved exhaust hood.
- Iodinations are to be conducted using a "closed" system (no pipetting & no open containers during iodination process). Only use rubber-septum sealed vials or containers and syringes.
- Whenever possible, perform iodination reactions in the original sealed shipping vial when handling potentially volatile radioiodine.
- Vent the airspace of stock and reaction vials through an activated charcoal-filled syringe trap during iodination procedures.
- Remove potentially contaminated syringe needles from stock an reaction vials through absorbent material (tissue paper, cotton, etc.).
- Store I-131 contaminated objects (syringes, stock vials, waste, etc.) in sealed containers (zip-lock bags, plastic containers, etc.).
- A solution of sodium thiosulfate should be on-hand during iodination procedures.

Radionuclide Safety Data Sheet

PHYSICAL DATA

Radionuclide:	Calcium-45 (Ca-45)
Decay Mode:	Beta (100% abundance)
Beta Energy :	257 keV (maximum); 77 keV (average)
Physical Half-Life:	162.7 days
Biological Half-Life:	18,000 days (Bone)
Effective Half-Life:	163 days
Specific Activity:	17,800 curies / gram
Maximum Beta Range in Air:	52 cm = 20”
Maximum Beta Range in Water/Tissue:	0.062 cm = 0.024” Ca-45 beta particles CANNOT penetrate lens of eye (0.3 cm)
Maximum Beta Range in Lucite/Plastic:	0.053 cm = 0.021”

RADIOLOGICAL DATA

Critical Organ:	Bone
Exposure Concerns:	Internal exposure & contamination
Committed Dose Equivalent (CEDE):	16.2 mrem/ uCi Bone (inhalation) 19.4 mrem/ uCi Bone (ingestion)
Annual Limit on Intake (ALI):	2 mCi (ingestion) 800 uCi (inhalation) 1 ALI = 5000 mrem CEDE

SHIELDING/LABELING

Shielding: Low atomic number material (e.g., 1/8” Lucite, plastic, acrylic) is recommended if working or storing millicurie amounts Ca-45.

Labeling: Container with $\geq$ 100 uCi must be labeled “Caution, Radioactive Material”

SURVEY INSTRUMENTATION

Ca-45 can be detected with a survey meter equipped with a GM probe (pancake probe preferable)
Counting efficiency with GM survey meters is about 6%
Wipes/smears should be counted on a liquid scintillation counter to detect Ca-45 contamination. Counting efficiency on a Perkin Elmer liquid scintillation counter is approximately 96%.

SKIN CONTAMINATION (Ca-45):

Localized Dose Rate to Basal Cells at 7 mg/cm^2 or 0.007 cm tissue depth (without air reflection)
Skin Contamination Dose Rate (Extremity Skin): 3180 mrem/hour per 1 uCi/cm^2
Ca-45 beta particles CANNOT penetrate lens of the eye (0.3 cm)

PERSONAL RADIATION MONITORING DOSIMETERS

Personnel dosimetry (whole body & ring badges) are typically NOT required when working with Ca-45

BIOASSAYS

Not normally required. Notify Radiation Safety if an intake of Ca-45 is suspected

DOSIMETRY

Millicurie quantities of Ca-45 do not present a significant external exposure hazard because the low energy betas emitted barely penetrate gloves and the horny outer skin layer. The critical organ for uptake of Ca-45 is the bone. The metabolism of Ca-45 is complex. The majority of Ca-45 is deposited in the bone and is retained with a long biological half-life of 1.8 x 104 days. A smaller fraction is rapidly eliminated. Ca-45 is initially eliminated via the urine but eventually half the radionuclide is eliminated via the feces.

RADIOACTIVE WASTE

Isolate waste from other radionuclides in clearly labeled containers.
Sanitary sewer disposal limit is 100 uCi in any one day via a designated “hot” sink provided it is readily soluble, dispersible in water, and contains no hazardous materials. A sewer log must be maintained.

GENERAL RADIOLOGICAL SAFETY INFORMATION (Ca-45)

Inherent Volatility (STP): Insignificant / Negligible

- Use transfer pipettes, spill trays or absorbent coverings to confine contamination.
- Volatile chemical forms will be handled in a certified fume hood.
- Use lab coats and disposable gloves. Select gloves appropriate for chemicals handled.
- Regularly monitor and replace gloves as needed.
- Regularly monitor and promptly decontaminate work surfaces to maintain contamination and exposures as low as reasonably achievable.
- Shielding provided by the vial is adequate.

Radionuclide Safety Data Sheet

PHYSICAL DATA

Radionuclide:	Phosphorous-33 (P-33)
Decay Mode:	Beta (100% abundance)
Beta Energy:	249 keV (maximum); 85 keV (average)
Physical Half-Life:	25.4 days
Biological Half-Life:	1155 days (Mineral Bone) 257 days (Whole Body)
Effective Half-Life:	24.9 days
Maximum Beta Range in Air:	51 cm = 20”
Maximum Beta Range in Water/Tissue:	0.06 cm = 0.025” P-33 beta particles CANNOT penetrate lens of eye (0.3 cm)
Maximum Beta Range in Lucite/Plastic:	0.05 cm = 0.020”

RADIOLOGICAL DATA

Critical Organ:	Bone for soluble forms Lung (inhalation) and GI Tract/LLI (ingestion for insoluble forms and non-transportable P-33 compounds
Routes of Intake:	Ingestion, Inhalation, Puncture, Skin Contamination (Absorption)
Exposure Concerns:	Internal exposure and contamination (millicurie quantities are NOT an external concern)
Annual Limit on Intake (ALI):	6 mCi (ingestion all compounds) 8 mCi (inhalation for all compounds except phosphates of Zn^{2+}, S^{3+}, Mg^{2+}, Fe^{3+}, Bi^{3+}) 3 mCi (inhalation for all compounds except phosphates of Zn^{2+}, S^{3+}, Mg^{2+}, Fe^{3+}, Bi^{3+}) (1 ALI = 5 rem CEDE)

SKIN CONTAMINATION (P-33):

Localized Dose Rate to Basal Cells at 7 mg/cm^2 or 0.007 cm tissue depth (without air reflection)
Skin Contamination Dose Rate (Extremity Skin): 3182 mrem/hour per 1 uCi/cm2
P-33 beta particles CANNOT penetrate lens of the eye (0.3 cm)

SURVEY INSTRUMENTATION:

P-33 can be detected with a survey meter equipped with a GM probe (pancake probe preferable)

Counting efficiency of P-33 with GM survey meters is about 6%
Wipes/smears should be counted on a liquid scintillation counter to detect P-33 contamination. Counting efficiency on a Perkin Elmer liquid scintillation counter is approximately 95%.

SHIELDING/LABELING

Shielding : Low atomic number material (e.g., 1/8" Lucite, plastic, acrylic) is recommended if working or storing millicurie amounts of P-33.

Labeling: Container with $\geq$ 100 uCi must be labeled "Caution, Radioactive Material"

PERSONAL RADIATION MONITORING DOSIMETERS

Personnel dosimetry (whole body & ring badges) are typically NOT required when working with P-33

BIOASSAY REQURIEMENTS

Not normally required. Notify Radiation Safety if an intake of P-33 is suspected

DOSIMETRY

Millicurie quantities of P-33 do not present a significant external exposure hazard because the low energy betas emitted barely penetrate glove and the horny outer layer of skin. Phosphorus metabolism is complex; 30% is rapidly eliminated from the body, 40% goes to soft tissue with a 19 day biological half-life, and the remaining goes to mineral bone which is reduced by its physical half-life of 25.4 days.

RADIOACTIVE WASTE

Isolate waste from other radionuclides in clearly labeled containers.
Sanitary sewer disposal limit is 100 uCi in any one day via a designated "hot" sink provided it is readily soluble, dispersible in water, and contains no hazardous materials. A sewer log must be maintained.

GENERAL RADIOLOGICAL SAFETY INFORMATION (P-33)

(Permission from University of Michigan Radiation Safety Office)

- Inherent Volatility (STP): Insignificant / Negligible. P-33 is not volatile, even when heated and can be ignored as an airborne contaminant unless aerosolized.
- White wine vinegar can be an effective decontamination solvent for this nuclide in most common chemical forms. Skin dose, internal contamination, and area contamination are the primary radiological concerns.
- Drying can form airborne P-33 contamination.
- Always wear a lab coat and disposable gloves when handling P-33.
- Monitor work areas for removable surface contamination by smearing, swabbing, or wipe testing where P-33 is used. Count smears or swabs in a liquid scintillation counter (LSC).

Radionuclide Safety Data Sheet

PHYSICAL DATA

Radionuclide:	Technetium-99m (Tc-99m)
Decay Mode:	Gamma
Gamma Energies (primary):	140.5 keV (89% abundance) 18.4 keV (4% abundance) 18.3 keV (2% abundance)
Gamma Constant:	0.076 mR/hr per mCi at 1 meter (760 mR/hr per mCi at 1 cm)
Physical Half-Life:	6.02 hours
Biological Half-Life:	24 hours
Effective Half-Life:	4.8 hours (Biological & Effective half-life varies with radiopharmaceutical)
Specific Activity:	5.244 E6 curies / gram ("carrier free"/pure Tc-99m) 3.4 E6 curies/gram (99m Tc-pertechnetate form)

RADIOLOGICAL DATA

Critical Organ:	Carrier/radiopharmaceutical specific
Exposure Concerns:	External & Internal exposure & contamination
Committed Dose Equivalent (CDE):	0.41 mrem / uCi (puncture/thyroid/adult) 0.313 mrem / uCi (ingestion/thyroid)
Annual Limit on Intake (ALI):	80 mCi (all compounds)* (oral ingestion / CEDE / Whole Body(* (all compounds, except oxides hydroxides, halides, and nitrates) 200 mCi (all compounds) (inhalation / CEDE / WB / 5 rem / Class "D" or “W) 1 ALI = 5000 mrem CEDE (Whole Body)

SHIELDING/LABELING

Shielding: ¼" – ½" lead shielding is adequate for Tc-99m 140 keV gammas

Half-Value Layer (HVL / Lead):	0.027 cm = 0.011“ (140 keV)
Tenth-Value Layer (TVL / Lead):	0.083 cm = 0.033” (140 keV)
Tenth-Value Layer (TVL / Concrete):	6.60 cm = 2.60”
Half-Value Layer (HVL / Water or Tissue):	4.60 cm = 1.81”

Attenuation Coefficient (100) Lead:	0.16 cm = 0.063”
Attenuation Coefficient (1000):	0.25 cm = 0.104”

Labeling: Container with $\geq$ 1 mCi must be labeled “Caution, Radioactive Material”

SURVEY INSTRUMENTATION

Survey meter equipped with a 1" x 1" or a low-energy NaI scintillation probe is preferred for the detection of Tc-99m contamination
Typical counting efficiencies for a 1" x 1" NaI probe = 39% and for a low-energy NaI probe = 12%

Survey meters equipped with a G-M pancake/frisker (15.5 cm2 surface area) can be used for gross contamination; however, they exhibit very low counting efficiencies (approximately, 1.2%) for the detection of low-energy Tc-99m gamma rays.

Indirect counting using a liquid scintillation counter (LSC) or gamma counter should be used to detect removable Tc-99m contamination on smears, swabs, or swipes.

PERSONAL RADIATION MONITORING DOSIMETERS

Personnel dosimetry (whole body & ring badges) recommended when working with Tc-99m
Dose rates from an unshielded 1 millicurie point source of Tc-99m:

1 cm = 760 mrem/hr 10 cm = 7.6 mrem/hr 100 cm = 0.0.76 mrem/hr

Skin Contamination Dose Rate (Basal Cells): 718 millirad/hour per uCi/cm2

BIOASSAYS

Bioassays NOT required for Tc-99m use

DOSIMETRY

Tc-99m is carrier/compound (radiopharmaceutical) specific:

- Tc-99m Pertechnetate ($^{99m}Tc0_4$) - (MUGA Scans) behaves similar to iodine and concentrates in thyroid, salivary glands, brain, blood pool, urinary bladder, and stomach. Stomach receives majority of dose and contains 25% of administered dose after 4 hours.
- Tc-99m-Labeled Sulfur Colloid - approximately 70-80% of the administered dose (3 mCi/injected) is localized in the liver. Used for liver, spleen, and bone-marrow scanning.
- Tc-99m-Labeled Macroaggregated Albumin (^{99m}Tc MAA) - primarily used for lung scanning; 90-95% of administered dose (3mCi/injected) is trapped in the capillary bed of the lungs within a few seconds after intravenous administration.
- Tc-99m (MUGA) - spleen receives approximately 2.6 rad/mCi.
- Tc-99m (DTPA) - brain or kidney scan; administered dose is 20 mCi (injected); bladder (0.5 rad/mCi); whole body (20 mrad/mCi)

RADIOACTIVE WASTE

Isolate waste from other radionuclides in clearly labeled containers.
Sanitary sewer disposal limit is 10 mCi in any one day via a designated “hot” sink provided it is readily soluble, dispersible in water, and contains no hazardous materials. A sewer log must be maintained.

GENERAL RADIOLOGICAL SAFETY INFORMATION (Tc-99m)

- Inherent Volatility (STP): Insignificant / Negligible
- Tc-99m is used in clinical and research diagnostic scanning and imaging.
- Whole body & extremity exposures, skin contamination (dose), ingestion, inhalation, puncture/injection, absorption through skin, and area contamination are primary radiological safety concerns.
- Drying can cause airborne Tc-99m dust contamination and rapid boiling can cause airborne Tc-99m aerosol contamination. Expelling Tc-99m solutions through syringe needles and pipette tips can generate airborne aerosols.
- Always wear a lab coat and disposable gloves when handling Tc-99m.
- Monitor personnel, work areas, and floors using a survey meter equipped with a 1" x 1" or a low-energy NaI scintillation probe for Tc-99m contamination. A survey meter equipped with a G-M pancake/frisker probe (15.5 cm^2 surface area) can be used for the detection of gross Tc-99m contamination.
- Monitor for removable surface contamination by smearing, swiping, swabbing, or wipe-testing where Tc-99m is used. Count smears or swabs in a liquid scintillation counter (LSC) or a gamma counter.
- Store millicurie amounts of Tc-99m behind ¼-inch thick lead shielding. Use a syringe shield when administering Tc-99m dosages via a syringe unless contraindicated.

Radionuclide Safety Data Sheet

PHYSICAL DATA

Radionuclide:	Lutetium-177 (Lu-177)
Decay Mode:	Beta (followed by gamma/IC)
Beta Energies (primary):	497 keV max; 149 keV ave (79% abundance) 385 keV max; 112 keV ave (9.1% abundance) 176 keV max; 48 keV ave (12.2% abundance)
Gamma Energies (primary):	113 keV max (6.4% abundance) 210 keV (11% abundance)
Gamma Constant:	0.028 mR/hr per mCi at 1 meter
Physical Half-Life:	6.7 days
Biological Half-Life:	~ 1 day (GI) ~ 30 days (Lung)
Effective Half-Life:	~ 0.9 day (GI) ~ 6 days (Lung)
Specific Activity:	1.1 E5 Ci/ gram
Half-value Layer (HVL) lead:	0.6 mm = 0.023”
Maximum Beta Range in Water:	1.6 mm = 0.06”
Maximum Beta Range in Air:	135 cm = 53”
Mean Beta Penetration in Tissue:	0.67 mm

RADIOLOGICAL DATA

Critical Organ:	Lower Large Intestine (ingestion); Lung (inhaled)
Routes of Intake:	Ingestion, Inhalation, Puncture, Wound, Skin Contamination (Absorption)
Radiological Concerns:	External & Internal exposure & contamination
Committed Dose Equivalent (CDE):	2.38 mrem/ uCi ingested (Lower Large Intestine) 1.12 mrem/ uCi inhaled (Lung)
Annual Limit on Intake (ALI):	2000 uCi Ingestion (LLI Wall) 2000 uCi Inhalation (Whole Body) 1 ALI Ingestion = 50,000 mrem CDE to the LLI Wall

SHIELDING/LABELING

Shielding :	Half-value Layer (HVL) lead:	0.6 mm = 0.023”
	Tenth-value Layer (TVL) lead:	2.1 mm = 0.08”
	Betas:	0.135 cm Plexiglass

Labeling: Container with $\geq$ 100 uCi must be labeled “Caution, Radioactive Material”

SURVEY INSTRUMENTATION

Survey meter equipped with a GM probe (preferably a GM pancake with 15.5 cm^2 surface area) GM probe.
Wipes/smears should be counted on a liquid scintillation counter or gamma well detector to detect contamination.
Counting efficiency on a Perkin Elmer liquid scintillation counter is approximately > 90%

PERSONAL RADIATION MONITORING DOSIMETERS

Personnel dosimetry (whole body & ring badges) recommended when working with Lu-177
External dose rates from an unshielded 1 millicurie point source of Lu-177:

1 cm = 280 mrem/hr 10 cm = 2.8 mrem/hr 100 cm = 0.028 mrem/hr

Skin Dose for 1 uCi over 10 cm^2 of skin = 1.82 mrad/hr (gamma); 483 mrad/hr (beta)

BIOASSAYS

Bioassays not normally required. However, if deemed necessary, urine samples for bioassay from 4 to 24 hours after handling ^{177}Lu to indicate uptake by personnel. Consider use of a whole body counter to determine ^{177}Lu retention.

DOSIMETRY

Gamma emissions from ^{177}Lu presents an external dose hazard. Beta emissions can present an external exposure hazard to skin. It may be assumed that 60%, 2% and 0.5% of ^{177}Lu uptakes in the transfer compartment are translocated to mineral bone, liver and kidneys respectively, and the rest is directly excreted. ^{177}Lu is retained in the bone and liver with a biological half-life of 3500 days and retained in the kidneys with a biological half-life of 10 days. However, the committed dose is significantly reduced due to the short physical half-life of ^{177}Lu (Taken from ICRP Publication 20, Part 3, Limits for Intakes of Radionuclides by Workers, 1981).

RADIOACTIVE WASTE

Isolate waste from other radionuclides in clearly labeled containers. In the production of ^{177}Lu there will be a small amount (<0.05%) of ^{177m}Lu (160 day half-life) generated. If disposal is by Decay In-Storage (DIS) waste should also be monitored for any residual ^{177m}Lu and disposed of appropriately.

Sanitary sewer disposal limit is 1000 uCi in any one day via a designated “hot” sink provided it is readily soluble, dispersible in water, and contains no hazardous materials. A sewer log must be maintained (disposal must also be documented on the UNMC RSO-8 form).

GENERAL RADIOLOGICAL SAFETY INFORMATION (Lu-177)
(Perkin Elmer suggestions for handling Lutetium-177)

- Near an unshielded ^{177}Lu source, dose rates from beta radiation can be much higher than dose rates due to gamma radiation.
- Designate area for handling ^{177}Lu and clearly label all containers.
- Store ^{177}Lu behind lead shielding.
- Wear extremity and whole body dosimeters while handling mCi (37 MBq) quantities.
- Use shielding to minimize exposure while handling ^{177}Lu.
- Use tools to indirectly handle unshielded sources and potentially contaminated vessels.
- Prohibit eating, drinking, smoking, and mouth pipetting in room where ^{177}Lu is handled.
- Use transfer pipettes, spill trays and absorbent coverings to confine contamination.
- Handle ^{177}Lu compounds that are potentially volatile or in powder form in ventilated enclosures.
- Sample exhausted effluent and room air by continuously drawing a known volume through membrane filters.
- Wear lab coat, wrist guards and disposable gloves for secondary protection.
- Maintain contamination and exposure control by regularly monitoring and promptly decontaminating gloves and surfaces.
- Use end window Geiger-Mueller detector or liquid scintillation counter to detect ^{177}Lu.
- Bioassay not normally required. If uptake suspected, submit periodic urine samples for bioassay from 4 to 24 hours after handling ^{177}Lu. Consider use of a whole body counter to determine ^{177}Lu retention.
- Isolate waste in clearly labeled, shielded container. Isolate waste from other radionuclides in clearly labeled containers. In the production of ^{177}Lu there will be a small amount (<0.05%) of ^{177m}Lu (160 day half-life) generated. If disposal is by Decay In-Storage (DIS) waste should also be monitored for any residual ^{177m}Lu and disposed of appropriately.
- Sanitary sewer disposal limit is 1000 uCi in any one day via a designated “hot” sink provided it is readily soluble, dispersible in water, and contains no hazardous materials. A sewer log must be maintained (disposal must also be documented on the UNMC RSO-8 form).

Radionuclide Safety Data Sheet

^{111}In

PHYSICAL DATA

Radionuclide:	Indium 111 (In-111)
Decay Mode:	Electron Capture
Gamma Energies (primary):	245 keV (94% abundance) 171 keV (90% abundance) 23 keV (69% abundance)
Gamma Constant:	0.502 mR/hr per mCi at 1 meter (5020 mR/hr per mCi at 1 cm)
Physical Half-Life:	2.8 days
Biological Half-Life:	Indefinite (specific labeled compound may alter)
Effective Half-Life:	2.8 days (specific labeled compound may alter)
Specific Activity:	4.19 E5 curies/gram

RADIOLOGICAL DATA

Critical Organ:	Lower Large Intestine (LLI)
Exposure Concerns:	External & Internal exposure; Contamination
Committed Effective Dose Equivalent (CEDE):	1.33 mrem / uCi (ingestion) 0.84 mrem / uCi (inhalation)
Annual Limit on Intake (ALI):	4000 uCi Ingestion (5000 mrem CEDE) 6000 uCi Inhalation (5000 mrem CEDE)

SHIELDING/LABELING

Shielding:	HVL for lead:	< 0.04” (< 0.1 cm)
	TVL for lead:	0.12” (0.3 cm)
Labeling:	Container with ≥ 100 uCi must be labeled “Caution, Radioactive Material”	

SURVEY INSTRUMENTATION

A survey meter equipped with a GM detector or a thin crystal NaI scintillation probe can be used for the detection of In-111. Typical efficiency for a thin crystal NaI scintillation probe (e.g., Ludlum 44-3) is 9% -11%.

Either a gamma counter or a liquid scintillation counter can be used to detect removable In-111 contamination on wipe tests smears.

PERSONAL RADIATION MONITORING DOSIMETERS

Personnel dosimetry (whole body & ring badges) recommended when working with In-111

Dose rates from an unshielded 1 millicurie point source of In-111:

1 cm = 5020 mrem/hr 10 cm = 50 mrem/hr 100 cm = 0.5 mrem/hr

Skin Contamination Dose Rate (Basal Cells): 1400 millirad/hour per uCi/cm^2

DOSIMETRY

^{111}In presents an external radiation exposure hazard. It may be assumed that 30%, 20%, 7%, 2% and 41% of ^{111}In uptakes in the transfer compartment are translocated to red bone marrow, liver, kidneys, spleen and all other organs and tissues respectively. Indium is assumed to be retained indefinitely, however the committed dose is significantly reduced due to the short physical half-life of ^{111}In (ICRP Publication 30, Part 2, Limits for Intakes of Radionuclides by Workers, 1980).

BIOASSAYS

Bioassays typically NOT required for In-111 use. Whole body count or urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

Isolate waste from other radionuclides in clearly labeled containers.

Sanitary sewer disposal limit is 100 uCi in any one day via a designated “hot” sink provided it is readily soluble, dispersible in water, and contains no hazardous materials. A sewer log must be maintained.

GENERAL RADIOLOGICAL SAFETY INFORMATION (In-111)

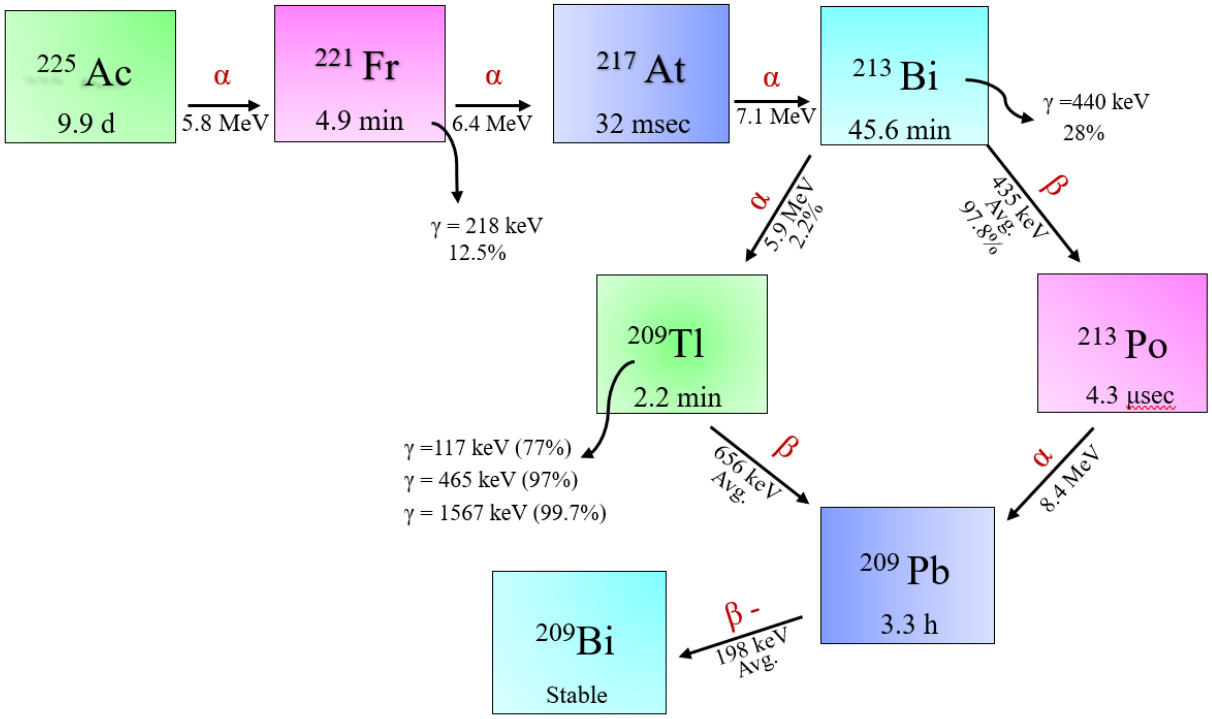
- Laboratory coat and gloves must be worn when handling In-111. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling In-111.
- Lead shielding (1/4”) shall be used to minimize exposure from higher activity amounts of In-111.
- Indirect viewing aids should be used to minimize exposure from In-111.
- Remote handling tools should be used when handling In-111.
- Practice procedures without radioactivity prior to performing the procedure with In-111. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.

Radionuclide Safety Data Sheet ^{225}Ac

PHYSICAL DATA

Radionuclide: Actinium-225 (Ac-225)

Decay Mode: Ac-225 decays by alpha emission, however, the daughter products have short half-lives and are in secular equilibrium. There are several alpha and beta decays. The decay scheme with the various half-lives is shown below:



Isotope	Half-life	Alpha	Beta (Average Energy)	Gamma
Ac-225	9.92 days	5.8 MeV (100%)	NA	NA
Fr-221	4.9 min	6.4 MeV (~100%)	NA	218 keV (12.5%)
At-217	32 msec	7.1 MeV (~100%)	NA	NA
Bi-213	45.6 min	5.9 MeV (2.2%)	435 keV (97.8%)	440 keV (28%)
Po-213	4.3 µsec	8.4 MeV (100%)	NA	NA
Tl-209 (Note: 2.2% of Ac-225 Decays)	2.2 min	NA	656 keV (100%)	117 keV (77%) 465 keV (97%) 1567 keV (99.7%)
Pb-209	3.3 hr	NA	198 keV	
Bi-209	1.9 E7 yr	3.1 MeV (100%)	NA	NA

Reference: “Radioactive Decay Data Tables”, D.C. Kocher, DOE/Tic-11026

RADIOLOGICAL DATA

Critical Organ:	Liver, Bone Surface
Exposure Concerns:	Internal exposure (inhalation or ingestion)
Annual Limit on Intake (ALI):	50 uCi Ingestion (50,00 mrem CDE LLI Wall) 0.3 uCi Inhalation (50,000 mrem CDE) Bone Surface
Gamma Constant:	0.191 mrem-m^2/mCi-hr

SHIELDING/LABELING

Shielding:	HVL for lead:	< 0.4 cm
	TVL for lead:	< 2.8 cm

Labeling: Containers with $\geq$ 0.01 uCi must be labeled "Caution, Radioactive Material"

SURVEY INSTRUMENTATION

Survey Meters: Because of the strong betas and gammas given off from daughter products in secular equilibrium, a survey meter with a GM probe can be used to monitor for Ac-225. An alpha probe (e.g., ZnS) can be used to monitor for alpha radiation (there are essentially 4 strong alphas given off from Ac-225 and progeny).

Liquid Scintillation Counting: Alphas can be counted with a Liquid Scintillation Counter with nearly 100% counting efficiency even with severe quenching. However, much of the alpha energy is not directly converted to light but is dissipated through molecular ionization. This ionization, coupled with molecular damage from decomposition and free radical formation, gives rise to a short-lived process called "ionization quench." Because of this phenomena, a 5 MeV alpha particle will appear to have the energy of 500 keV or about 1/10 of its particle energy. Alpha emitting radionuclides, when quantitated by liquid scintillation counting, generally produce a symmetrical peak around the energy maximum of the alpha particle with an energy resolution in LSC is approximately 25% Full Width at Half Maximum (FWHM).
The progeny Bi-213 and Pb-209 emit strong beta particles (97.8% and 100%) that will have high counting efficiency on the LSC. With five (5) progeny in secular equilibrium, the total activity measured on a LSC will be 5 to 6 times greater than the Ac-225 activity alone.

Gamma Counters: Progeny Bi-213 emits a 440 keV (28%) which can be measured with a gamma counter (e.g., GeLi) with high efficiency.

PERSONAL RADIATION MONITORING DOSIMETERS

Personnel dosimetry (whole body & ring badges) recommended when working with millicurie amounts of Ac-225.
Dose rates from an unshielded 1 millicurie point source of Ac-225:

1 cm = 1910 mrem/hr 10 cm = 19 mrem/hr 100 cm = 0.19 mrem/hr

DOSIMETRY (ICRP Publication 30, Part 3, Limits for Intakes of Radionuclides by Workers, 1980)

Uptake to Blood: Early studies indicated that the fractional absorption of actinium from the GI tract was less than 0.05. Later studies indicates the fractional absorption of actinium form the GI tract of rats is considerably less than 0.01 when the element is administered as a chloride. In ICRP Publication 30, f1 is taken to be 10^{-3} for all compounds of actinium.

Inhalation Class: The ICRP Task Group on Lung Dynamics (1966) assigned oxides and hydroxides to inhalation class Y (f_1= 10^{-3}), nitrates to inhalation class W (f_1= 10^{-3}) and all other compounds to inhalation class D (f_1= 10^{-3}).

Distribution and Retention: Like the other actinides, intravenously or intramuscularly injected actinium concentrates in the liver. It is assumed that the actinium leaving the transfer compartment fractions of 0.45 translocated to the mineral bone (100 year biological half-life) and 0.45 translocated to the liver (biological half-life of 40 years). The majority of the remainder is assumed to go directly to excretion.

BIOASSAYS

The need for bioassays is determined on a case by case basis. For working with non-volatile forms in a well-ventilated fume hood involving heating or chemical reaction of materials, a bioassay is required when more than 25 mCi is put into process in a month time period (NOTE: Higher amounts may require the use of a glove box). Bioassays are required for suspected internal contamination. The bioassay may be performed using urine, feces, or whole body counting. The dose will be calculated using the Intake Retention Factor (IRF) from NUREG-4884 for Ac-227 and modifying it for difference in radiological half-lives.

RADIOACTIVE WASTE

Isolate Ac-225 waste from other radionuclides in clearly labeled containers. Radiation Safety will pick up and dispose of Ac-225 waste by Decay in Storage (DIS). If the waste measures above background after ten half-lives (i.e., 100 days) it may be due to the long lived contaminant Ac-227 and the waste will be disposed using a commercial waste vendor.

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GENERAL RADIOLOGICAL SAFETY INFORMATION (Ac-225)

- Laboratory coat and gloves must be worn when handling Ac-225. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling millicurie amounts of Ac-225.
- Absorbent pad will be used on surfaces where radioactive material will be used.
- Individuals working with Ac-225 must survey themselves and the work area after working with Ac-225. A survey meter with a GM probe can be used to detect contamination.
- The contamination action level for Ac-225 is 100 dpm above background.
- Practice procedures without radioactivity prior to performing the procedure with Ac-225. Practice will improve dexterity and speed, along with providing opportunity to determine errors.

RADIOACTIVE MATERIAL RULES OF THUMB

A. Miscellaneous:

1. The activity of any radionuclide is reduced to less than 1% after 7 half-lives (i.e., 2-7 x 100 = 0.8%).
2. The activity of any radionuclide is reduced to less than 0.1% after 10 half-lives (i.e., 2-10 x 100 = 0.09%).
3. For material with a half-life greater than six days, the change in activity in 24 hours will be less than 10%.

B. Alpha Particles:

It requires an alpha particle of at least 7.5 MeV to penetrate the 0.007 cm thick protective layer of skin.

C. Beta Particles:

1. Beta particles with an energy of at least 70 KeV are required to penetrate the 0.007 cm thick protective layer of skin.
2. The average energy of a beta-ray spectrum is approximately one-third the maximum energy.
3. The range of beta particles in air is approximately 12 ft/MeV. (Maximum range of P-32 beta is 1.71 MeV x 12 ft/MeV = approximately equal to 20 ft.)
4. The dose rate in rads per hour in a solution by a beta emitter is 1.12 EC/p, where E is the average beta energy in MeV, C is the concentration in microcuries per cubic centimeter, and p is the density of the medium in grams per cubic centimeter. The dose rate at the surface of the solution is one-half the value given by this relation. (For P-32 average energy of approximately 0.7 MeV, the dose rate from 1 $\mu Ci/cm^3$ (in water) is 0.784 rads/hr.)

5. The surface dose rate through the nominal protective layer of skin (0.007 cm thick) from a uniform thin deposition of 1 μCi/cm^2 is about 9 rads/hour for energies greater than 0.6 MeV. Note that in a thin layer, the beta dose rate exceeds the gamma dose rate for equal energies released by about a factor of 100.
6. For a point source of beta radiation (neglecting self and air absorption) with millicurie (mCi) activity, the dose rate at 1 cm, is approximately equal to 200 x mCi rads/hour and varies little with beta energy. Dose rate for 1 mCi P-32 at 1 cm is approximately 200 rads/hour.
7. The intensity of bremsstrahlung increases approximately with the energy of the beta particle and about the square of the atomic number of the absorbing material.
8. When the betas of 1 to 2 MeV pass through light materials such as water, aluminum, or glass, less than 1% of their energy is dissipated as bremsstrahlung.
9. The bremsstrahlung from 1 Ci P-32 aqueous solution in a glass bottle is about 1 mR/hr at 1 meter.

D. Gamma Rays:

1. For a point source gamma emitter with energies between 0.07 and 4 MeV, the exposure rate (mR/hr) within ± 20% at 1 foot is 6 x mCi x E x n, where mCi is the number of millicuries; E, the energy in MeV; and n, the number of gammas per disintegration.
2. Inverse Square Law states that photon radiation intensity, or dose rate, from a point photon (i.e., gamma or x-ray) source varies inversely as the square of the distance from the source.

$$\frac{D_1}{D_2} = \frac{R_2^2}{R_1^2} \quad \rightarrow \quad D_2 = D_1 \frac{R_1^2}{R_2^2}$$

Where D = distance from source; R = Distance from radiation source

GUIDELINES ON RADIONUCLIDE LABORATORY CLASSIFICATIONS

The Radiation Safety Committee reviews facilities for a variety of operations which cover a wide range of types, quantities, and forms of radioactive material usage. The information in Tables I, II, and III are guidelines to be reviewed in designing or remodeling facilities. A faculty member who applies for Authorization to Use Radioactive Material should ensure that facilities and equipment safeguards present in the work place are consistent with these guidelines.

Explanation of Tables

Laboratory hazard classification is based on three factors: (1) relative radiotoxicity of nuclides in use; (2) maximum amounts of activity stored or used in the area; and (3) type of use in terms of relative hazard of the handling procedures.

Table I	Commonly used radionuclides are classified as to their relative radiotoxicity in relation to internal dose. The hazard of a radioisotope depends on the effective half-life of the nuclide in the body or organ, the type and energy of the emitted radiation, the physical and chemical form of the material, and the organ of maximum concentration. The Radiation Safety Office has information for radionuclides not listed.
Table II	Provides limitations on activities in various types of laboratories. These may be adjusted by approval from the Radiation Safety Committee.
Table III	Indicates the design equipment, facilities, and protective clothing specifications for each laboratory type. In designing new areas, the researcher should consult the Radiation Safety Officer to discuss requirements for a particular facility.

Table I

Radionuclides Classified According to Relative Toxicity

Excerpted from IAEA Safety Standard, Safety Series No.1, "Safe Handling of Radionuclides, 1973 Edition"

Group I Very High Toxicity		Group I High Toxicity		Group I Moderate Toxicity		Group I Low Toxicity	
Pb-210	Po-210	Na-22	Cl-36	Be-7	Au-198	H-3	Os-191m
Ra-226	Ra-228	Co-56	Co-60	Sc-48	C-14	Co-58m	Th-232
Th-227		Zr-95	I-125	Zn-65	V-48	Ge-71	O-15
Pu-231		Sb-125	Ir-192	Sr-91	Zn-69m	Rb-87	Kr-85
U-233		I-131		Ru-103	Y-90	Nb-97	Tc-99m
Pu-238		Ce-144		Te-125m	P-32	Rh-103m	
Am-243		Hf-181		La-140	S-35	Xe-131m	
Cm-244		Bi-207		Gd-153	Cr-51	Cs-125	
Cf-249		Ac-228		W-187	Na-24		

Table II

Limitations on Activities in Various Types of Working Place or Laboratory [See Note]

Radiotoxicity of Radionuclides	Minimum Quantity µCi	Type of Working Place or Laboratory Required		
		Type C	Type B	Type A
Very High	0.1 (3.7 kBq)	< 10 µCi (< 370 kBq)	10 µCi (370 kBq)	10 µCi or more (> 370 kBq)
High	1 (37 kBq)	< 100 µCi (< 3.7 MBq)	10 µCi (3.7 MBq)	100 µCi or more (> 3.7 MBq)
Moderate	10 (370 kBq)	< 10 mCi (< 37 MBq)	1 mCi – 1 Ci (37 MBq – 37 GBq)	1 Ci or more (> 37 GBq)
Low	100 (3.7 MBq)	< 10 mCi (< 370 MBq)	10 mCi – 10 Ci (370 MBq – 370 GBq)	10 Ci or more (> 370 GBq)

NOTE: Laboratory types correspond to the laboratory classification criteria of IAEA Safety Standard, Safety Series No. 1. Type C is a good quality chemical laboratory. Type B is a specially designed radioisotope laboratory. Type A is a specially designed laboratory for handling large activities of highly radioactive materials. In the case of a conventional modern chemical laboratory with adequate ventilation and non-porous work surfaces, it may be possible to increase the upper limits of activity for Type C laboratories towards the limits for Type B for toxicity groups 3 and 4.

Table III

Design, Equipment, and Clothing Guidelines

For Radionuclide Laboratories

	Type C Laboratory	Type B Laboratory	Type A Laboratory
Required Equipment and Facilities	No special facilities or equipment	Fume hoods and/or glove boxes, decontamination supplies, Dosimetry, appropriate survey meter (e.g., GM or NaI)	Fume hoods and/or glove boxes, Access to decontamination facilities, Dosimetry, appropriate survey meter, air monitor (if appropriate)
Required Protective Clothing	Lab coat, light gloves recommended	Lab coat, gloves	Lab coat, double gloves recommended
Floors	Smooth, nonabsorbent	Smooth, nonporous, or easily removable protective over layer	Smooth, nonporous or easily removable protective over layer
Walls	Painted, smooth	Smooth, nonporous, strippable if possible	Smooth, nonporous, strippable if possible
Work Surface	Smooth, sealed coating; Cover with absorbent paper	Smooth, nonabsorbent; Removable covering (absorbent paper)	Smooth, nonabsorbent; Removable covering (absorbent paper)
Ventilation	Any	Work area under net negative pressure; Filter considered.	Consider charcoal and/or HEPA filters in exhaust, Work area under net negative pressure
Hood	Any ducting. Flow Rate: 100 linear feet per minute [1]	"Radiochemical hood" ducted from hood to roof. Filter considered. Flow Rate: 100+ linear feet per minute [1]	"Radiochemical hood" ducted from hood to roof; Filter considered. Flow Rate: 100+ linear feet per minute [1]
Other	Portable, localized shielding as needed	Consider: Build in shields, special handling	Consider: Build in shields, special handling

[1] Face velocity of hood of 100 lfpm taken from SEFA 1-2010, “Recommended Practices for Laboratory Fume Hoods”.

GLOSSARY

ABSORBED DOSE - The amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material. Measured in Rad or Gray.

ABSORPTION - The phenomenon by which radiation imparts some or all of its energy to any material through which it passes.

ACTIVITY - The rate of disintegration (transformation) or decay of radioactive material per unit time. The units of activity (also known as radioactivity) are the curie (Ci) and the becquerel (Bq)

AGREEMENT STATE - A State that has signed an agreement with the NRC authorizing the State to regulate certain uses of radioactive materials within the State (many states, including Nebraska, are Agreement States).

ALARA - ALARA is an acronym for "as low as (is) reasonably achievable," which means making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical, consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations.

ALPHA PARTICLE - A strongly ionizing particle emitted from the nucleus during radioactive decay having a mass and charge equal in magnitude to a helium nucleus, consisting of 2 protons and 2 neutrons with a double positive charge.

ALPHA RAY - A stream of fast-moving helium nuclei (alpha particles), a strongly ionizing and weakly penetrating radiation.

ANNIHILATION (Electron) - An interaction between a positive and negative electron (i.e., positron and negatron); their energy, including rest energy, being converted into electromagnetic radiation (annihilation radiation).

ANNUAL LIMIT OF INTAKE (ALI) - The derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion a year. ALI is the smaller value of intake of a given radionuclide in a year by the "reference man" that would result in a committed effective dose

equivalent (CEDE) of 5 rems (0.05 sievert) or a committed dose equivalent (CDE) of 50 rems (0.5 sievert) to any individual organ or tissue..

ATOM - The smallest particle of an element that cannot be divided or broken up by chemical means. It consists of a central core (or nucleus), containing protons and neutrons, with electrons revolving in orbits in the region surrounding the nucleus.

ATOMIC NUMBER (Z) - The number of positively charged protons in the nucleus of an atom.

AUTORADIOGRAPHY - Record of radiation from radioactive material in an object, made by placing the object in close proximity to a photographic emulsion.

BACKGROUND RADIATION - The natural radiation that is always present in the environment. It includes cosmic radiation which comes from the sun and stars, terrestrial radiation which comes from the Earth, and internal radiation which exists in all living things. The typical average individual exposure in the United States from natural background sources is about 300 millirems per year.

BECQUEREL (Bq) - A unit of activity equal to one disintegration per second (dps). One (1) Bq represents a rate of radioactive decay equal to 1 dps and 37 billion (3.7 E10) Bq equals 1 curie (Ci).

BETA PARTICLE - A charged particle that is emitted from the nucleus of a radioactive element during radioactive decay (or disintegration) of an unstable atom. A negatively charged beta particle is identical to an electron, while a positively charged beta particle is called a positron. Large amounts of beta radiation may cause skin burns, and beta emitters are harmful if they enter the body. Beta particles may be stopped by thin sheets of metal or plastic.

BETA RAY - A stream of high speed electrons or positrons of nuclear origin more penetrating but less ionizing than alpha rays.

BIOLOGICAL HALFLIFE - The time required for a biological system, such as that of a human, to eliminate, by natural processes, half of the amount of a substance (such as a radioactive material) that has entered it.

BREMSSTRAHLUNG - Electromagnetic (x-ray) radiation associated with the deceleration of charged particles passing through matter. Usually associated with energetic beta emitters (e.g., Phosphorus-32) and material with a high atomic number (e.g., lead).

BYPRODUCT MATERIAL - As defined by NRC regulations includes any radioactive material (except enriched uranium or plutonium) produced by a nuclear reactor. Additionally, it is any material that has been made radioactive through the use of a particle accelerator (e.g., cyclotron).

CALIBRATION - Determination of variation from standard, or accuracy, of a measuring instrument to ascertain necessary correction factors.

CARRIER FREE - An adjective applied to one or more radionuclides of an element in minute quantity, essentially undiluted with a stable isotope carrier.

COMMITTED DOSE EQUIVALENT (CDE) - (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 (CEDE) - (H_E,50) Is 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 these organs or tissues.

CONTAMINATION, RADIOACTIVE - Deposition of radioactive material in any place where it is not desired, and particularly in any place where the presence may be harmful. The harm may be vitiating the validity of an experiment or a procedure, or is actually being a source of excessive exposure to personnel.

COUNT (Radiation Measurements) - The external indication of a device designed to enumerate ionizing events. It may refer to a single detected event (counts) or to the total registered in a given period of time (e.g., counts per minute, cpm). The term is often erroneously used to designate a disintegration, ionizing event, or voltage pulse.

CPM – Acronym for Counts per Minute , the number of total ionizing events registered by a device in a given period of time. To convert cpm into dpm (amount of radioactivity), it must be divided by the efficiency of the device for the type of radiation being measured.

CRITICAL ORGAN - That organ or tissue, the irradiation of which will result in the greatest hazard to the health of the individual or his descendants.

CURIE (Ci) - The quantity of any radioactive material in which the number of disintegrations is 3.7 E10 disintegrations per second (dps) which is equal to 3.7 E10 becequerel (Bq).

Millicurie (mCi):	One-thousandth of a curie (3.7 E7 dps)
Microcurie (µCi):	One-millionth of a curie (3.7 E4 dps) equal to 2.22 E6 dpm
Nanocurie (nCi):	One-trillionith of a curie (3.7 E1 dps) equal to 2.22 E3 dpm

DAUGHTER PRODUCTS - Isotopes that are formed by the radioactive decay of some other isotope. In the case of radium-226, for example, there are 10 successive daughter products, ending in the stable isotope lead-206.

DECAY, RADIOACTIVE - The spontaneous transformation of one radioisotope into one or more different isotopes (known as "decay products" or "daughter products"), accompanied by a decrease in radioactivity (compared to the parent material). This transformation takes place over a defined period of time (known as a "half-life"), as a result of electron capture; fission; or the emission of alpha particles, beta particles, or photons (gamma radiation or x-rays) from the nucleus of an unstable atom. Each isotope in the sequence (known as a "decay chain") decays to the next until it forms a stable, less energetic end product. In addition, radioactive decay may refer to gamma-ray and conversion electron emission, which only reduces the excitation energy of the nucleus.

DECAYS PER MINUTE (DPM) – A unit of measurement of radioactivity. There are 2.22 E+6 dpm in 1 microcurie (µCi).

DECAYS PER SECOND (DPS) – A unit of measurement of radioactivity, equivalent to the Becquerel (Bq). There are 3.7 E+10 dps in 1 Curie, 60 dps in 1 dpm.

DECLARED PREGNANT WOMAN (DPW) - Means a woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception.

DEEP DOSE EQUIVALENT (DDE) - (H_d) - Which applies to external whole-body exposure, is the dose equivalent at a tissue depth of 1 cm (1000 mg/cm^2).

DERIVED AIR CONCENTRATIONS (DAC) - Means the concentration of a given radionuclide in air which, if breathed by the reference man for a working year of 2,000 hours under conditions of light work (inhalation rate 1.2 m^3/hr), results in an intake of one ALI.

DOSE - A general term, which may be used to refer to the amount of energy absorbed by an object or person per unit mass. Known as the "absorbed dose," this reflects the amount of energy that ionizing radiation sources deposit in materials through which they pass, and is measured in units of radiation-

absorbed dose (rad). The related international system unit is the gray (Gy), where 1 Gy is equivalent to 100 rad.

DOSE, ABSORBED - The amount of energy absorbed by an object or person per unit mass. Known as the "absorbed dose," this reflects the amount of energy that ionizing radiation sources deposit in materials through which they pass, and is measured in units of radiation-absorbed dose (rad). The related international system unit is the gray (Gy), where 1 Gy is equivalent to 100 rad.

DOSE EQUIVALENT - A quantity used in radiation protection expressing all radiation on a common scale for calculating the effective absorbed dose. The unit of dose equivalent is the rem or Sievert (100 rem = 1 Sievert), which is numerically equal to the absorbed dose (rad or Gray) multiplied by certain modifying factors such as the quality factor to quantify the biological effect of the type of radiation imparted.

DOSIMETER - A small portable instrument (such as a radiation badge or pocket dosimeter) used to measure and record the total accumulated personal dose of ionizing radiation.

dpm, dps – Acronyms for Decays per Minute (dpm) and Decays per Second (dps), both units of radioactivity.

EFFECTIVE DOSE EQUIVALENT (EDE) - (H_E) The sum of the products of the dose equivalent to the organ or tissue (H_T) and the weighting factors (w_T) applicable to each of the body organs or tissues that are irradiated ($H_E = \Sigma w_T H_T$).

EFFECTIVE HALFLIFE - The time required for the activity of a particular radioisotope deposited in a living organism, such as a human or an animal, to be reduced by 50 percent as a result of the combined action of radioactive decay and biological elimination.

EFFICIENCY (Counters) - A measure of the probability that a count will be recorded when radiation is incident on a detector. For radiation counters (which commonly record/display results in counts per minute or cpm), dividing the cpm by the counter efficiency will give the dpm (activity) of the material.

ELECTRON - An elementary particle with a negative charge and a mass 1/1837 that of a proton. Electrons surround the positively charged nucleus of an atom, and determine its chemical properties.

ELECTRON CAPTURE - A mode of radioactive decay involving the capture of an orbital electron by its nucleus. Capture from the particular electron shell is designated as "K-electron capture," "L-electron capture," etc. This mode occurs in radionuclides that are "proton-rich".

ELECTRON VOLT - A unit of energy equivalent to the amount of energy gained by an electron in passing through a potential difference of 1 volt, abbreviated eV. Larger multiple units of the electron volt frequently used are: keV for thousand or kiloelectron volts, and MeV for million electron volts.

EXPOSURE - 1) A measure of the ionization produced in air by x or gamma radiation. It is the sum of the electrical charges on all ions of one sign produced in air when all electrons liberated by photons in volume element of air are completely stopped in air, divided by the mass of air in the volume element. The special unit of exposure is the roentgen; 2) Exposure is also defined as the absorption of ionizing radiation or ingestion of a radioisotope.

EXTREMITY - Means hand, elbow, and arm below the elbow, foot, knee, or leg below the knee.

FILM BADGE - A packet of photographic film used for the approximate measurement of radiation exposure for personnel monitoring purposes. The badge may contain two or more films of differing sensitivity, and it may contain filters which shield parts of the film from certain types of radiation.

FILTER (Radiology), PRIMARY - A sheet of material, usually metal, placed in a beam of radiation to remove, as far as possible, the less penetrating components of the beam.

GAMMA RAY - High-energy, short-wavelength, electromagnetic radiation emitted from the nucleus of an atom. Gamma radiation frequently accompanies emissions of alpha particles and beta particles, and always accompanies fission. Gamma rays are similar to x-rays, but are very penetrating and are best stopped or shielded by dense materials, such as lead or depleted uranium.

GEIGER-MUELLER (G-M) COUNTER - A radiation detection and measuring instrument. It consists of a gas-filled tube containing electrodes, between which there is an electrical voltage, but no current, flowing. When ionizing radiation passes through the tube, a short, intense pulse of current passes from the negative electrode to the positive electrode and is measured or counted. The number of pulses per second measures the intensity of the radiation field. It was named for Hans Geiger and W. Mueller, who invented it in the 1920s. It is sometimes called simply a Geiger counter or a G-M counter and is the most commonly used portable radiation instrument.

GRAY (Gy) - The System International (SI) I unit of absorbed dose. One gray is equal to an absorbed dose of 1 Joule/kilogram (100 rads).

HALF-LIFE, BIOLOGICAL - The time required for a biological system, such as that of a human, to eliminate, by natural processes, half of the amount of a substance (such as a radioactive material) that

has entered it. This time is approximately the same for both stable and radionuclides of a particular element.

HALF-LIFE, EFFECTIVE - The time required for the activity of a particular radioisotope deposited in a living organism, such as a human or an animal, to be reduced by 50 percent as a result of the combined action of radioactive decay and biological elimination. It is calculated by dividing the product of the biological and radioactive half-lives by the sum of the biological and radioactive half-lives.

HALF-LIFE, RADIOACTIVE - The time required for a radioactive substance to lose 50 percent of its activity by decay. Each radionuclide has a unique half-life.

HALF VALUE LAYER (Half thickness) - The thickness of any specified material necessary to reduce the intensity of an x-ray or gamma ray beam to one half its original value.

HEALTH PHYSICS - The science concerned with recognizing and evaluating the effects of ionizing radiation on the health and safety of people and the environment, monitoring radiation exposure, and controlling the associated health risks and environmental hazards to permit the safe use of technologies that produce ionizing radiation.

HIGH RADIATION AREA - Means an area accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.1 rem (1 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

HOT - A colloquial term meaning highly radioactive.

INVERSE SQUARE LAW - The intensity of radiation at any distance from a point source varies inversely as the square of that distance. For example: If you double the distance from a radioactive source, the dose rate will drop by 1/4.

IN VITRO - From the Latin for "in glass," isolated from the living organism and artificially maintained, as in a test tube.

IN VIVO - From the Latin for "in one that is living," occurring within the living

ION - Atomic particle, atom, or chemical radical bearing an electrical charge, either negative or positive.

IONIZATION - The process by which a neutral atom or molecule acquires either a positive or a negative charge.

IONIZATION CHAMBER - An instrument designed to measure the quantity of ionizing radiation in terms of the charge of electricity associated with ions produced within a defined volume.

IONIZATION, SPECIFIC - The number of ion pairs per unit length of path of ionizing radiation in a medium (e.g., per centimeter of air or per micron of tissue).

IONIZING RADIATION - Any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, in its passage through matter.

ISOTOPES - Nuclides having the same number of protons in their nuclei, and hence having the same atomic number, but differing in the number of neutrons, and therefore in the mass number. Almost identical chemical properties exist between isotopes of a particular element.

LABELED COMPOUND - A compound consisting, in part, of labeled molecules, by observations of radioactivity or isotopic composition this compound or its fragments may be followed through physical, chemical or biological processes.

LENS DOSE EQUIVALENT (LDE) - The external exposure dose equivalent to the lens of the eye at a tissue depth of 0.3 centimeters (300 mg/cm^2).

LICENSED MATERIAL - Source material, byproduct material, or special nuclear material that is received, possessed, used, transferred, or disposed of under a general license or specific license issued by the NRC or Agreement States.

LICENSEE - A company, organization, institution, or other entity to which the NRC or an Agreement State has granted a general license or specific license to construct or operate a nuclear facility, or to receive, possess, use, transfer, or dispose of source material, byproduct material, or special nuclear material.

LIQUID SCINTILLATION COUNTER (LSC) – This piece of laboratory equipment is used to primarily quantify the activity in a sample that emits beta or alpha radiation. Samples are dissolved in a "cocktail" consisting of a solvent containing a small amount of other additives known as fluors (i.e., scintillators). 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 a liquid scintillation counter. The counter has two photomultiplier tubes connected in a coincidence circuit which measures the light and quantifies the amount and energy of the beta particles emitted.

LUXEL RADIATION BADGES - An optically stimulated luminescence (OSL) dosimeter that measures radiation exposures from x-ray, gamma and beta radiation through a thin layer of aluminum oxide.

MASS NUMBER - The number of nucleons (neutrons and protons) in the nucleus of an atom. Also known as the atomic weight.

MICRO (μ) - A prefix that divides a basic unit by 1,000,000.

MILLI (m) - A prefix that divides a basic unit by 1000.

MONITORING, RADIOLOGICAL - Periodic or continuous determination of the amount of ionizing radiation or radioactive contamination present in an occupied region as a safety measure for purposes of health protection.

> Area Monitoring: Routine monitoring of the level of radiation or of radioactive contamination of any particular area, building, room or equipment.
>
> Personnel Monitoring: Monitoring any part of an individual, his breath, excretions, or any part of his clothing (See Radiological Survey).

NEUTRON - Elementary particle with a mass approximately the same as that of a hydrogen atom and electrically neutral. It has a half-life in minutes and decays in a free state into a proton and an electron.

NONSTOCHASTIC EFFECTS - Means health effects, the severity of which varies with dose and for which a threshold is believed to exist. Radiation-induced cataract formation is an example of a nonstochastic effect (also called a deterministic effect).

NUCLEAR REGULATORY COMMISSION (NRC) - The U.S. Nuclear Regulatory Commission (NRC) was created as an independent agency by Congress in 1974 to ensure the safe use of radioactive materials for beneficial civilian purposes while protecting people and the environment. The NRC regulates commercial nuclear power plants and other uses of nuclear materials, such as in nuclear medicine, through licensing, inspection and enforcement of its requirements.

NUCLEUS - The small, central, positively charged region of an atom. The number of protons determines the total positive charge or atomic number. This number is the same for all the atomic nuclei of a given chemical element. The total number of neutrons and protons is called the mass number.

NUCLIDE - A species of atom characterized by its mass number, atomic number, and energy state of its nucleus, provided that the atom is capable of existing for a measurable time. A radionuclide is a nuclide that decays or disintegrates spontaneously, thereby emitting radiation.

OCCUPATIONAL DOSE - The total dose of ionizing radiation received by workers in the course of employment in such areas as fuel cycle facilities, industrial radiography, nuclear medicine, and nuclear power plants. These workers are exposed to varying amounts of radiation, depending on their jobs and the sources with which they work. Occupational dose does not include the dose received from natural background sources, doses received as a medical patient or participant in medical research programs, or "second-hand doses" received through exposure to individuals treated with radioactive materials.

OSL - Acronym for optically stimulated luminescence (OSL) dosimeter that measures radiation exposures from x-ray, gamma and beta radiation through a thin layer of aluminum oxide (see Luxel Radiation Badge).

PARENT - A radionuclide that upon radioactive decay or disintegration yields a specific nuclide (the daughter).

PERSONNEL MONITORING - The use of portable survey meters to determine the amount of radioactive contamination on individuals, or the use of dosimetry (e.g., dosimeters) to determine an individual's occupational radiation dose.

PHOTON - A quantum (or packet) of energy emitted in the form of electromagnetic radiation. Gamma rays and x-rays are examples of photons.

POSITRON - Particle equal in mass but opposite in charge to the electron. A positive electron.

PROTECTIVE BARRIERS - Barriers of radiation absorbing material, such as lead, concrete, plaster, and plastic, that is used to reduce radiation exposure.

Protective Barriers, Primary:	Barriers sufficient to attenuate the useful beam to the required degree.

Protective Barriers, Secondary: Barriers sufficient to attenuate stray or scattered radiation to the required degree.

PUBLIC DOSE - The dose received by a member of the public from exposure to radiation or to radioactive material released by a licensee, or to any other source of radiation under the control of a licensee. Public dose does not include occupational dose or doses received from background radiation, from any medical administration the individual has received, from exposure to individuals administered radioactive materials and released in accordance with patient release regulations, or from voluntary participation in medical research programs.

QUALITY FACTOR - The factor by which the absorbed dose (rad or gray) is to be multiplied to obtain a quantity that expresses, on a common scale for all ionizing radiation, the biological damage (rem or sievert) to an exposed individual. It is used because some types of radiation, such as alpha particles, are more biologically damaging internally than other types.

RAD - The special unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs/gram or 0.01 Joule/kilogram (100 rad = 1 Gray).

RADIATION - Alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions. Radiation, as used in regulations (i.e., 10 CFR Part 20), does not include non-ionizing electromagnetic radiation, such as radio or microwaves, 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 0.005 rem (0.05 mSv) in 1 hour at 30 centimeters.

RADIATION WARNING SYMBOL - An officially prescribed magenta or black trefoil on a yellow background, which must be displayed where certain quantities of radioactive materials are present or where certain doses of radiation could be received.

RADIOACTIVE CONTAMINATION - Undesirable radioactive material (with a potentially harmful effect) that is either airborne or deposited in (or on the surface of) structures, objects, soil, water, or living organisms (people, animals, or plants) in a concentration that may harm people, equipment, or the environment.

RADIOLOGICAL SURVEY - Evaluation of the radiation hazards incident to the production, use or existence of radioactive materials or other sources of radiation under a specific set of conditions. Such

evaluation customarily includes a physical survey of the disposition of materials and equipment, measurements or estimates of the levels of radiation that may be involved, and a sufficient knowledge of processes using or affecting these materials to predict hazards resulting from expected or possible changes in materials or equipment.

RADIONUCLIDE - A nuclide with an unstable ratio of neutrons to protons placing the nucleus in a state of stress. In an attempt to reorganize to a more stable state, it may undergo various types of rearrangement that involve the release of radiation.

RELATIVE BIOLOGICAL EFFECTIVENESS (RBE) - For a particular living organism or part of an organism, the ratio of the absorbed dose of a reference radiation that produces a specified biological effect to the absorbed dose of the radiation of interest that produces the same biological effect.

RESTRICTED AREA - Any area to which access is controlled for the protection of individuals from exposure to radiation and radioactive materials.

REM - The special unit of dose equivalent. The dose equivalent in rem or Sievert (SI) is numerically equal to the absorbed dose in rads or Gray multiplied by the quality factor, for the radiation type (e.g., alpha, beta, and gamma).

ROENTGEN (R) - A unit of exposure to ionizing radiation. It is the amount of gamma or x-rays required to produce ions resulting in a charge of 0.000258 coulombs/kilogram of air under standard conditions. Named after Wilhelm Roentgen, the German scientist who discovered x-rays in 1895.

SCINTILLATION COUNTER - A counter in which light flashes produced in a scintillator by ionizing radiation are converted into electrical pulses by a photomultiplier tube.

SHALLOW DOSE EQUIVALENT (SDE) - The external exposure of the skin or an extremity is taken as the dose equivalent at a tissue depth of 0.007 centimeters (7 mg/cm^2) averaged over an area of 1 square centimeter. Shallow Dose Equivalent, Whole Body (SDE-WB) means for purposes of external exposure, head, trunk (including male gonads), and arms above the elbow or legs above the knee. Shallow Dose Equivalent, Maximum Extremity (SDE-ME) means for purposes of external exposure, arms below the elbow or legs below the knee.

SHIELDING MATERIAL - Any material which is used to absorb radiation and thus effectively reduce the intensity of radiation, and in some cases eliminate it. Lead, concrete, aluminum, water, and plastic are examples of commonly used shielding material.

SIEVERT - The international system (SI) unit for dose equivalent equal to 1 Joule/kilogram. One (1) sievert = 100 rem. Named for physicist Rolf Sievert.

SMEAR (Smear or Swipe Test) - A procedure in which a swab, e.g., a circle of filter paper, is rubbed on a surface and its radioactivity measured to determine if the surface is contaminated with loose radioactive material.

SPECIFIC ACTIVITY - Total radioactivity of a given nuclide per gram of a compound, element or radioactive nuclide.

STOCHASTIC EFFECT - Means health effects that occur randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a linear function of dose without threshold. Genetic effects and cancer incidence are examples of stochastic effects from radiation.

SURVEY METER - Any portable radiation detection instrument especially adapted for inspecting an area or individual to establish the existence and amount of radioactive material present.

THERMOLUMINESCENT DOSIMETER (TLD) - A dosimeter made of certain crystalline material which is capable of both storing a fraction of absorbed ionizing radiation and releasing this energy in the form of visible photons when heated. The amount of light released can be used as a measure of radiation exposure to these crystals.

TOTAL EFFECTIVE DOSE EQUIVALENT (TEDE) - Means the sum of the Deep Dose Equivalent, H_d, (for external exposures) and the Committed Effective Dose Equivalent, $H_{E,}50$ (for internal exposures). The annual occupational TEDE limit is 5 rem (0.05 Sv).

TOTAL ORGAN DOSE EQUIVALENT (TODE) - Means the sum of the Deep Dose Equivalent (H_d) and the Committed Dose Equivalent ($H_{T,}50$) to any individual organ or tissue, other than the lens of the eye. The annual occupational TODE limit is 50 rem (0.5 Sv).

TRACER, ISOTOPIC - The isotope or non-natural mixture of isotopes of an element which may be incorporated into a sample to make possible observation of the course of that element, alone or in combination, through a chemical, biological, or physical process. The observations may be made by measurement of radioactivity or of isotopic abundance.

VERY HIGH RADIATION AREA - Means an area, accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads (5 grays) in 1 hour at a meter from a radiation source or from any surface that the radiation penetrates.

WEIGHTING FACTORS (W_T) - Multipliers of the dose equivalent to an organ or tissue used for radiation protection purposes to account for different sensitivities of different organs and tissues to the induction of stochastic effects of radiation.

WHOLE BODY EXPOSURE - Whole body exposure includes at least the external exposure, head, trunk, arms above the elbow, or legs above the knee. Where a radioisotope is uniformly distributed throughout the body tissues, rather than being concentrated in certain parts, the irradiation can be considered as whole-body exposure.

X-RAYS - Penetrating electromagnetic radiations having wave lengths shorter than those of visible light. They are usually produced by bombarding a metallic target with fast electrons in a high vacuum. In nuclear reactions it is customary to refer to photons originating in the nucleus as gamma rays, and those originating in the extranuclear part of the atom as x-rays. These rays are sometimes called roentgen rays after their discoverer, W.C. Roentgen

Section D-1

UNMC X-Ray Policy Overview

A. Introduction

There are various devices and equipment used at the University of Nebraska Medical Center (UNMC) that electronically generate x-rays for dental treatment of patients, or for research in the analysis and/or examination of materials and animals. All non-dental x-ray devices on campus used for the diagnostic or therapeutic treatment of human patients or clinical trial subjects fall under authority of The Nebraska Medical Center, which also has its own dental equipment.

B. Registration of X-Ray Devices

All x-ray generating devices must be registered with the State of Nebraska Department of Health & Human Services, X-Ray Registration Program. Registration requirements are provided in Title 180 Nebraska Administrative Code 2 (180 NAC 2). Currently, "Certification of Registration for Radiation Generating Equipment" registrations have been issued for x-ray devices used by UNMC at the following locations:

1. UNMC Omaha Campus Research
2. UNMC Adult Dentistry
3. Pediatric Dentistry (Children's Hospital in Omaha, Nebraska)
4. Munroe Meyer Institute (Aksarben Campus)
5. College of Dentistry (University of Nebraska Lincoln East Campus in Lincoln, Nebraska)

All x-ray units used in the Nebraska Medicine hospital are on the hospital's

own separate registration.

C. X-Ray Devices Used at UNMC

The following devices are currently used under the UNMC X-Ray registration:

1) Electron Microscopes (Section D-2)
2) X-Ray Diffraction Units (Section D-3)
3) Radiographic Cabinet X-rays (Section D-4)
4) X-Ray Tube Irradiators (Section D-5, Note that in registering these units, the State has categorized these irradiators as Radiographic Cabinet X-ray units)
5) Package X-ray System (Section D-6)
6) Fluoroscopic & CT Animal Research Units (Section D-7)
7) Bone Densitometers (Section D-8)
8) Dental Equipment (Section D-9)

D. Regulations/Requirements for X-Ray Devices

Various sections of Title 180 Nebraska Administrative Code (180 NAC) are applicable depending on the type of x-ray device. However, certain regulations, such as the dose limits given in 180 NAC 4 (e.g., dose limits to occupational workers and individuals of the general public) and 180 NAC 10 (Notices, Instructions and Reports to Workers: Inspections) are applicable to all uses of ionizing radiation on the UNMC campus. Radiation dose received from the operation and use of the x-ray devices on the UNMC registration adhere to the UNMC ALARA Policy, Section A-3. The specific requirements (e.g., training, dosimetry, interlock checks, surveys/audits, postings/labels) associated with each x-ray device is provided in the section for that device. Additional information pertaining to each x-ray unit is maintained by Radiation Safety and/or the principal owner of the unit.

E. UNMC Radiation Safety Organization/Responsibilities

The use of x-ray producing devices is under the responsibility of the UNMC

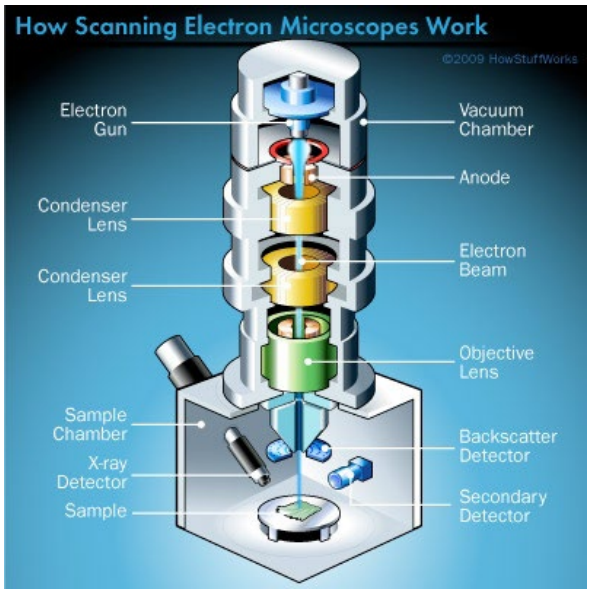
Radiation Safety Organization as described in Section A. As indicated in that section, the designations of Authorized User and Radiation Worker are used for individuals using radioactive material. Individuals operating x-ray producing devices are referred to as “x-ray users” or specifically for the device they are using (e.g., individuals authorized to operate the RS-2000 X-Ray Irradiators may be referred to as ““RS-2000 X-ray Irradiator Operators” or simply “X-ray Irradiator Operators”).

Section D-2

Electron Microscopes

A. Introduction

An electron microscope (EM) is a type of microscope that uses an electron beam to illuminate a specimen and produce a magnified image. X-rays are produced in the electron microscope whenever the primary electron beam or back scattered electrons strike metal parts with sufficient energy to excite continuous and/or characteristic X-radiation. In terms of X-ray hazards, two aspects are important: the composition of the parts which are struck and their efficiency as X-ray sources and the effectiveness/integrity of the shielding provided by the metal casing of the microscope around these. The degree of X-ray "leakage" also depends on the shielding provided by the metal casing. A poorly designed microscope may have weak points where X-rays can escape, for example, between the gasket sealed junction of two sections of the column.



The radiation safety concerns are related to the electrons that are backscattered from the sample, as well as X-rays produced in the process. However, EMs are typically extremely well shielded and do not produce exposure rates greater than background.

B. Regulations

In accordance with Title 180 Nebraska Administrative Code 2 (180 NAC 2), EMs are exempt from the registration and notification requirements of 180 NAC 2, provided the dose equivalent rate averaged over an area of 10 square centimeters does not exceed 0.5 mrem per hour.

C. Training

Individuals who wish to operate electron microscopes are not required to complete documented radiation safety training. It is recommended that all users receive hands-on instruction and training (e.g. working with experienced users, reading the manufacturer's operation manual) before independently using the equipment. This is the responsibility of the department possessing the EM.

D. Dosimetry

Because of the extremely low dose rates EM operators are not required to wear dosimetry and area monitors (badges) are not required.

E. Interlock Checks

No interlock checks required.

F. Surveys/Audits

Radiation emitted from electron microscopes shall not exceed a dose equivalent rate (averaged over 10 square centimeters) of 0.5 mrem (5 µSv)/hr at 5 cm from any accessible surface of the equipment. Radiation Safety will conduct a dose rate survey of an EM upon installation. Radiation Safety may decide to conduct a survey if an EM is relocated, after maintenance/repair, or modifications. At a minimum, EMs should be inventoried annually.

G. Postings/Labeling/Warning Devices

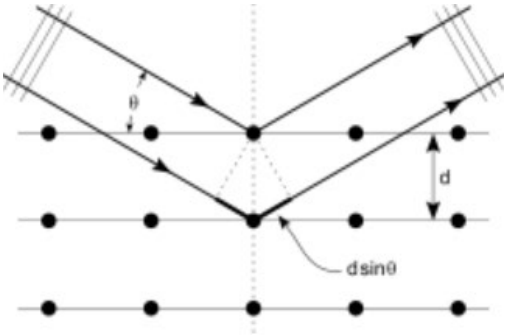
No area posting is required for electron microscopes. It is recommended that a label bearing the statement: “CAUTION: THIS EQUIPMENT PRODUCES RADIATION WHEN ENERGIZED - TO BE OPERATED BY QUALIFIED PERSONNEL ONLY", words having similar intent, should be posted on the electron microscope.

Section D-3

X-Ray Diffraction Units

A. Introduction

X-ray Diffraction (XRD) is used for identifying the atomic and molecular structure of a crystal, in which the crystalline atoms cause a beam of incident X-rays to diffract into many specific directions. The highly focused x-ray beam produced by diffraction units are very high in intensity but low in energy (5 – 30 keV). These low energy x-rays are highly absorbed in soft tissue, and severe burns can result from exposure of the hands, arms, skin or eyes to the direct or diffracted beams (most radiation injuries are to the hands).



There are two types of XRDs, open and closed beam. Open-beam means an XRD in which an individual could place some part of his/her body in the primary beam during normal operation, while in closed-beam this exposure situation should not occur (unless an interlock was not operating properly or intentionally defeated).

B. Regulations

Regulations for XRDs are provided in 180 NAC 8, “Radiation Safety Requirements for Non-Healing Arts Radiation Generating Devices”.

C. Training

No individual is allowed to operate XRDs unless the individual has received

four (4) hours of instruction in and demonstrated competence in the following:

1. Identification of radiation hazards associated with the use of the equipment;
2. Significance of the various radiation warning and safety devices and interlocks incorporated into the equipment, or the reasons they have not been installed on certain pieces of equipment and extra precautions required in those cases;
3. Appropriate operating procedures for the equipment;
4. Recognition of symptoms of an acute localized exposure;
5. Appropriate procedures for reporting an actual or suspected exposure;
6. Radiation protection appropriate for the hazards of the radiation generating device; and
7. Performing surveys where applicable.

Annual refresher training may be provided to operators of the XRD units at the discretion of Radiation Safety.

D. Dosimetry

Extremity (ring) badge must be used by open-beam XRD workers and by persons maintaining XRDs if the maintenance procedure requires the presence of a primary beam when a local component is disassembled or removed.

E. Interlock Checks

Tests of all safety devices, including but not limited to, interlocks, shutters, warning lights, and required emergency shut-off switches, must be conducted at intervals not to exceed 12 months or following any of the conditions listed in 180 NAC 8-006 (e.g., following maintenance).

If any safety device fails during testing, the radiation generating device must be removed from service until the safety device failure is corrected or temporary administrative controls are established and approved in writing by the radiation safety officer.

F. Surveys/Audits

Requirements for surveys are provided in 180 NAC 8-004.02. An initial and annual audit is performed at a minimum. The “Analytical X-Ray Radiation Audit/Survey” form is used by Radiation Safety to document these inspections. The form provides a checklist of requirements indicated in 180 NAC 8.

G. Postings/Labeling/Warning Devices

Each area or room containing an XRD must be posted with a sign bearing the radiation symbol and the words “Caution X-Ray Equipment” or words having similar intent. Labeling requirements are provided in 180 NAC 8. In addition, open-beam configuration XRDs must be provided with warning devices indicated in 180 NAC 8. Warning light requirements are provided in 180 NAC 8.

Section D-4

Radiographic Cabinet X-Ray Units

A. Introduction

Cabinet radiography is industrial radiography using radiation machines not subject to Food and Drug Administration (FDA) performance standards for cabinet x-ray systems, in an enclosed, interlocked cabinet in which the portion of a material being irradiated is contained (i.e., closed beam), and where:

1) The radiation machine will not operate unless all openings are closed with interlocks activated;
2) The cabinet is shielded so that every location on the exterior meets the conditions for an unrestricted area as defined in 180 NAC 4 of these regulations; and
3) The cabinet is constructed or arranged to exclude the entrance of any part of the body of an individual during irradiation.

B. Regulations

Regulations for cabinet x-ray systems are provided in 180 NAC 8, “Radiation Safety Requirements for Non-Healing Arts Radiation Generating Devices”.

C. Training

Individuals must receive training in the operation of the unit and is the responsibility of the researcher who possesses the device. Training may be documented by a memo, email, or log-sheet.

D. Dosimetry

No dosimetry is required for the operation of these units.

E. Interlock Checks

Tests of all safety devices, including but not limited to, interlocks, shutters, warning lights, and required emergency shut-off switches, must be conducted at intervals not to exceed 12 months or following any of the conditions listed in 180 NAC 8-006.

If any safety device fails during testing, the radiation generating device must be removed from service until the safety device failure is corrected or temporary administrative controls are established and approved in writing by the radiation safety officer.

F. Surveys/Audits

Surveys must be performed every 12 months and after any of the conditions in listed in 180 NAC 8-004. The radiation emission for all closed beam radiation generating devices must not exceed a dose rate of 0.005 milliSievert (0.5 millirem) in one hour at five centimeters outside any accessible surface. This survey will also serve to demonstrate compliance with the dose limits in 180 NAC 4.

G. Postings/Labeling

Each area or room containing radiation generating devices must be clearly posted with a sign or signs bearing the radiation symbol and the words "CAUTION X-RAY EQUIPMENT", or words having a similar intent.

All radiation generating devices must be labeled with a readily visible sign or

signs bearing the radiation symbol and the words: "CAUTION RADIATION - THIS EQUIPMENT PRODUCES RADIATION WHEN ENERGIZED", or words having a similar intent, near any switch that energizes an x-ray tube.

Section D-5

X-Ray Tube Irradiators

A. Introduction

These units use an x-ray tube to expose products to x-ray radiation. X-ray irradiators at UNMC are used in research to irradiate cells and small animals. The process does not leave radioactive residue or cause the treated products to become radioactive. Although high doses and dose rates are generated, the units are shielded such that dose rates external to the unit are minimal.

B. Regulations

Regulations for x-ray irradiators are provided in 180 NAC 8, “Radiation Safety Requirements for Non-Healing Arts Radiation Generating Devices”.

C. Training

For the X-ray tube irradiators UNMC requires individuals to complete the following training:

1) Online training pertaining to the operation and radiation safety aspects for the irradiator (contact Radiation Safety), and;
2) Meeting with Radiation Safety to conduct firsthand training operating the irradiator (for irradiation of animals, a representative from Comparative Medicine will be present to cover procedures in the Animal Facility).

D. Dosimetry

No dosimetry is required for the operation of these units.

E. Interlock Checks

Tests of all safety devices, including but not limited to, interlocks, shutters, warning lights, and required emergency shut-off switches, must be conducted at intervals not to exceed 12 months or following any of the conditions listed in 180 NAC 8-006.

If any safety device fails during testing, the radiation generating device must be removed from service until the safety device failure is corrected or temporary administrative controls are established and approved in writing by the radiation safety officer.

F. Surveys/Audits

Surveys must be performed every 12 months and after any of the conditions in listed in 180 NAC 8-004. The radiation emission for all closed beam radiation generating devices must not exceed a dose rate of 0.005 milliSievert (0.5 millirem) in one hour at five centimeters outside any accessible surface. This survey will also serve to demonstrate compliance with the dose limits in 180 NAC 4.

G. Postings/Labeling

Each area or room containing radiation generating devices must be clearly posted with a sign or signs bearing the radiation symbol and the words "CAUTION X-RAY EQUIPMENT", or words having a similar intent.

All radiation generating devices must be labeled with a readily visible sign or signs bearing the radiation symbol and the words: "CAUTION RADIATION - THIS EQUIPMENT PRODUCES RADIATION WHEN ENERGIZED", or words having a similar intent, near any switch that energizes an x-ray tube.

Section D-6

Package X-Ray Inspection Units

A. Introduction

Package x-ray systems (also referred to as "security screening units") are non-human use x-ray system with accessible openings designed for the detection of weapons or bombs, or contraband concealed in baggage, mail, packages, or other commodities or structures. The package to be examined is placed on a conveyor belt and an x-ray image of the contents is displayed on a monitor.

B. Regulations

Regulations for security screening units are provided in 180 NAC 8, "Radiation Safety Requirements for Non-Healing Arts Radiation Generating Devices".

C. Training

Individuals must receive initial training in the operation of the unit. Training may be documented by a memo, email, or log-sheet.

D. Dosimetry

No dosimetry is required for the operation of these units.

E. Interlock Checks

Because of the operation of the unit (conveyor system) there is no interlock check.

F. Surveys/Audits

Tests of all safety devices, including but not limited to, interlocks, shutters, warning lights, and required emergency shut-off switches, must be conducted at intervals not to exceed 12 months or following any of the conditions listed in 180 NAC 8-006.

If any safety device fails during testing, the radiation generating device must be removed from service until the safety device failure is corrected or temporary administrative controls are established and approved in writing by the radiation safety officer.

G. Postings/Labeling

Each area or room containing radiation generating devices must be clearly posted with a sign or signs bearing the radiation symbol and the words "CAUTION X-RAY EQUIPMENT", or words having a similar intent.

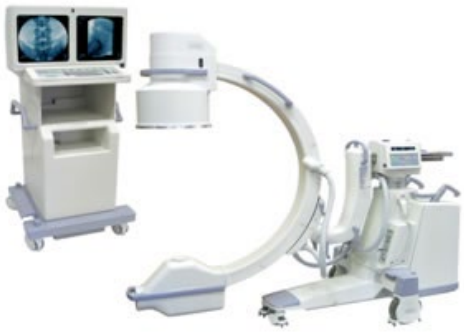
The label, "CAUTION RADIATION - THIS EQUIPMENT PRODUCES RADIATION WHEN ENERGIZED", or words having a similar intent, is required near any switch that energizes an x-ray tube.

At all object entries, the following must be posted at or near each opening: “CAUTION – X-RAY HAZARD: DO NOT INSERT ANY PART OF THE BODY WHEN SYSTEM IS ENERGIZED,” or words having similar intent.

Section D-7

Fluoroscopic, CT Animal Research Units

A. Introduction



Fluoroscopic and CT x-ray units can be used to perform research on animals. For larger animals (e.g., pigs, dogs, monkeys), the units may be the same type used in a hospital for human patients. For smaller animals (e.g., mice) the units may be designed specifically for animal research.

B. Regulations

The State of Nebraska regulations do not address the use of x-rays in animal research. The State of Nebraska Office of Radiological Health has concluded that the following provisions of 180 NAC 1, 2, 4, 10, 17, and 18 are applicable to x-ray use in animal research:

1. Registration of X-ray Producing Equipment (180 NAC 2): The units must be registered.
2. Occupational Dose Limits (180 NAC 4): The occupational radiation dose limits for individuals apply to individuals working with these units.
3. Radiation Dose Limits for Individual Members of the Public (180 NAC 4): The radiation exposure to members of the general public cannot exceed 100 mrem annually.
4. Surveys and Monitoring (180 NAC 4): Individuals likely to receive in excess of 10% of the occupational dose limits must be monitored for radiation dose.

5. Precautionary Procedures, Records and Reports (180 NAC 4): Must comply with record and reporting requirements (e.g., report of overexposure, notifications and reports to individuals).
6. Notices, Instructions and Reports to Workers (180 NAC 10): Workers likely to exceed 100 mrem annually must receive annual radiation safety training.

C. Training

Although not a regulatory requirement, it is recommended individuals be trained in the operation of the unit by an experienced user. For persons operating fluoroscopic equipment of the same type used on human subjects, it is recommended that these individuals complete the initial fluoroscopy radiation safety training required for physicians at Nebraska Medicine who administer fluoroscopic x-rays to human patients/subjects.

D. Dosimetry/Personnel Protection

Dosimetry and personnel protection (e.g., lead apron) requirements for each unit is determined by Radiation Safety. Individuals suites where fluoroscopic x-rays are administered with C-arms must be protected from direct scatter radiation by protective aprons or whole body protective barriers of not less than 0.25 mm lead equivalent. Individuals administering fluoroscopic x-rays are to wear a whole body radiation badge. The badge is to be worn outside the lead apron in the region of the collar.

Area radiation badges may be used to demonstrate compliance with public dose limits in 180 NAC 4.

E. Interlock Checks

No interlock check is performed on this unit.

F. Surveys/Audits

Survey/audit requirements for each unit are determined by Radiation Safety.

G. Postings/Labeling

The control panel containing the main power switch must bear the warning statement “WARNING: This x-ray unit may be dangerous to patient and operator unless safe exposure factors and operating instructions are observed.”

Doors that are an integral part of room shielding must be closed during x-ray procedures and must be posted “Close door during x-ray procedures.”

Section D-8

Bone Densitometer

A. Introduction

The "gold standard" of bone density measurement is Dual Energy X-ray Absorptiometry (DEXA) in which the absorption of X-rays is quantified at two key X-ray energies. This method is used to calculate absolute bone density in humans, mice and other laboratory animals. The clinical use of DEXA in human patients falls under Nebraska Medicine. UNMC has a DEXA unit which is used for human subjects under research protocols that have been approved by the Institutional Review Board (IRB).

B. Regulations

The applicable regulations depend on if the unit is intended for laboratory animals or human subjects.

Small Animal Use

Although not defined as cabinet x-ray systems, because the use of bone densitometry used for small animals meets the definition of cabinet x-rays (examination of structure of materials by non-destructive methods using ionizing radiation conducted in an enclosure or cabinet so shielded that none of the radiation dose limits are exceeded), the regulations for cabinet radiographic x-ray systems (180 NAC 8) are used. In accordance with 180 NAC 8 the use of x-rays from these devices are exempted from the requirements except for the following:

1. The radiation emisssion for all closed beam radiation generating devices must not exceed a dose rate of 0.5 mrem/hr at 5 cm outside any

accessible surface (UNMC will perform this survey annually).

2. Annually demonstrate compliance with all the dose limits for members of the general public (180 NAC 4). This is accomplished by performing the annual radiation survey.

Human Subjects Use

The use of DEXA unit for human subjects falls under 180 NAC 6. DEXA units are exempted from the equipment performance testing and room shielding plan requirements. The use of this equipment on human subjects must be by or under the supervision of one licensed to practice the healing arts in Nebraska.

C. Training

1. Non-Human Use: No individual may operate the unit until they have received a copy of, and instruction in, the operating procedures (need to maintain training records). Individuals must receive initial training in the operation of the unit. Training may be documented by a memo, email, or log-sheet.
2. Human Use: To operate a DEXA unit on human patients/subjects, the operator must either be a licensed (e.g., ARRT) radiology technologist or an individual who has passed the ARRT in Bone Densitometry.

D. Dosimetry/Personnel Protection

No dosimetry is required for the operation of these units. An area radiation monitoring badge may be placed in the vicinity of each unit to demonstrate compliance with the regulatory dose limits to members of the general public (180 NAC 4) if deemed appropriate.

E. Interlock Checks

Tests of all safety devices on the animal bone densitometry unit, include but

are not limited to, interlocks, shutters, warning lights, and required emergency shut-off switches. These tests must not exceed 12 months.

If any safety device fails during testing, the radiation generating device must be removed from service until the safety device failure is corrected or temporary administrative controls are established and approved in writing by the radiation safety officer

F. Surveys/Audits

If an area radiation badge is not used, an instrument radiation survey must be performed at least annually to demonstrate compliance with all the dose limits for members of the general public (180 NAC 4-003).

G. Postings/Labeling

Each area or room containing radiation generating devices must be clearly posted with a sign or signs bearing the radiation symbol and the words "CAUTION X-RAY EQUIPMENT", or words having a similar intent.

All radiation generating devices must be labeled with a readily visible sign or signs bearing the radiation symbol and the words: "CAUTION RADIATION - THIS EQUIPMENT PRODUCES RADIATION WHEN ENERGIZED", or words having a similar intent, near any switch that energizes an x-ray tube.

Section D-9

Dental Equipment

A. Introduction

Dental x-ray units are used on human patients at both UNMC and Nebraska Medicine. For UNMC, there are separate registrations for each of the following locations of use :

- Adult Dentistry (Main Campus)
- College of Dentistry (UNL East Campus)
- UNMC Pediatric Dentistry (Children's Hospital)
- Munroe Meye Institute (Aksarben Village campus)

Each of these dental locations have their own radiation safety policies.

B. Regulations

Dental radiographic equipment regulations are in Title 180 NAC 6 (Diagnostic X-Rays in the Healing Arts).

C. Training

Only those persons authorized to operate radiographic equipment in the State of Nebraska are permitted to make exposures using the device. This includes licensed dentists and dental assistants and hygienists who meet the radiography requirements in the State of Nebraska.

For the NOMAD handheld dental x-ray unit, each individual operating the device must complete the manufacturer's training course and the UNMC Nomad Radiation Safety module. Students in the College of Dentistry may use the NOMAD under the supervision of an individual authorized to use the system.

D. Dosimetry/Personnel/Patient Protection

Individual monitoring is not required for personnel operating only dental radiation generating equipment for dental diagnostic purposes. However, radiation badging is available upon request.

Lead aprons and thyroid shields are not required for staff performing diagnostic dental procedures.

In accordance with the American Dental Association, thyroid shielding for patients during diagnostic intraoral, panoramic, cephalometric, and CBCT imaging should NOT be used in routine practice. Additionally, the use of a lead vest/apron is not necessary for dental procedures regardless of pregnancy status or age. However, due to the sensitive nature of these situations, a lead vest may be used, so long as the vest lies fully in contact with the patient's body, does not bunch up, elevate, and enter the field of view while imaging.

E. Interlock Checks

No interlock check is performed on these units.

F. Surveys/Audits

Radiation Safety typically performs an audit at each dental facility annually. For most dental equipment, an equipment performance evaluation is required every five (5) years. The exception is Cone Beam CT (CBCT) is required every two (2) years.

G. Postings/Labeling

Dental equipment falling under 180 NAC 21 must have the warning statement,

legible and accessible to view, “WARNING: This x-ray unit may be dangerous to patient and operator unless safe exposure factors and operating instructions are observed” at the control panel containing the main power switch.

Doors that are an integral part of room shielding must be closed during x-ray procedures and must be posted “Close door during x-ray procedures”.