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Foreword

This *Radiation Safety Handbook* is the official training manual and policy and procedure guide for users of radioactive materials, radiation producing equipment, and sources of non-ionizing radiation at Northwestern University. This document has been reviewed by the University's Radiation Safety Committee and approved by the Vice President for Research. It is maintained by the Office of Research Safety (ORS).

Radioactive materials and sources of ionizing and non-ionizing radiation are essential elements of research and teaching at Northwestern. This handbook provides answers to fundamental questions about the nature of radiation, guidance on protecting against radiation's harmful effects, detailed University policies and procedures, and important regulatory information. Understanding the material in this handbook will help you evaluate the risks and benefits of working with these indispensable tools.

Your responsibilities as authorized investigators, supervisors, or radiation workers are described in the following pages; remember that using sources of ionizing radiation is a privilege, not a right, so review this document carefully. Responsibility for maintaining the University's radiation safety licenses and registrations, and coordinating the safety program, is assigned to ORS. If you have questions or comments about the information contained in this handbook please contact ORS at 3-8300 (Chicago) or 1-5581 (Evanston).

The Office of Research Safety is on-call for emergencies 24 hours a day, 7 days a week by calling University Police at 456 and asking them to page Research Safety.

1.0 Introduction

1.1 General Policy Statement

It is the policy of Northwestern University to permit the use of radioactive materials and sources of ionizing and non-ionizing radiation while providing for their safe use. The use of radiation sources is a privilege; in order to retain the privilege, all persons who use sources of radiation must follow University policies and procedures for their safe and legal use.

While program emphasis is on safety, please note use of the standard regulatory language "shall" and "should" throughout this document. "Shall" is used when adherence to the recommendations is necessary to meet accepted standards of protection or to comply with regulatory requirements or University policy. "Should" indicates recommendations that are to be applied, where possible, in the interest of minimizing radiation exposure or meeting radiation safety program objectives.

1.2 Access to Records and Program Documents

State regulations require that the University inform radiation workers where they may view important radiation safety program documents. Radiation workers may request a record of their exposure to radiation or radioactive material annually or upon termination of employment. Radiation workers may see the following documents in ORS, room B-106 Ward Building, Chicago campus:

- Regulations in Part 32 of the Illinois Administrative Code (32IAC), including Part 400 (Notices, Instructions and Reports to Workers; Inspections) and Part 340 (Standards for Protection Against Radiation).
- University licenses, registration certificates, conditions, and documents incorporated into the licenses by reference and amendment.
- Operating procedures applicable to activities under the licenses and registrations.
- Documents pertaining to license inspections.

1.3 ALARA Principle

Safe use of radioactive materials and sources of ionizing radiation means more than simple adherence to the regulations and recommendations of standards-setting agencies. Current regulations reflect the viewpoint that some degree of risk may be associated with any exposure to radiation. In keeping with this regulatory position, it is incumbent on all authorized investigators, registrants, and radiation workers to keep doses to personnel and releases to the environment A*s Low As is Reasonably Achievable*--ALARA.

The Illinois Administrative Code defines ALARA in 32IAC Part 340 as "making every reasonable effort to maintain exposures to radiation as far below the dose limits in 32IAC as is practical consistent with the purpose for which the licensed or registered activity is undertaken, taking into account the state of technology, the economics of improvements in relation to the state of technology, the economics of improvements in relation to benefits to the public health and safety and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed or registered sources of radiation in the public interest." Evaluate how the ALARA philosophy may be applied for each procedure in which you use a source of radiation.

2.0 Program Organization and Responsibilities

2.1 Administration

The vice president for research is responsible for overall administration of the radiation safety program and administers the program through the office of the associate vice president for research administration.

The associate vice president for research administration is the administration's representative on the Radiation Safety Committee.

The radiation safety officer (RSO) reports to the vice president for research through the associate vice president for research administration, and is responsible for the following:

- Managing the radiation safety program and ensuring compliance with license conditions, applicable governmental rules and regulations, and University policies and procedures. The RSO has the right to enter any University property at all reasonable times to determine whether there is compliance.
- Writing and maintaining the broad-scope license under which the University may possess and use radioactive material.
- Distributing and reviewing applications and issuing authorizations granted by the Radiation Safety Committee.

2.2 Radiation Safety Committee

The Radiation Safety Committee--required by license condition--is appointed by the president of the University upon recommendation of the vice president for research. It has three major purposes:

- Formulating policies governing the safe use of ionizing radiation.
- Reviewing proposals for the use of ionizing radiation and qualifications of applicants, and issuing authorizations for such use.
- Reviewing and evaluating the performance of the radiation safety program.

2.3 Authorized Investigator and X-Ray Registrant Responsibilities

Authorized investigator and X-ray registrant responsibilities include the following:

- Conducting research, academic, and clinical activities in accordance with the applicable regulations, conditions of their authorizations, and University policies and procedures as set forth in this handbook.
- Training their employees and students, and ensuring their understanding of safe work practices, operational and engineering controls necessary to work safely with sources of radiation.
- Ensuring that their radiation workers know and understand the regulations, license conditions, and University policies for radiation safety.
- Posting a current list of all radiation workers under their authorization or registration.
- Investigating incidents related to radiation sources, taking remedial actions as necessary, and completing incident report forms.
- Ensuring that sources of radiation are safeguarded from improper use or use by unregistered or unqualified persons.
- Reporting incidents such as spills, theft, loss, or personal injury related to radiation sources.

- Posting, or otherwise making available for viewing by radiation workers under their control, their authorization documents and any attachments, results of surveys and inspections, and the *Radiation Safety Handbook* and any supplements.

2.4 Radiation Worker Responsibilities

Each individual who use sources of ionizing radiation is classified as a radiation worker except for electron microscope users. Each radiation worker is responsible for the following:

- Registering with ORS before working with sources of radiation.
- Using radiation sources only under the supervision of an authorized investigator or registrant.
- Knowing, understanding, and putting into practice the regulations, license conditions, and University policies and procedures related to their work with sources of radiation.
- Reporting work-related incidents or injuries to their supervisor.

2.5 Office of Research Safety Services

- Training. ORS develops and distributes written training information such as this handbook, *Research Safety News*, *NUtrino* newsletter, and the New Radiation Worker packet. Staff members present or participate in departmental radiation safety seminars. ORS maintains a library of training videotapes and publications of national and international standards organizations (e.g., the National Council on Radiation Protection and Measurements, the International Commission on Radiological Protection, and the National Academy of Sciences), professional organizations (the Health Physics Society), and regulatory agencies (Illinois Department of Nuclear Safety).
- Dosimetry. ORS provides personnel dosimetry services for qualifying radiation workers at nominal cost to the authorized investigator or registrant, and maintains associated records.
- Radioactive Waste Disposal. ORS provides waste disposal containers. ORS picks up, processes, packages, ships for disposal or directly disposes, and maintains official records for radioactive waste generated in University facilities.
- Surveys and Inspections. ORS conducts periodic surveys of facilities in which radioactive materials are used or stored to assess the level of safety and compliance. ORS surveys most facilities on quarterly or monthly schedules based on radionuclides used, amounts of activity, complexity of procedures, and compliance history. ORS may conduct spot checks and special surveys including surveys requested by authorized users and radiation workers. ORS arranges for annual inspection of operable X-ray producing equipment, and maintains inspection records.
- Bioassay. ORS provides bioassay services for individuals using specified quantities of activity. ORS performs two types of bioassay: thyroid counting for persons who use radioiodine, and urinalysis for euthyroid individuals and persons using other radionuclides.
- Radionuclide Inventory. ORS prepares inventory documents for each shipment and maintains an inventory database for each radionuclide for each authorized user. ORS conducts a semiannual sealed source inventory.

- Calibrations and Leak Tests. ORS provides calibration services for portable radiation survey instruments. ORS conducts periodic leak tests of larger sealed sources and maintains the official records pertaining to calibrations and leak tests.
- Licenses, Registrations, and Authorizations. ORS maintains official files for all authorized users and registrations. ORS staff provide administrative support and coordinate the activities of the Radiation Safety Committee.
- Shipping and Receiving. ORS is the designated receiving point for all radioactive materials entering the University. ORS inspects incoming shipments for external contamination and measures external exposure rate of some packages. ORS inspects packaging, applies labels, and prepares certain shipping documents for radioactive materials that are shipped out of the University or between campuses.
- Emergency Response. ORS works closely with University Police (UP) and maintains a fully trained and equipped emergency response team on call 24 hours a day to respond to hazardous material emergencies. ORS staff are available to lend technical assistance to authorized investigators and radiation workers during decontamination or other remediation efforts.
- Laboratory Safety. In addition to radiation safety, ORS is responsible for programs addressing many aspects of general laboratory and occupational safety including chemical and biological hazards. See the ORS documents *Chemical and Biological Safety in Laboratories*, *Hazard Communication Program*, *Bloodborne Pathogens Program*, and *Recombinant DNA Safety Program* for more information.

3.0 University License and X-Ray Registrations

3.1 Illinois Department of Nuclear Safety

The Illinois Department of Nuclear Safety (IDNS) is the state cabinet-level agency responsible for regulating use of radioactive material and sources of radiation. IDNS conducts all licensing, registration, and inspection activities.

3.2 Broad-scope License

The University's broad-scope license governs possession and use of the following materials:

- Naturally occurring radioactive material.
- Source material (uranium, thorium, and certain ores of uranium and thorium).
- Special nuclear material (plutonium and certain isotopes of uranium).
- Byproduct material (most commonly used radionuclides are made as a result of neutron bombardment of material within a nuclear reactor, so they fall under the classification of byproduct material).
- Accelerator produced radioactive material.
- Large irradiation sources.

IDNS inspects Northwestern’s license periodically--usually annually--to determine whether the University complies with IDNS rules, regulations and license conditions. IDNS also may inspect the program on behalf of federal agencies such as the Department of Transportation or Environmental Protection Agency. IDNS may conduct spot checks of laboratories and interview authorized users and radiation workers to gauge their understanding and practice of radiation safety principles and practices and University policies and procedures.

3.3 Radioactive Materials in Human Subjects

The use of radioactive materials in human subjects for diagnosis, treatment, or research is prohibited in University facilities. Physicians desiring to use radioactive materials in human subjects must request approval from the hospital or clinic where the material will be used.

3.4 X-Ray Registrations

IDNS requires registration of all X-ray producing devices and regulates administration of medical X-rays; ORS maintains the University’s 3 registrations. IDNS requires annual inspection of each operable X-ray tube. In addition, IDNS may conduct audits that include record reviews and physical inspection of X-ray units. ORS submits annual reports and pays fees to IDNS for X-ray registrations and X-ray inspections. X-ray registrants who charge a fee to others who use their equipment or who charge for medical, dental, or analytical X-ray services are required to reimburse ORS.

4.0 Investigator Applications and Authorizations

4.1 General Information

The broad license allows the Radiation Safety Committee to grant authorizations (which are sub-licenses) to individual users. The committee grants authorizations to qualified individuals for specified radionuclides with activity limits, for use in approved facilities for well-defined research, academic, and clinical objectives.

The committee may grant authorizations to use unsealed radioactive material, sealed sources (such as check sources, calibration sources, standards, and gas chromatograph foils), and irradiators. Possession and use of any radioactive material subject to the University license in University facilities (including leased facilities) without committee authorization is prohibited. Investigators may pick up application forms in the ORS office on either campus.

4.2 Authorized User Qualifications

As a general rule the committee grants authorizations only to faculty members. The committee shall evaluate the applicant's relevant training and experience prior to granting authorization. When the committee judges an applicant has insufficient training and experience for the proposed use, the applicant may be advised to work under supervision of an authorized investigator to gain experience. Acceptable training and experience should include, but is not limited to:

- Principles and practices of radiation protection as they apply to the requested radionuclide, activity, and procedure.
- Radioactivity measurement techniques and instruments.
- Mathematics basic to measurements of radioactivity.
- Radiobiological effects.

4.3 New Applications

The RSO provides the Application for Possession and Use of Radioactive Material form. Applicants should provide considerable detail because committee members usually will evaluate the qualifications, facilities, proposed uses, and radiation safety measures solely on the information provided on the form. The application should demonstrate sufficient knowledge of University policies and procedures and radiation safety practices so as to keep doses ALARA and maintain compliance for the specific radionuclides, activities, sources of radiation, and procedures requested. The RSO reviews the application and forwards it to each member of the committee. Authorization requires unanimous approval of the voting members. The RSO issues an authorization document which may include special conditions imposed by the committee.

4.4 Adding Radionuclides

Investigators wishing to add a new radionuclide to their authorization shall complete a new Application for Possession and Use of Radioactive Material form for committee review.

4.5 Increases in Quantity of Radionuclides

Investigators wishing to increase an authorized limit for a radionuclide shall complete the Application for Increase in Quantity of Radioactive Material form. The RSO is authorized to approve the increase temporarily provided the applicant has demonstrated that any additional radiation safety precautions have been addressed. The RSO submits applications for increase to the committee for final approval. The RSO or committee may impose new conditions.

4.6 Five Year Reviews

A University license condition requires the committee to review each authorization at five-year intervals. ORS initiates the process and distributes the Radioactive Material Authorization - Five Year Review form in advance of the anniversary date. The earliest authorization date or previous five year approval date is the baseline. The process folds subsequent radionuclide additions and increases in quantity into the five-year review even though they may be less than five years old.

4.7 Irradiator Applications

Investigators desiring to use the gamma irradiators shall submit the completed Application for Cesium-137 Irradiator Use form to the committee.

5.0 Radiation Worker Registration and Personnel Dosimetry

5.1 Registration Requirement

All radiation workers shall register with ORS *prior* to beginning work with any source of ionizing radiation. A radiation worker changing laboratories shall re-register prior to commencing work with sources of radiation in the new laboratory.

5.2 New Radiation Worker Packet

ORS provides a New Radiation Worker Packet to each radiation worker. It contains instructions, the Radiation Worker Registration Form, information concerning risks from occupational radiation exposure, instruction concerning prenatal radiation exposure, and the *Radiation Safety Handbook*.

5.3 Radiation Worker Registration Form

Each radiation worker shall complete the Radiation Worker Registration form, obtain the authorized investigator's signature, view the training videotape, and return the form to ORS. ORS reviews the information on the form and determines whether personnel dosimetry is required.

5.4 Training Videotape

New radiation workers shall view the training videotape in ORS on either campus unless excused by ORS on the basis of previous training and experience.

5.5 Posted Radiation Worker List Requirement

Authorized investigators and registrants shall post a list of all current radiation workers under their authorization. ORS staff will review the list during surveys and compare it to registration forms on file. If your laboratories are contiguous you do not need to post the list in every laboratory.

5.6 Dosimetry Requirement

All radiation workers register with ORS, however most radiation workers do not wear dosimeters because the potential for significant exposures is very low. The decision whether to issue a dosimeter is based upon the use and form of radiation sources, as described on the Radiation Worker Registration Form.

IDNS regulations require that the University provide personnel dosimetry to adults likely to receive in one year--from sources external to the body--a dose in excess of 10 percent of the applicable limit. Dosimetry also is required for minors and declared pregnant women likely to receive a dose in excess of 10 percent of the applicable limit.

5.7 Types of Dosimeters

Body badges and TLDs are the types of dosimeter most widely used. Both rely on analysis of a physical change that takes place in the dosimeter when it is exposed to radiation. The *body badge* consists of a plastic-enclosed optically stimulated luminescence (OSL) dosimeter that snaps into a plastic holder. It usually is used to measure doses to the whole body. The TLD or *thermoluminescent dosimeter* is used when more localized exposures are of concern such as irradiation of the hands or eyes. The typical TLD uses a crystal of lithium fluoride or calcium fluoride phosphor. Plastic finger rings typically contain TLDs.

5.8 Minimum Reportable Doses

OSL body badges can provide a minimum reportable dose equivalent of 0.01 mSv (1 mrem). TLD ring dosimeters have a minimum reporting dose of 0.3 mSv (30 mrem) for X and gamma rays and 0.4 mSv (40 mrem) for energetic beta particles. Readings falling below these levels are recorded on the report as *M; M* reports are added as zero to the accumulated dose equivalent. A conservative estimate of accumulated dose for *M* reports would be the product of the appropriate minimum dose times the number of months the dosimeter was worn.

5.9 Control Dosimeters

Control dosimeters measure dose during transit. ORS issues a control dosimeter with each monthly shipment of dosimeters and each dosimeter delivered separately from the regular shipment. Any dose to the control dosimeter is subtracted from the total dose recorded for each user’s dosimeter. Always return the control dosimeter to ORS along with the dosimeters for which it was issued. Otherwise, the transit doses cannot be corrected for and reports may show doses that were not occupationally received.

5.10 Deep and Shallow Dose

Doses are reported as *deep dose* or *shallow dose*. The deep dose pertains to radiation that could penetrate to the blood forming organs (such as bone marrow) or other sensitive tissues. The shallow dose pertains to radiation that affects the skin. The terms deep and shallow dose therefore correspond to the terms "penetrating" and "nonpenetrating" dose. The reverse side of the dosimetry report provides detailed information.

5.11 Proper Use of Dosimeters

Dosimeters are not protective devices. They only tell us whether a dose has been received and give some information about it. Dosimetry reports are an aid in evaluating the efficacy of radiation safety measures in a laboratory, class, or clinic, assessing health effects in exposed individuals, revealing accidental exposures, and helping prevent recurring doses. They help keep doses ALARA, but only if they are properly worn and used.

Wear body badges on either a lapel or pocket, and make sure they are visible at all times. Insert the film correctly into the holder so the name shows through the window. Wear ring dosimeters *under* protective gloves, with the sensitive element on the palm side. Store dosimeters away from sources of radiation when they are not in use.

If you are interested in the ambient radiation field in your work area, do not use your personal dosimeter to measure it! ORS supplies area monitors for this purpose. Also, never wear another person's dosimeter; the dosimetry report is a permanent, legal record of your occupational dose.

5.12 Instructions to Dosimetry Coordinators

Authorized investigators and registrants should select a *dosimetry coordinator* who is responsible for receiving and distributing dosimeters for the group, returning used dosimeters to ORS, maintaining dosimetry reports, and handling correspondence with ORS regarding dosimeter orders and billing. If the dosimetry coordinator becomes unable to fulfill the dosimetry program obligations (e.g., because of vacation, illness, or reassignment), the investigator or supervisor should designate another individual to manage the dosimeters and notify ORS of this change.

5.12.1 Series Code

The *series code* is a two-or-three letter code unique to each research or clinical group. It appears on body badges and ring dosimeter labels, on mailing labels, and on top of service change orders and monthly reports. Please refer to this code when calling or corresponding with ORS about dosimetry matters.

5.12.2 Wear Dates

Most dosimeters are worn for 2 months, beginning on the 10th of the month. In a few cases dosimeters may be worn for longer or shorter time periods, but the bimonthly schedule is the general rule. Dosimeters are issued in September, November, January, Marach, May, and July.

5.12.3 Distributing Dosimeters

ORS mails dosimeters to series codes on about the 5th of each month. Check the packing list (called the "Service Change Order") and make sure all are accounted for and information is correct. Then distribute the dosimeters to radiation workers.

5.12.4 Collecting Dosimeters

Collect all used dosimeters on the 10th of the new wear date month. Make sure all are accounted for and mail them to ORS by campus mail only. ORS must receive the dosimeters by no later than the 15th of the month. All dosimeters must be accounted for, so you should attach an explanation if any is missing. Mail dosimeters in sealed envelopes to prevent their loss.

5.12.5 Changes in Service

Direct all requests for changes in service to ORS; do not deal directly with the vendor. You may request changes either by phone or mail.

- Additions. Each new worker must receive the "New Radiation Worker" packet, view the training videotape, and complete the green Radiation Worker Registration form before using any radiation source. You may pick up "New Radiation Worker" packets at ORS on either campus. ORS will order any dosimeters after receiving the completed registration form signed by the authorized investigator (or the laboratory or clinic supervisor where sources of radiation other than radioactive materials--such as X-rays--are used). New radiation workers who will wear dosimeters at Northwestern *and* wore dosimeters at another institution during the current calendar year shall complete the "Occupational Exposure History Request" form in addition to the registration form.
- Deletions. Write or call ORS as soon as possible when you wish to remove a radiation worker from the series code. You will continue to be responsible for, and will be charged for, all dosimeters unless you request deletion from the series code.
- Transfers. Persons transferring between laboratories must re-register with ORS.
- Changes in Dosimeter Type. If new procedures require a new dosimeter type it must be recorded on the registration form in ORS.

5.12.6 Temporary Dosimeters

In some cases ORS may issue temporary dosimeters for very short-term use while awaiting delivery of the permanent dosimeters. Because dosimeters are ordered electronically they usually arrive in just a few days. ORS may issue temporary dosimeters if permanent dosimeters become lost. In all cases, the radiation worker shall have a registration form on file and shall have met all other requirements for dosimeter use before ORS will issue a temporary dosimeter.

5.12.7 Classes

Special dosimeters are available for short courses and classes. Class members must complete registration forms. ORS keeps only a few temporary dosimeters on hand, so place orders for large numbers of dosimeters well in advance of their intended use. These "special" series-code dosimeters are billed separately from regular series-code dosimeters, so you may need to arrange for separate payment. Your dosimetry coordinator should coordinate distribution and collection of dosimeters and control issuance of registration forms.

5.12.8 Fees

ORS bills series codes semiannually for the following expenses:

- Service charge for each dosimeter issued. Charges differ depending on dosimeter type.
- Lost and missing dosimeters. Ring dosimeters and TLD controls contain reusable radiation-sensitive elements; if they become lost the series code pays the cost.

- Setup Charge. There is a one-time setup charge for each new dosimeter ordered.
- Lost body badge holders. The vendor loans body badge holders to the University, so charges for missing holders will be passed along to the series code.
- Late Fee. There is a penalty fee for each dosimeter not accounted for within 90 days of issue.

ORS totals all charges on a semiannual statement. Series codes provide a valid CUFS number used for transferring funds.

5.12.9 Reports

Reports for the previous wear date dosimeters will be included with the current wear date shipment if the previous wear date dosimeters were returned to ORS on schedule. See the back of the form for detailed information on the analysis, dose limits, and report codes. Authorized investigators and registrants shall make dosimetry reports available for viewing by their radiation workers.

6.0 Training

6.1. The Importance of Training

Training in personal protection, contamination and exposure control may be the most important means to reduce dose. This handbook provides the first step in that training. In large measure, protection is the individual responsibility of the knowledgeable worker. A thorough grounding in radiation protection fundamentals can increase worker awareness of the hazards unique to the working environment. The knowledgeable worker knows when to seek assistance with problems. Because authorizations are issued to investigators for radionuclides and procedures unique to each laboratory, the principle investigator has a responsibility to provide training in the specific aspects of radiation protection that apply to that laboratory.

6.2 Authorized User or X-Ray Registrant Responsibilities

The authorized user or registrant shall provide specific radiation safety training to all radiation workers appropriate for the types of radiation, amounts of activity, procedures, and conditions of use in the laboratory. The training shall include instruction in the policies and procedures contained in the *Radiation Safety Handbook* and supplemental material issued by ORS. The authorized user or registrant shall inform all individuals working in or having access to an authorized radiation laboratory of the following:

- Policies and practices regarding storage, transfer, or use of radioactive material.
- Any special conditions of the authorization under which the radioactive material is used.
- Appropriate response to any audible or visual warnings that signify potential exposure to radiation.
- Emergency policies and procedures for the laboratory.

6.3 ORS Training Resources

ORS provides general, written training information to each radiation worker, and each radiation worker is required to view the radiation safety videotape prior to commencing work. In addition, ORS provides the following training resources to assist the authorized investigator:

- Radiation safety seminars.
- Radiation safety videotapes.
- Guidelines issued by regulatory agencies.
- Guidelines issued by standards organizations.
- Library of radiation protection materials.
- The following publications: *Research Safety News*, *Radiation Safety Handbook*, New Radiation Worker packet, *NUtrino* newsletter, *Chemical and Biological Safety in Laboratories*, Hazard Communication Program, Bloodborne Pathogens Program, and Recombinant DNA Safety Program.

7.0 Security, Theft, and Loss

The potential for harm from willful misuse or accidental loss of radioactive materials is a serious concern that each authorized investigator must address. Regulatory agencies may pay particular attention to this issue during inspections. In the event of a theft or loss, the investigator’s security measures and record keeping may come under intense regulatory and public scrutiny. Therefore, investigators should implement and maintain all reasonable precautions to control and secure their sources, even small ones such as check sources.

Sources of radiation shall be secured against unauthorized removal from the place of storage. Lock laboratory doors when the laboratory is unattended. Keep stock materials in a designated storage location, preferably locked. Consider establishing a checkout procedure whereby persons authorized to use them sign out stock materials, record the use on inventory forms or other written documents, and sign the remaining stock back in immediately at the conclusion of the experiment. Also consider implementing “line-of-site” rules for larger quantities or sources: if you are working where you can’t see your stock material, put it away. Challenge strangers in the laboratory.

Investigators shall ensure that there is a one-to-one correlation between stock vials or sources and inventory forms. This likely will be reviewed during random IDNS laboratory inspections. Inspectors may look at each stock vial and ask to see the associated inventory and usage records.

Report the theft or loss of any source of radiation to ORS immediately. Call ORS at 3-8300 (Chicago) or 1-5581 (Evanston) to report the loss. After hours call University Police at 456 and ask them to contact ORS.

8.0 Violations

8.1 IDNS Regulatory Penalties

Violation of any provision of the Illinois Radiation Protection Act is a misdemeanor offense. Violations of the IDNS rules and regulations promulgated pursuant to the Act may result in civil penalties not exceeding $1,000 per violation for each day the violation continues. ORS makes every effort to ensure that the policies and procedures in this handbook are compatible with--and accurately reflect the intent of--the Act and IDNS rules and regulations.

8.2 Enforcement Actions for Items of Noncompliance

The possession and use of radioactive material is a privilege accorded to investigators and radiation workers by the Radiation Safety Committee. Each authorization carries with it both explicit and implicit responsibilities for compliance. Authorized investigators and registrants are responsible for ensuring that radiation workers conduct their work in accordance with University policies and procedures. An instance of noncompliance by a radiation worker is charged against the investigator's authorization or registration.

The privilege of possessing and using radioactive materials or sources of radiation may be lost due to noncompliance with University policies and procedures. The Radiation Safety Committee has formulated the following enforcement policy for items of noncompliance in laboratories approved for the use of radioactive materials:

- Instances of noncompliance shall be noted on laboratory survey reports or in a letter to the authorized investigator or registrant.
- The issuance of a second citation for a similar item of noncompliance shall result in a warning letter from the Radiation Safety Officer.
- The issuance of a third citation for a similar item of noncompliance within five years of the first citation shall result in the suspension of the privilege to possess and use sources of ionizing radiation.
- Reinstatement of the authorization shall require meeting with the Radiation Safety Officer and written reapplication subject to approval by the Radiation Safety Committee.

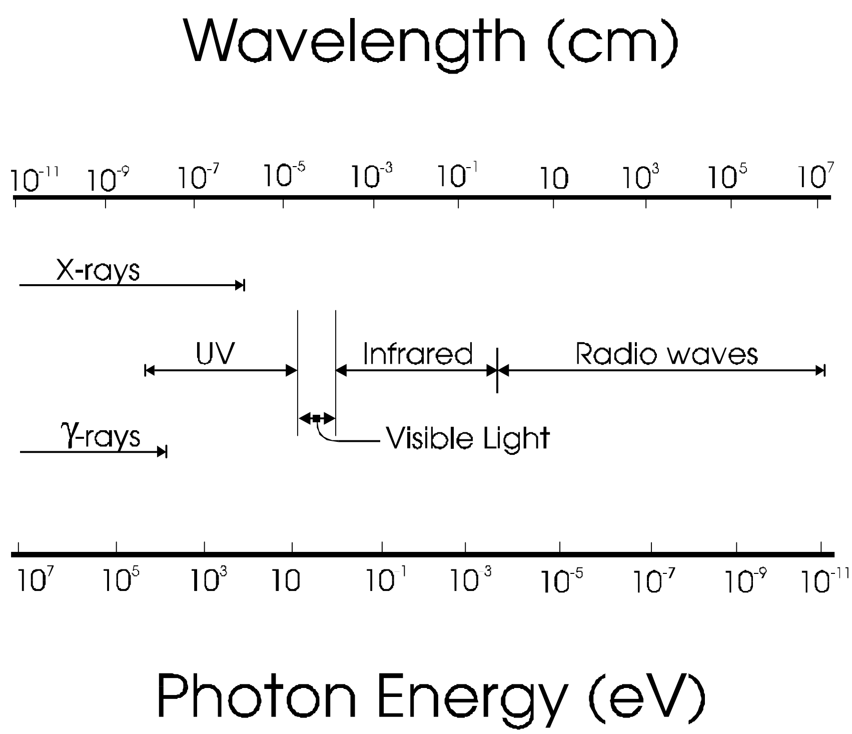
Appeal of the decisions of the Radiation Safety Committee may be made to the vice president for research.

9.0 What is Radiation?

9.1 Definitions

Radiation is the emission and propagation of energy in the form of waves or particles. Radiation *waves* vary in frequency and wavelength and may be described according to their position on the electromagnetic spectrum. The electromagnetic spectrum includes X- and gamma rays, ultraviolet radiation, visible light, infrared radiation, and radio waves.

Figure 9.1 Approximate Wavelengths and Photon Energies of Electromagnetic Radiation.



According to the quantum theory model, electromagnetic radiation consists of bundles of energy called photons, which travel at the speed of light. Gamma rays and X-rays are identical-- they both are photons--but differ in origin. Gamma rays result from transformations that take place in the nucleus of an atom, and X-rays are formed by interactions outside the nucleus.

There are several types of *particulate* radiation:

- *Beta particles* are identical to electrons. They carry an electrical charge of -1.
- *Alpha particles* are heavier. They are identical to the nucleus of a helium atom, with 2 protons and 2 neutrons, and have an electrical charge of +2.
- *Positrons* are equal in mass to electrons and have an equal but opposite charge of +1.
- *Neutrons* are approximately equal in mass to the proton and have no electric charge.

A *nuclide* is a species of atom characterized by the constitution of its nucleus, as specified by the number of protons, the number of neutrons, and the energy content. A *radionuclide* is a nuclide that spontaneously emits radiation in the form of electromagnetic or particulate radiation.

The emission of radiation by atoms is complex. Radioactive atoms may spontaneously emit combinations of photons and particles; many are beta/gamma emitters. Positron emission results in the production of gamma photons. Different atoms of a given radionuclide may emit different combinations of radiation types, or emissions of the same type but differing in energy or frequency.

9.2 Ionization

Understanding the *ionization* concept is fundamental to understanding how radiation causes changes and damage to the material with which it interacts and how radiation may be detected. *Ionizing radiation*, whether electromagnetic or particulate, differs from other kinds of radiation in that it may add enough energy to atoms to eject electrons from their orbits, leaving charged atoms or *ions*. On the molecular scale, ionization may break bonds and disrupt normal biochemical processes. One consequence is the formation of highly reactive free radicals.

Alpha and beta particles are *directly ionizing*, that is, they are capable of directly transferring energy to target atoms. Electromagnetic radiation (gamma rays and X-rays) and neutrons are *indirectly ionizing*. They do not carry an electrical charge but they do cause liberation of secondary charged particles (electrons) that are directly ionizing.

Charged and uncharged particles exhibit differing rates of ionization in matter. This *specific ionization* may be defined as the number of ion pairs produced per unit track length of the ionizing particle. The specific ionization of alpha particles may range from 40,000 to 60,000 ion pairs per centimeter of air traveled. In comparison, beta particles have a longer range but a specific ionization of roughly 50 to 300 ion pairs per centimeter of air. A relatively constant amount of energy is transferred from the ionizing particle to each ion pair produced. This value, known as the *W* value, averages about 33.7 *electron volts* (eV) per ion pair. A single beta particle with an energy of 500,000 electron volts (500 *keV*) could produce 15,000 ion pairs.

9.3 Range in Matter

Uncharged electromagnetic radiation such as the photon (gamma- or X-ray) has a longer range in matter than either alpha or beta particles. While charged particles make a large number of small energy transfers in matter, photons make a small number of large energy transfers. A photon's penetration in matter is described by a probability distribution rather than by a discrete range. Alpha particles may be shielded by a piece of paper, and beta particles have finite ranges in different materials; however, it cannot be said with certainty that a photon will be stopped by a given thickness of material. All we can say is that there is a certain probability it will be stopped.

9.4 Radioactive Decay

Radioactive decay occurs when an unstable nucleus rearranges its structure to achieve stability and emits particles or photons in the process. Not all of these particles or photons come from the nucleus. Some may originate in or between electron shells as the electrons themselves are ejected from an atom or as they drop into lower energy levels to fill the gaps left by ejected or absorbed electrons.

Because radioactive decay is a random process, we can say only that there is a probability it will occur within a specified interval. For a population of atoms of the same element and mass number, this probability is called the *decay constant*, lambda (λ). Lambda is equal to the natural logarithm of 2 divided by the *half-life*.

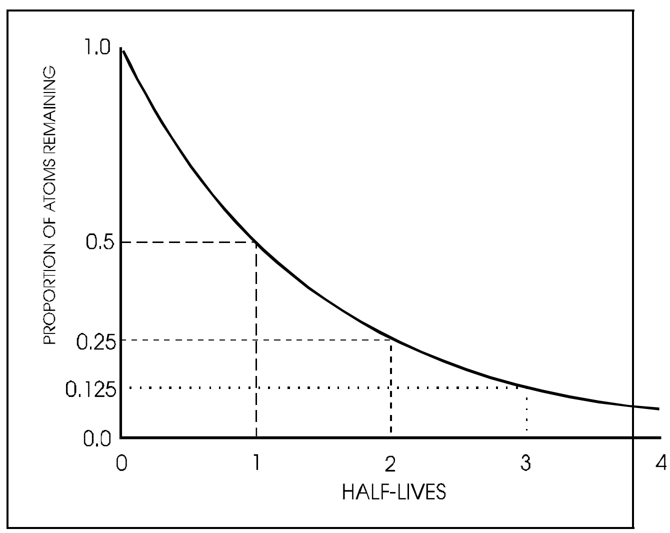
Equation 9.1 Decay Constant

$$\lambda = \frac{.693}{t_{1/2}}$$ **Error! Switch argument not specified.**

One half-life is the time during which one-half of the radioactive atoms in a sample will decay or disintegrate. This is illustrated graphically in Figure 9.2.

Figure 9.2 Radioactive Decay

The formula of this curve (an exponential function) enables us to determine, among other things, the number of radioactive atoms remaining at any time t, provided we know how many were present to begin with.



Equation 9.2 Decay Equation

$$N = N_o e^{-\lambda t}$$

where N = number of atoms at time t, N_o = number of atoms at start (time t = 0), and e = base of natural logarithms.

9.5 Maximum and Average Beta Energy

Beta particles are emitted from excited atoms with a spectrum of energies rather than a discrete energy. The beta particle energy in Table 9.1 is the maximum energy. The average energy is usually about one-third of the maximum. Photons, on the other hand, are emitted with discrete energies each time an atom of the same radionuclide disintegrates.

9.6 Characteristics of Commonly Used Radionuclides

The elements of the periodic table comprise a population of more than 1,500 *nuclides*. Of these, Northwestern researchers use about 50 in their investigations. Fewer than a dozen are used routinely, although they may be found in many hundreds of chemical compounds. Investigators frequently select radionuclides as labels on the basis of their ability to substitute for stable atoms in molecules of interest as well as their ease of detection and measurement. Some of their physical properties are detailed in Table 9.1.

Table 9.1 Commonly Used Radionuclides

Radio-nuclide	Half Life	Emission	Energy (MeV)
H-3	12.26 y*	beta	0.0186 max**
C-14	5,730 y	beta	0.156 max
Na-22	2.26 y	beta	1.820, 0.545 max
		gamma	0.511, 1.275
P-32	14.28 d	beta	1.71 max
P-33	24.4 d	beta	0.248 max
S-35	87.9 d	beta	0.167 max
Ca-45	165 d	beta	0.252 max
Cr-51	27.8 d	gamma	0.320, 0.315
Rb-86	18.66 d	beta	1.78 max
		gamma	1.078
I-125	60.2 d	gamma	0.035

* d = days, y = years
** max = maximum beta energy; average energy is about 1/3 of the maximum

Table 9.1 is by no means exhaustive; only major radiations are shown. Iodine-125, for example, has a complex decay scheme in which more than 14 different particles or photons may be emitted with varying frequencies and in varying combinations. Sodium-22 emits positrons, which interact with orbital electrons and vanish, producing two photons of 0.511 MeV each that are emitted in opposite directions.

10.0 Units of Radiation Activity

10.1 Activity Definition

Activity is defined as the number of disintegrations (also known as transformations) that occur per unit time and is equal to the decay constant lambda (λ) times the number of radioactive atoms present.

Equation 10.1 Activity

$$A = \lambda N$$

where A = activity, λ = decay constant (0.693/half life), and N = number of atoms present.

10.2 SI System

Two systems of units are in use in the radiation sciences, the "common" system and the "SI" (Systeme International) system. This handbook uses SI units followed by common units in parentheses. The SI system has seven base units as its core. These base units are supplemented by a number of derived units that are products or quotients of powers of the base units. The derived unit of activity is the *becquerel* (Bq), equal to one transformation per second.

Table 10.1 SI Base Units

Unit	Symbol
meter	m
kilogram	kg
second	s
ampere	A
kelvin	K
candela	-
mole	-

10.3 Units of Activity

Table 10.2 Common and SI Units of Activity

Type of Unit	Name	Symbol	Value
Common	curie	Ci	3.7×10^{10} transformations/second
	millicurie	mCi	3.7×10^{7} transformations/second
	microcurie	uCi	3.7×10^{4} transformations/second
SI	becquerel	Bq	1 transformation/second

Table 10.3 Prefixes

Factor	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-3}	milli	m
10^{-6}	micro	u
10^{-9}	nano	n
10^{-12}	pico	p

Table 10.4 Conversion from Common to SI Units

Common Unit	SI Unit
1 Curie (1 Ci)	37 gigabecquerels (3.7 x 10^{10} Bq)
1 millicurie (1 mCi)	37 megabecquerels (3.7 x 10^{7} Bq)
1 microcurie (1 uCi)	37 kilobecquerels (3.7 x 10^{4} Bq)
1 nanocurie (1 nCi)	37 becquerels (37 Bq)
1 picocurie (1 pCi)	37 millibecquerels (3.7 x 10^{-2} Bq)

11.0 Dose and Exposure

11.1 Dose

The term *dose* routinely is used to mean "the amount of energy or radiation absorbed in matter." While true in a general sense, this definition must be more carefully qualified to fit certain conditions of irradiation.

11.2 Absorbed Dose

A reference to dose usually denotes *absorbed dose*, or the energy deposited by charged particles per gram of the material of interest. The SI unit of absorbed dose is the *gray* (Gy), equal to one joule per kilogram. The common unit of absorbed dose is the *rad*, equal to 100 ergs of energy deposited per gram.

1 Gy = 100 rads
1 rad = 0.01 Gy

11.3 Dose Equivalent

Dose equivalent is the dose in gray multiplied by a normalizing factor such as the *quality factor*, Q. The quality factor is a modifier that takes into account the varying effectiveness of different radiations in depositing energy in matter. An example is the difference in specific ionization between alpha and beta particles. The quality factor varies significantly for different radiations, ranging from 1 for gamma and X-rays to 25 for neutrons and heavier ions. The SI unit for dose equivalent is the *sievert* (Sv). The common unit of dose equivalent is the *rem*. If you wear a body badge or ring dosimeter, your reports will be expressed as dose equivalent, in units of rem.

1 Sv = 100 rem
1 rem = 0.01 Sv

11.4 Exposure

Exposure is another term in everyday use with a more specific meaning than is usually implied. The common unit of exposure is the *roentgen* (R). The roentgen is used for X- or gamma radiation and is based on the ionization these radiations produce in air. It is not used for particulate radiation. The value of one roentgen is 2.58 x 10^{-4} coulombs per kilogram (C/kg) in air. There is no equivalent SI unit of exposure. When ORS inspects laboratories where gamma-ray-emitting radionuclides are used or where radiation-producing equipment such as X-ray machines are used, the survey may be done with an instrument that measures exposure rate, and survey results are reported as R/hour or mR/hour.

12.0 Time, Distance, and Shielding

12.1 Three Effective Strategies

Unsealed radionuclides, sealed sources, X-ray machines, irradiators, and other sources may present a hazard of external exposure. Protection from these sources is based on applying three fundamental strategies:

- *Minimize the time* spent near sources (a linear reduction).
- *Maximize the distance* from sources (an inverse square reduction).
- *Use shielding* of appropriate type (an exponential reduction).

12.2 Time

Simply reducing the amount of time spent near or in contact with any source results in a proportionate reduction in dose. Minimize the time and you will minimize the dose.

sieverts/hour x hour = sieverts

12.3 Distance

Exposure decreases with distance according to the *inverse square law*, by which the radiation intensity varies inversely with the square of the distance from a source. Increasing the distance from a source by a factor of two reduces the intensity to one quarter. Increasing the distance from a source by a factor of three reduces the intensity to one ninth:

$$\frac{1}{2^2} = \frac{1}{4} \qquad\qquad \frac{1}{3^2} = \frac{1}{9}$$

This rule has important practical applications. A source with an exposure rate of 100 mR/hr at 10 centimeters from the surface has an exposure rate of 1 mR/hr at 100 centimeters from the surface, or little more than an arm's length away.

Remote handling tools may be necessary for sources with high-energy beta particles (such as P-32), high gamma exposure rates (such as Cs-137), or both (such as Na-22). These can be forceps, tongs, vial racks, trays--in short, anything that will put distance between you and the source. In the laboratory, place stock solutions, equipment, and wastes as far as possible from occupied areas and doorways.

12.4 Shielding

Proper shielding can result in an exponential reduction of dose for gamma emitters and a near-total reduction for beta emitters. Select appropriate shielding materials during the planning stages of any experiment or clinical procedure. Shielding design may be simple--no more complex or costly than sheets of plywood or plastic--or may involve complex calculations that depend on the type of radiation, the energy and frequency of emission, the configurations of source and room, and the occupancy factors.

12.4.1 Shielding for Beta Particles

Beta particles are relatively easy to shield. Since all beta particles have a definite range in matter, one may calculate a thickness of material that will stop them all. See Appendix A for shielding information for common beta-emitters.

Lead is *not* the best material for shielding beta particles. Low density material--wood, plastic, or aluminum--works better. Lead actually may increase the exposure from certain radionuclides. When a beta particle passes close to the nucleus of an atom, its path and velocity may change, giving off excess energy in the form of photons called *bremsstrahlung* radiation. The yield of bremsstrahlung radiation is proportional to the energy of the beta particles and to the atomic number of the shielding material. Lead has a high atomic number, so the amount of beta-particle energy converted to penetrating bremsstrahlung photons may be large. Although only a small fraction of the beta particles may be converted in this fashion, the resulting photons are more penetrating than the beta particles, resulting in unnecessary dose.

Plastics make better shields for beta particles because they have low atomic numbers and little beta energy is converted into photons. If necessary--such as with very large or energetic beta sources--shielding may be layered, with the plastic shield nearest the source and a higher-density shield farthest from the source. The higher-density shield absorbs photons produced by beta interaction in the plastic shield.

12.4.2 Shielding for Gamma Photons

When photons interact with matter, they lose energy through two processes, *absorption*, in which the photon may completely disappear, and *scattering*, in which some of the energy may be lost and the direction of the photon changed. These processes lead to a decrease in the intensity of a beam of photons.

There is no specific value for the range of a photon in matter; rather, there is a probability that a photon will interact within a specified thickness of absorbing material. This probability is called the attenuation coefficient, *u*. The value of *u* is primarily a function of the energy of the photons and the nature of the absorber. Denser absorbers are better for photons; lead is the material of choice. The ratio I/I_o is the fraction of photons remaining after a beam passes through an absorber of thickness *x:*

Equation 12.1 Intensity of a Photon Beam

$$I = I_o e^{-\mu x}$$

where I = intensity of a beam after passing through an absorber
I_o = original intensity of the beam
e = base of natural logarithms
μ = attenuation coefficient
x = absorber thickness

The term *half-value layer* (HVL) specifies the thickness of material required to stop half of the photons. The HVL for I-131 and Cs-137 is approximately 7 mm of lead. Most photons of I-125 will be stopped by 1 mm of lead. Another term, the *tenth-value layer* (TVL), is used to specify the thickness of material needed to reduce the beam intensity to one-tenth of its original value. See Appendix A for HVLs and TVLs for some common radionuclides.

Not all gamma emitters are significant exposure hazards in the quantities typically used in research laboratories. I-125, for example, is a minimal exposure hazard even in millicurie quantities. It is effectively shielded by several layers of lead foil. The most important considerations when using I-125 are volatility, inhalation, and skin absorption, not exposure.

13.0 Radiation Standards

13.1 Occupational Radiation Dose Limits

Authorized investigators and registrants shall endeavor to maintain doses to radiation workers and the general public ALARA. Table 13.1 provides the regulatory occupational dose limits.

Table 13.1 Annual Allowable Occupational Dose

Part of the Body	Rem	Sievert
Whole Body	5	.05
Individual organ or tissue other than the lens of the eye	50	.5
Lens of the eye	15	.15
Skin	50	.5
Extremity	50	.5

13.2 Occupational Dose Limits for Minors

Authorized investigators and registrants shall ensure that doses to individuals under 18 do not exceed 10 percent of the limits in Table 13.1.

13.3 Dose to an Embryo or Fetus

The dose to the embryo or fetus during the entire pregnancy, from occupational exposure of a woman who informs her employer of the estimated date of conception, must be limited to 0.5 rem (5 mSv). If occupational circumstances make a dose to the embryo or fetus unavoidable, the exposure should be as uniform as possible and should not exceed 0.05 rem (.5 mSv) per month. When a woman declares that she is pregnant but does not provide an estimated date of conception, the dose to the embryo or fetus must be limited to 0.05 rem (.5 mSv) per month.

ORS encourages female radiation workers to provide an estimated date of conception because it helps in determining the appropriate precautions to take during the remainder of the pregnancy. Declaration of pregnancy is voluntary. Information must be in writing and shall remain confidential. If you are pregnant or planning to become pregnant, please contact ORS so we may discuss your potential radiation exposure with you and provide guidance in minimizing the exposure risk.

13.4 Permissible Levels of Exposure in Unrestricted Areas

Doses must be controlled in unrestricted areas, such as public areas, offices, and corridors adjacent to radiation laboratories or X-ray facilities. Authorized users and registrants shall not possess, use, or transfer sources of radiation in such a manner as to create radiation levels in any unrestricted area that could result in a total effective dose equivalent, to an individual member of the public, of 0.5 rem (5 mSv) in any year from sources installed prior to January 1, 1994, or 0.1

rem (1 mSv) in any year from sources installed or where sources or their use have changed since January 1, 1994. The dose in any unrestricted area must not exceed 0.002 rem (0.02 mSv) in any one hour. ORS can measure radiation fields directly or use area monitors for long-term evaluations.

14.0 Radiation Risks

14.1 General Information about Risk

As a radiation worker, you are employed in a profession that has one of the best safety histories of all occupations. It is important, however, to be aware that current regulatory thinking (which is controversial) holds that any exposure to radiation may involve some degree of risk. Therefore, keep radiation doses as low as reasonably achievable and avoid unnecessary doses. ORS provides the following document for radiation workers interested in knowing more about the risks from occupational radiation exposure: *Instruction Concerning Risks from Occupational Radiation Exposure*, Appendix to Regulatory Guide 8.29, U.S. Nuclear Regulatory Commission.

14.2 Prenatal Radiation Exposure

When an occupationally exposed woman is pregnant, exposure of her body to penetrating radiation (radiation capable of delivering a dose equivalent at a depth of 1cm or greater in tissue) or the intake of either penetrating or non-penetrating radiation also exposes the embryo or fetus. Studies have shown that the embryo or fetus is more sensitive to radiation than an adult--particularly during the first trimester of pregnancy, when a woman may not be aware that she is pregnant. ORS therefore provides the following document to radiation workers interested in knowing more about prenatal radiation exposure: *Appendix to Regulatory Guide 8.13: Instruction Concerning Prenatal Radiation Exposure*, U.S. Nuclear Regulatory Commission.

15.0 Authorized Laboratories

15.1 General Requirements

Radioactive material and other sources of ionizing radiation shall be used only in facilities approved by ORS as radiation laboratories. Investigators shall request authorization from ORS to store or use radioactive material in a new location prior to commencing such work. ORS will inspect the location for suitability, post required signs, determine the survey schedule, and provide waste containers. Each radiation laboratory shall be under the jurisdiction and authority of a designated authorized investigator who has the authority to ensure compliance.

When more than one investigator or department share facilities, all persons using the laboratory shall adhere to the radiation safety program policies and procedures described in this handbook. Everyone must comply with certain rules for radiation laboratories even when all employees and students using the facility may not be radiation workers or use radioactive materials. For example, smoking and the storage and consumption of food or beverages is prohibited in all radiation laboratories including departmental cold rooms.

15.2 Minimum Physical Requirements

Laboratories in which radioactive materials are used or stored must meet the following standards:

- Floors shall be covered with a smooth, non-porous, and easily cleaned surface such as linoleum or tile or its equivalent. Work with radionuclides shall not be permitted in laboratories with unsealed concrete, clay tile, or wooden floors.
- Bench surfaces shall be composed of a non-porous, easily decontaminated material, or shall be covered with a protective, non-porous coating. Surfaces of high quality plastic laminate, epoxy resin, or stainless steel are preferable.
- Sinks shall be composed of stainless steel or seamless molded materials.
- Chemical fume hoods of adequate design and air flow characteristics shall be installed in laboratories in which the potential release of radioactive dusts, mists, fumes, vapors, or gases reasonably may be expected. Fume hood walls shall be of stainless steel, molded fiberglass, or other high quality, smooth, chemically resistant, and easily decontaminated material. Hoods in which radioactive material is to be used must be approved for such work by ORS.
- Biological safety cabinets (laminar flow cabinets) shall not be used for protection against airborne radioactive contaminants.
- Radiation laboratories shall be identified with a "Caution, Radioactive Material," "Caution, Radiation Area," or "Caution, High Radiation Area" sign on the door, as appropriate.

16.0 Laboratory Guidelines for Unsealed Sources

16.1 General Information

Most radiation workers at Northwestern use "unsealed" radiation sources, typically small volumes of organic or inorganic chemicals or carrier-free solutions containing radionuclides. The contents of these unsealed sources are readily accessible to the user. Most come in liquid form, with potential for spills, splashes, aerosolization, and vaporization. Stock vials may not provide adequate shielding. While each radionuclide has different physical characteristics making safety precautions unique, a few general guidelines will help minimize the chance of accidents and the consequences should they occur.

16.2 Controlling Contamination

From a safety standpoint, controlling contamination imposes the most stringent requirements on handling the majority of unsealed sources. Some high-energy beta emitters and some gamma emitters need to be handled cautiously to prevent unnecessary dose as well as prevent contamination. See Appendix A for more information about common radionuclides.

A good starting point is general housekeeping in the laboratory including proper organization and storage of chemicals and tools, adequate space in which to work, a clutter-free environment, and ease of access to sinks, eyewash stations and safety showers. Keep fume hoods free of clutter, especially at the face and floor of the hood where the air flow may be disrupted. Work well inside the hood--not right at the hood face--and keep your face out of the hood.

Good personal hygiene can protect you from unnecessary dose. Wash hands thoroughly after every procedure and before leaving the laboratory.

Always wear protective clothing and equipment. Gloves shall be worn every time you handle vessels containing radioactive material (and those that may be contaminated). Select gloves which are most appropriate for the chemical hazard. Never wear disposable gloves outside of the lab. Lab coats shall always be worn when there is a potential for exposure to hazardous materials. Lab coats shall be removed upon leaving the lab when there is a potential of contamination from a hazardous material on the lab coat. Keep lab coats buttoned up. Approved eye protection shall be worn when there is a potential exposure to the eyes from any hazardous material. Bare skin can be an important pathway for uptake of radioactive materials. Do not wear shorts, sandals, or cloth shoes in any laboratory containing hazardous materials.

Protect the laboratory as well. Accidents could require extensive decontamination--a potentially serious loss of time and resources. Double containers shall always be used to transport radioactive materials. A second, outer container with absorbent material will cushion a dropped sample or broken vessel. Establish a designated radiation work area and make sure that vessels, tools, and equipment used for radioactive materials work are labeled and stay in that area. Protect the work area with plastic-backed absorbent paper. Work on a tray that is also lined with absorbent paper.

Label all containers that hold or are contaminated with radioactive material; another worker may not know what is in or on the container or tool and may unknowingly spread contamination. Labels shall identify the radionuclide, the amount of activity, and the date. Labels help workers distance themselves from exposure hazards and help them avoid accidental intake from hand contamination and skin absorption. Labels also help with inventory control because licensees must be able to account for all activity in stock, in use, and in waste. These labels must be removed or defaced before discarding containers or boxes. In short, labels shall provide sufficient information to permit all workers in the vicinity, or those handling the material, to take appropriate precautions to minimize their risk from contamination or exposure.

Smoking and the consumption of food and beverages are prohibited in laboratories where radioactive or other hazardous materials are used or stored. Storage of food and beverages in radiation laboratories also is prohibited. Disposal of food waste, beverage containers, or food containers inside the laboratory--even though food was consumed outside the laboratory--is prohibited. Do not store food preparation equipment, such as utensils, in the laboratory.

Preparing food in laboratory microwave ovens likewise is prohibited. Evidence of the consumption or storage of food and beverages may result in the suspension of privileges to possess and use radioactive materials for all who work in the laboratory.

16.3 Recommendations for Hot Lab Conduct

Post the "Recommendations for Hot Lab Conduct" in each radiation laboratory. The posting summarizes the minimum requirements that shall be followed in University laboratories.

- Plan ahead. Perform a practice run with nonradioactive materials to test procedures whenever possible.
- Establish a radiation work area. Designate an area for radioactive materials work and confine such work to the area. Cover the work area with absorbent paper.
- Practice good housekeeping. Keep the lab neat and clean. Store equipment and radioactive material away from the radiation work area when they are not being used.
- Use labels. Put a warning label on all containers of radioactive material and all contaminated containers and equipment.
- Use secondary containers. Use secondary containers, especially when transporting radioactive material between laboratories. Use enough absorbent material to completely contain any spilled liquid.
- Safeguard radioactive materials. Protect radioactive materials against theft or loss. Close laboratory doors. Return materials to storage when work is completed.
- Use personal protective clothing. Wear disposable gloves when handling radioactive material or potentially contaminated tools and equipment. Wear laboratory coats when unsealed sources are used. Change protective clothing if it becomes contaminated.
- Wear assigned dosimeters. Wear dosimeters whenever working with the radioactive materials for which dosimetry is provided.
- Mouth pipetting of radioactive material is prohibited. Use bulbs, syringes, or other mechanical devices.
- Smoking and the consumption, storage, and preparation of food and beverages are prohibited in radiation laboratories where unsealed sources are used.
- Practice good personal hygiene. Wash hands after working with radioactive materials and before leaving the laboratory.
- Monitor your equipment. Monitor equipment containing radioactive material for contamination before disposal or transfer.

17.0 Laboratory Surveys

17.1 ORS Surveys

ORS inspects most radiation laboratories quarterly and some laboratories monthly. The ORS survey is a general evaluation of both radiation safety and regulatory compliance. The survey may cover general housekeeping, contamination, exposure rates, labels and postings, protective clothing and equipment, dosimeters, and food or beverages in the lab. ORS also may examine inventory and waste records and cross-check stock materials with inventory forms. In short, ORS reviews laboratory safety and compliance with all of the "Recommendations For Hot Lab Conduct."

ORS measures air flow through fume hoods and posts the maximum window-sash height or width at which an acceptable average air flow is achieved. Avoid exceeding this maximum opening when you work with hazardous materials.

ORS mails the survey results and recommendations to the authorized investigator, and also posts the survey form on the laboratory door. Radiation workers are entitled to know the results of any survey and are expected to comply with recommendations on the survey report. In some cases, workers may be asked to clean contamination or correct deficiencies during the survey.

17.2 User Surveys

Survey your work areas after every use of radioactive materials. Don't wait for ORS to survey your laboratory to discover contamination. IDNS inspectors may perform surveys during inspections and issue citations if they find contamination. Survey the radiation work area immediately following a procedure and clean up any contamination at once. Frequent contamination checks are an important aspect of radiation hygiene and should become a part of the laboratory routine. Wipe tests with filter paper counted in a liquid scintillation counter are an effective qualitative method when a portable radiation detector is not available, and when H-3 (tritium) is used.
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17.3 Contamination Limits

Acceptable contamination limits are very low. Because of the conservative limits and the low sensitivity of most portable survey instruments, virtually any contamination you detect will exceed the guidelines and should be cleaned up. Spills shall be cleaned up promptly and thoroughly by the worker causing the spill. While ORS will provide technical assistance in the event of a spill, it remains the obligation of the individual causing the spill to clean it up.

Table 17.1 Contamination Limits for Beta and Gamma Emitters

Removable or Fixed	**Average Activity**	**Maximum Activity or exposure rate**
removable (all beta-gamma emitters except H-3)	220 dpm/100 cm^2	1,100 dpm/100 cm^2
removable (H-3)	2,200 dpm/100 cm^2	11,000 dpm/100 cm^2
fixed (all radionuclides)	-	25 mSv/hr (0.25 mrem/hr)

17.4 Wipe Tests

Tritium (H-3) contamination can be detected only by the wipe-test method. It cannot be detected using ordinary survey instruments. Wipe tests counted in liquid scintillation are effective for detecting--at least qualitatively--contamination from any of the commonly used radionuclides. To perform a wipe test, rub the surface with filter paper, using moderate pressure. Insert the filter paper into a scintillation vial. Add about 10 ml of counting cocktail; if your cocktail will accept it (check your product literature), add 1 ml of water to solubilize the sample. Make sure that the filter paper is completely covered by the cocktail. Shake vigorously, and then count. This is not a quantitative test, because some activity always will be trapped in the filter, but it does reveal contamination and tell us something about its severity.

17.5 Survey Instruments

If your laboratory is interested in purchasing a survey instrument, contact ORS before selecting one. ORS recommendations are based on experience with various brands and take into account ease of calibration, reliability, versatility, ruggedness, ease of servicing, and value. Instruments ordered out of catalogues may not have these characteristics.

ORS encourages radiation workers to use portable survey instruments to find contamination. The authorized user shall ensure that individuals conducting such surveys are knowledgeable in the capabilities, use, and maintenance of the survey instrument. ORS can provide training in survey instrument use and maintenance. Authorized users shall make sure that instruments operate correctly and are maintained in a serviceable condition.

It is important to select an instrument that is appropriate for the radionuclides used. The most common instruments are "ratemeters" that display counts per unit time, used with either Geiger-Mueller (GM) detectors or scintillation detectors. Ion chambers, which measure exposure rate, are useful in certain applications.

17.5.1 GM Detectors

There are two basic types of GM detectors: long, thin end-window detectors and short, broad "pancake" detectors. Both types operate on the same principle, but the pancake detector usually has higher counting efficiencies. *Counting efficiency* is the ratio of counts detected per unit time (e.g., cpm) divided by the activity of the source expressed as disintegrations per unit time (e.g., dpm).

Equation 17.1 Efficiency

$$\textit{efficiency} = \textit{counts per minute/disintegrations per minute} = \textit{cpm/dpm}$$

Some characteristics of GM detectors are:

- They cannot be used to measure H-3 radiation because the 18 keV beta particle is so weak.

- Counting efficiency for gammas may be very low--for I-125, as low as 1 count for every 10,000 disintegrations. GM detectors are not recommended for measuring gamma contamination in the laboratory. Scintillation detectors are superior for that purpose.
- GM detectors may overrespond by a factor of up to 10 when measuring exposure rate from low-energy photons such as I-125. Consult your instrument manual for your instrument's unique energy-response curve. Measurement of exposure rates is more accurately performed with an "energy compensated" GM detector or an ionization chamber instrument.
- At very high counting rates, GM detectors may become "saturated" and the meter reading will fall to zero, potentially causing a false sense of security. When performing surveys or entering areas where significant exposure rates or contamination are suspected, always approach the area cautiously with the survey meter turned on. A rapid increase in count rate followed by a drop to zero indicates a high radiation field. Saturation may occur when measuring as little as a few microcuries of P-32 or several hundred mR/hr of gamma photons.
- Response time for ratemeter/GM combinations may be relatively slow. Perform surveys slowly enough to detect small changes in count rates. About 3 cm/second is a good survey rate. GM survey meters may take 10 seconds or more to reach 90% of final value.
- Pancake detectors have about twice the counting efficiency for beta emitters than end-window detectors. Typical counting efficiencies for end-window detectors range from about 6% for C-14 to 25% for P-32.

17.5.2 Scintillation Detectors

Scintillation detectors are used for detecting and measuring gamma photons, and are the best detectors for I-125 contamination. Some characteristics of scintillation detectors are:

- Efficiency may be several orders of magnitude higher for gammas than GM detectors.
- Scintillation detectors do not become saturated. The meter will "peg" on the high end of the scale in an extreme radiation field.
- Scintillation detectors are fragile. They contain glass photomultiplier tubes and brittle, thin crystals. They are significantly more expensive than GM detectors.
- Plastic scintillators are available for detecting beta particles. Restrict their use to beta particle detection; they are not for gamma photons. Gamma and beta scintillators are made out of different materials and have different operating characteristics.
- Tritium (H-3) is not detectable with scintillation detectors.

17.5.3 Ionization Chambers

Ionization chambers (ion chambers), are designed to measure exposure rate. Some instruments may read out in dose equivalent rate (mrem/hr). They are useful only in measurement of gamma fields. Most unsealed gamma-emitting radionuclides are used in small quantities that do not present significant exposure problems. ORS uses ion chambers to measure exposure rates from waste containers, large irradiators and some processes. An alternative to the ion chamber is the energy-compensated GM detector. When used, the entire detector volume of the ion chamber must be in the beam of radiation for the measurement to be accurate.

17.5.4 Survey Meter Maintenance

- Avoid contaminating meters and detectors, but remember that protective coverings (such as plastic wrap) on GM detector windows reduces counting efficiency.
- Switch off meters before changing detector probes. Probes may operate at different voltages and may be damaged if meters are left on. Consult your owner's manual.
- Verify instrument performance each time you use the instrument by counting a standard, long-lived check source. Use the same counting geometry each time and record the results. Typical check sources are 1 uCi or less of C-14 for GM detectors and I-129 for thin-crystal scintillation detectors. These sources may be purchased from radiopharmaceutical and instrument suppliers. Check sources shall be safeguarded to control their use and prevent their loss. If you purchase a check source, you should inform ORS. Old lantern mantles--such as used in gas camping lanterns--are effective and inexpensive check sources because they contain radioactive thorium. The mantle does not have to be removed from the plastic bag. Simply place the detector near the mantle to verify instrument performance.
- Check the batteries each time you use your survey instrument. Most instruments use common D cells or 9-volt batteries. Replace them when they are low to prevent unreliable readings and damage to the instrument. Measure your check source after changing the batteries to verify instrument response.
- The attachment point between cable and detector may be the weak link. Do not hold the detector by the cable. Do not pull the detector out of its cradle by the cable.
- Thin windows on GM tubes are extremely fragile, so never touch them! If the window is punctured, the tube is ruined and will have to be replaced.
- Corrosion from batteries or corrosive atmospheres can destroy an instrument quickly. Replace low batteries promptly and perform a visual check occasionally. Do not keep survey meters in fume hoods or cabinets in which you use or store corrosives; the fumes can quickly render the instrument useless. If the instrument will not be used for an extended period of time, remove the batteries and attach a tag stating that batteries have been removed.
- Survey instruments are fragile and expensive. Protect them from bumps and falls. They may be top-heavy if the detector is in a cradle on top of the instrument. Broken scintillation detectors may cost several hundred dollars to replace.
- Component failure is relatively rare. Keep all instrument manuals, calibration reports, and related materials for reference in the event of instrument failure.
- Many instruments work best if the humidity is low. High humidity may cause the meter to read much higher than background even when no radiation source is present. A small container or porous bag of silica gel desiccant placed inside the instrument's case may prevent problems. Inspect color-indicating silica gel frequently for color change.

17.5.5 Calibration

ORS provides calibration services for survey meters. Calibrate your meters at least annually and following each repair. Ratemeters are calibrated electronically if they have counts-per-minute or counts-per-second scales. The batteries, high voltage, and input sensitivity are also checked.

Sources of differing emissions and energies may be measured, and counting efficiencies are calculated. In some cases, exposure rate measurements are made using a Cs-137 source.

18.0 Radiation Emergencies

18.1 Emergency Phone Numbers

Office of Research Safety	**3-8300 (Chi)**	**1-5581 (Ev)**
University Police (Fire, Police, Ambulance)	**456**	

18.2 Procedure for Major Spills

1. **Notify** all other persons in the lab at once. Direct uninvolved personnel to vacate the area immediately.
2. **Minimize** the spread of contamination provided you can avoid unnecessary radiation exposure. Use absorbent material if the spill is wet, or use dampened materials such as paper towels if the spill is dry.
3. **Remove** contaminated clothing and leave it in the lab.
4. **Leave** the laboratory as quickly as possible and prohibit access.
5. **Call** ORS at **3-8300** (Chicago) or **1-5581** (Evanston). You may call University Police at **456** at any time in an emergency and ask them to page ORS.

18.3 Procedure for Small Spills

1. **Notify** other persons in the laboratory at once.
2. **Confine** the spill immediately. Wear gloves, lab coat, and eye protection.

- Use absorbent material on wet spills.
- Dampen dry spills; use absorbent material on wet spills--do not spread contamination.

3. **Call** ORS at **3-8300** (Chicago), or **1-5581** (Evanston) for assistance.
4. **Decontaminate** the spill area.
5. **Monitor** all persons involved in the spill and decontaminate if needed.

18.4 Radioactive Dusts, Gases, Organic Vapors

- Uninvolved personnel vacate area immediately.
- Leave the room, close the door and prohibit access.
- Call ORS at **3-8300** (Chicago), or **1-5581** (Evanston) immediately for assistance.

18.5 Spill Control

The primary concern when spills occur is the safety of individuals. The objective of spill control is to minimize contamination and exposure, consistent with protecting individuals from nonradiological hazards. Contamination and exposure to radiation generally are of secondary importance when there are risks of acute bodily harm due to fire, toxic fumes, or other sources of injury. Of course, loss of equipment or materials is less important than the safety of personnel.

For major spills, the only measures to take before calling ORS are those which minimize the spread of contamination such as righting containers and putting absorbent material on the spill. Remove clothing suspected of contamination and place it in a closed container inside the laboratory. If possible, secure the laboratory and restrict access while waiting for assistance. Smaller spills are "minor" only in the sense they probably do not present an acute hazard to personnel. However, they must be handled in much the same way as major spills. Call ORS for any spill at 3-8300 (Chicago) or 1-5581 (Evanston).

18.6 Decontamination

There are 2 key points to understand about contamination: (1) it is the responsibility of the person causing it to clean it up, and (2) when it is discovered it must be cleaned up at once.

If skin becomes contaminated start decontamination measures immediately while waiting for assistance. Washing with warm water and soap is a good method. Scrub the skin thoroughly but do not abrade or break the skin. Monitor and repeat as necessary.

For most spills, ordinary detergents and water, applied with disposable cleaning materials will be adequate. Most commercially available decontamination solutions are strong detergents with complexing agents or surfactants. ORS will provide guidance and waste containers for contamination incidents but the actual decontamination procedure should be performed by those persons involved in the incident. Always conduct decontamination efforts in a manner that minimizes the dose to workers from external exposure, contamination and intake. Follow these guidelines:

- Wear disposable gloves, a lab coat, and protective eyewear. If the floor is contaminated, use disposable shoe covers or cover the floor with plastic-backed paper.
- Wear your dosimeter if you have one, and protect it from contamination.
- Call ORS for assistance at **3-8300** (Chicago) or **1-5581** (Evanston) if you have doubts about how to proceed. In the event of an after-hours emergency call University Police at **456** and ask them to page Research Safety.
- Use disposable materials for cleaning: paper towels and plastic bags.
- Place contaminated items in approved radioactive waste containers.
- Dampen dry spills with water (e.g., by applying a dampened paper towel, taking care not to spread contamination). Absorb wet spills immediately with paper towels.
- Work from the least contaminated area (e.g., the perimeter of the spill) to the most contaminated area. Try to avoid increasing the contaminated area.
- Use the strategies of time, distance, and shielding to minimize dose. Use long-handled tools for spills of energetic beta-gamma emitters. Avoid hand contact.
- For tritium (H-3) spills, monitor your progress by wiping the area with filter paper. Put the filter paper into a scintillation vial, add counting media, and count by liquid scintillation. If

your cocktail will accept it (check your product literature), adding a milliliter of water to the vial will help solubilize material on the filter. H-3 is not detectable with portable survey instruments.

- Use your survey meter to check your progress (but not for H-3). Survey slowly enough to detect small differences in count rates. If you do not have a survey meter, wipe test the area and use scintillation counting as described above.
- The limits for removable contamination are very conservative. Any activity you detect with ordinary survey instruments probably will exceed the limits. If the activity is not removable (determined by wipe testing the area), call ORS for advice on how to proceed.
- Do not reuse or release for general use any equipment that was contaminated or was used in the decontamination effort until it has been checked for contamination.

18.7 Emergencies with Radiation Producing Equipment

Emergencies with radiation producing equipment such as X-ray machines, analytical X-ray equipment, and gamma irradiators are rare. The consequences of accidental exposure may be severe, however, because by design most radiation producing equipment generates intense beams of radiation.

Radiation-producing equipment produces radiation only when energized. When the switch is turned off or the plug is pulled radiation ceases to be emitted. Even the gamma irradiators are designed so that the sources return to a safe position when power fails.

Unlike spills of radioactive materials, exposure to such equipment may not be apparent immediately so it is important to have written procedures for all uses of the equipment and make sure they are followed. Emergency procedures, which contain as a minimum the phone numbers of persons to call in an emergency, shall be posted and known by all workers in the area. Follow this procedure for emergencies:

1. **Turn off** equipment.
2. **Post** a sign on the equipment to prevent its use during incident investigation.
3. **Call** ORS immediately at **3-8300** (Chicago) or **1-5581** (Evanston). After hours call University Police at **456** and ask them to page Research Safety.
4. **Safeguard** body badges and ring dosimeters to prevent loss.

19.0 Bioassay

19.1 General Information

ORS provides a program of bioassay as an aid to determine whether intake of radioactive materials has occurred and, if so, to assess it’s magnitude and the need for further investigation. ORS performs two types of analyses, urinalysis and thyroid counting for radioiodine. Authorized investigators are responsible for ensuring that their radiation workers comply with the bioassay requirements.

19.2 Urinalysis Procedure

Urinalysis enables determination of whether radionuclides have entered the body and, if so, estimation of the doses to specific organs and tissues. Appropriate measures may then be taken to minimize the dose.

Radiation workers shall provide urine samples at the frequency specified in Table 19.1. Authorized investigators shall maintain records of radionuclide usage on inventory forms that identify the radionuclides used, the amount of activity used per procedure, the names of individuals using the material, the dates of use, and whether bioassay samples have been provided. ORS reviews the returned Radionuclide Inventory Forms and compares the information on the forms to the bioassay records to gauge compliance with the bioassay policy. IDNS reviews the program and investigator records during their annual inspection.

Pick up urinalysis containers from ORS and complete the attached label. Bring the samples to ORS. Labels shall specify the date the sample was collected, radiation worker's name, radionuclide for which sampling is required, amount used, authorized investigator's name, and control number of the inventory form to which the sample applies.

Table 19.1 Urinalysis Schedule

Radionuclide	**Amount Used Per Procedure**	**Sample Frequency**
H-3	10.0 mCi	within 1 week of use
H-3 thymidine	1.0 mCi	within 2 weeks of use
P-32	1.0 mCi	within 1 week of use
P-33	7.0 mCi	within 1 week of use
S-35	5.0 mCi	within 2 weeks of use
Ca-45	3.0 mCi	within 1 month of use

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19.3 Thyroid Counting Procedure

Urinalysis is not always the best bioassay method because a radionuclide may be selectively taken up by an organ or tissue. The radioactive emission from the organ may be measured by *in vivo* counting. For example, when I-125 is inhaled or absorbed through the skin, iodine isotopes circulate in the blood and are taken up by the thyroid gland. Most of their decay energy is deposited in this small mass of tissue. Because of the superficial position of the thyroid, escaping photons can be measured directly by scintillation counting.

Routine thyroid counting is required when a worker uses unsealed quantities of radioiodine that exceed at any one time the quantities shown in table 19.2. All workers who either handle radioiodine or are sufficiently close to the process that intake is possible (e.g., within a few meters and in the same room) are required to participate in this program. Euthyroid individuals must provide urine samples in lieu of thyroid counts.

It is useful to have a benchmark against which later counts can be compared. Therefore, a baseline count is required within 2 weeks prior to beginning work with radioiodine. A routine count is required within 72 hours following the use for which bioassay is specified (but waiting at least 6 hours for distribution of a major part of the iodine to the thyroid). If a radiation worker will be unable to meet the 72-hour deadline for any reason, the investigator shall notify ORS in advance of the deadline at the earliest opportunity. Do not plan iodinations if the radiation worker intends to be absent from the workplace for more than 72 hours following the iodination.

As with the urinalysis schedule, radiation workers are responsible for knowing and adhering to the thyroid counting requirements. Thyroid counting is performed in the ORS office in a 10-minute procedure. Call ORS to schedule the count.

Table 19.2 Thyroid Counting Schedule

Type of Operation	**Activity Levels Requiring Thyroid Counting**	
	Volatile/Dispersible	**Bound to Non-Volatile Agent**
Processes in open room or bench with possible escape of iodine from process vessels*	0.1 mCi	1.0 mCi
Processes with possible escape of iodine carried out within a fume hood of adequate design, face velocity, and performance reliability	1.0 mCi	10.0 mCi

*Note: Procedures in which the escape of volatile iodine is a possibility should *always* be done in a fume hood.

20.0 Procurement of Radioactive Materials

20.1 General Requirement

ORS approval of all requisitions is required. Authorized users may order and possess radioactive material up to the authorized limit for each radionuclide. The limit means the total activity of all radioactive material of one radionuclide in stock, in process, and in storage.

20.2 Electronic Ordering

Investigators order radioactive materials using the Electronic Procurement and Payment System (EP^2S). Authorized investigators must ensure that each person placing orders, whether department office staff or laboratory staff, understands these requirements. Direct all questions pertaining to the EP^2S system to the EP^2S helpline. ORS can answer questions pertaining to an investigator's authorized limits or required information on radioactive materials orders. The following items are required on all radioactive material purchase orders. If any one item is missing, ORS will not approve the order.

1. The SHIP TO field for Chicago users must be "RS2," and the BLDG/ROOM field for Chicago users must be "Ward B106". The SHIP TO field for Evanston users must be "RS1," and the BLDG/ROOM field for Evanston users must be "Tech NG65."
2. Enter the name of the *authorized investigator* in the RESP PERSON field. The authorized investigator is the person whose name appears on the authorization form issued by the Radiation Safety Committee. No other name will be accepted.
3. Enter the radionuclide for each item being ordered in the DESCRIPTION field. Examples: P-32, S-35, H-3.
4. Enter the quantity of activity for each item being ordered in units of microcuries (uCi) or millicuries (mCi) in the DESCRIPTION field. Examples: P-32, 250 uCi or P-32, .25 mCi.
5. Enter the chemical form of each item being ordered in the DESCRIPTION field. Example: P-32, dATP, 250 uCi.
6. The COMMODITY CODE must be "Radioactive." Intentional circumvention of the purchasing system by using other than the "Radioactive" commodity code is a violation of University policy subject to enforcement action up to and including suspension of the authorization.

20.3 ORS Electronic Approval

ORS scans EP^2S orders daily and selects the radioactive materials orders for review. If all the above information has been entered correctly and the investigator is authorized to use the material, ORS will approve the order electronically. ORS will not approve purchase orders for radioactive products intended for use outside of authorized University facilities. In other words, an investigator may not use the University purchasing system for radioactive products if the materials will be used in another institution.

20.4 Shipping Address

As previously noted, all radioactive material shall be shipped directly to ORS on the respective campus. Shipment of any radioactive material directly to any other laboratory or room is prohibited. Use the following street addresses for shipments to ORS.

Chicago Campus

Northwestern University
Office of Research Safety
745 N. Fairbanks Ct.
Chicago, IL 60611
Room: Ward B-106 phone: (312) 503-8300
Attn: RSO/_____________ (fill in name of **authorized investigator only**)

Evanston Campus

Northwestern University
Office of Research Safety
2145 Sheridan Rd.
Evanston, IL 60208
Room: Tech Inst. NG65 phone: (847) 491-5581
Attn: RSO/_____________ (fill in name of **authorized investigator only**)

20.5 Blanket Orders

The blanket order method of procurement is allowed. Blanket orders shall contain all of the information listed in section 20.2. The product description shall list each specific radionuclide, maximum authorized activity, and chemical form for all the materials the investigator expects to order on the blanket. Enter the blanket expiration date in the product description field. In addition, the print class for new blanket orders must be “FA” (fax) or “MO” (mail out).

20.6 Orders Placed Directly with Vendors

Placing orders for radioactive materials directly with vendors without prior ORS approval is prohibited.

20.7 Delivery, Inspection, and Authorized Limits

Couriers deliver shipments directly to ORS. ORS inspects each package for removable contamination on exterior surfaces and may make exposure-rate measurements for some packages. ORS checks inventory records to ensure that the package contents are approved and within authorized activity limits. ORS delivers shipments to the laboratory as soon as possible following delivery.

If the investigator’s authorized limit would be exceeded by adding the shipment to inventory, ORS shall not deliver the shipment to the laboratory. ORS shall not release the shipment until the investigator documents on an inventory form that sufficient activity of the radionuclide has decayed, been consigned to waste, or been transferred with ORS approval to another authorized investigator so the authorized limit is not exceeded.

20.8 Radionuclide Inventory Form

ORS issues a three-part Radionuclide Inventory Form for each shipment. After checking in the shipment, ORS prints the inventory form, removes and keeps the top (white) copy, and updates the investigator's inventory database. The second and third copies of the inventory form accompany the shipment to the laboratory. The authorized investigator shall ensure that each radiation worker does the following:

- Maintains records of each instance of radionuclide usage on the inventory form, including date used, activity used (in quantities of millicuries, mCi, or microcuries, uCi), bioassay samples provided, and the complete name of the person using the material (initials alone are not acceptable).
- Uses the inventory form to record decay corrections, activity consigned to waste, and activity transferred to another authorized investigator with prior approval of ORS.
- Returns the inventory form to ORS immediately when the material balance reaches zero.

Do not keep inventory records in units of volume or concentration. ORS records, including inventory, bioassay, and waste disposal, are maintained in units of mCi or uCi or their SI equivalents. Units of volume or concentration cannot be used to determine compliance.

Consigning material to waste is considered to be an inventory reduction. The only ways in which an investigator may remove material from inventory are radioactive decay, consignment to waste, and transfer to another authorized investigator. When all activity has been removed from inventory according to prescribed procedures, return one copy of the form promptly to ORS and keep one copy for your records. ORS then will delete the activity from the inventory record.

20.9 Correlating Inventory Forms with Stock Vials

Investigators shall maintain an inventory form for each source or stock vial in their possession. IDNS inspectors may review this correlation during inspections.

20.10 Radioactive Material Received from Other Sources

Radioactive material received outside of normal purchasing channels (i.e., material received from another institution) shall be brought to ORS immediately on receipt and prior to any use of the material. Inspection and inventory policies and procedures are the same as for orders placed through normal purchasing channels.

20.11 Replacement Shipments and Samples

The same preapproval, inventory and shipment address conditions apply to materials such as replacement shipments or samples sent for evaluation.

20.12 Radioactive Material to be Used at Other Institutions

ORS will not approve purchase requisitions for radioactive material to be used at other institutions.

21.0 Transfer of Radioactive Material

21.1 General Requirement

Transfer of radioactive material between investigators, campuses and institutions is prohibited without prior approval of ORS. Call ORS before transferring any material, regardless of the radionuclide or activity. Transfers are governed by license conditions reflecting the policies and regulations of each involved institution, so allow time for completing the necessary groundwork in advance of the transfer.

21.2 Intracampus Transfer to Another Investigator

Call ORS in advance for approval. ORS will adjust the inventories for both investigators. Record the transfer on your Radionuclide Inventory Form. ORS will provide a new inventory form to the recipient. Packaging for all transfers must meet the following basic requirements:

- Use a strong, tightly sealed inner container with a secure cap or tight seal.
- Surround this inner container with enough absorbent material to contain at least twice the volume of any liquid within the container.
- Make sure there is no contamination on the container.
- Put a label on the container specifying the radionuclide, the activity, and the date.
- Use an unbreakable secondary container to hold the material in case the inner container spills or breaks.

21.3 Intercampus Transfer

Call ORS in advance for approval. Follow all packaging instructions in 21.2. Bring the package to ORS for inspection of the packaging, a contamination check, and inspection of any labels, markings, and documents required for transportation. Advance review and approval by ORS is required because transportation of some radioactive materials by investigators is prohibited by law. You may ship the package after ORS has approved the packaging, documentation, and mode of transportation. The package shall be delivered to ORS on the recipient's campus. Record the transfer on your Radionuclide Inventory Form. ORS will provide a new inventory form to the recipient.

21.4 Transfer To Other Institutions

Call ORS in advance for approval. Before the transfer can be approved, the authorized user shall verify that the recipient institution's license authorizes the type, form, and quantity of radioactive material to be transferred. There are several acceptable methods of verification:

- The authorized investigator may obtain a copy of the recipient institution's license or registration certificate.
- The authorized investigator may obtain a written certification that the recipient institution is authorized by license or registration certificate to receive the material, specifying the license or registration certificate number, issuing agency, and expiration date.
- For emergency shipments, the authorized investigator may obtain oral certification from the recipient that the recipient institution is authorized by license or registration certificate to receive the material, specifying the license or registration certificate number, issuing agency, and expiration date, providing the oral certification is confirmed in writing within 10 days.

When the license or registration certificate verification is received, you may contact the courier of your choice. Follow all packaging instructions in 21.2. Bring the package to ORS for an inspection of the packaging, a contamination check, and review of any labels, markings, and documents required for transportation. Courier documents must be filled out by the shipper, not by ORS. Record the transfer on your Radionuclide Inventory Form.

21.5 Transfer From Other Institutions

Call ORS in advance for approval. ORS can provide a copy of the University license to the other institution on request. All radioactive material shall be shipped to ORS. ORS will inspect and deliver the material in the same way as material purchased from a vendor, and issue a Radionuclide Inventory Form to the recipient.

22.0 Radioactive Waste

22.1 General Responsibilities

The generation, regulation, and disposal of radioactive waste are among radiation workers' most important activities. *Generation* involves much more than simply creating contaminated material; it also involves controlling the composition and volume as well as paying attention to chemical, biological, and radiation safety and record keeping. *Regulation* involves complying with the evolving requirements of the University, governmental agencies, waste brokers, and waste-site operators. *Disposal* involves handling of the wastes by many individuals and businesses in the chain of custody from the generator to the disposal site.

The generator has cradle-to-grave responsibility for hazardous wastes, a responsibility that never can be relinquished. There are institutional, civil, and criminal penalties for failure to fulfill generator's obligations, so you must exercise positive control over what you place in radwaste containers and associated records. Disposal of any radioactive material except by ORS is prohibited without express prior consent of ORS.

22.2 Reducing Non-Radiological Hazards

Illinois regulations state, "Waste containing hazardous, biological, pathogenic, or infectious material shall be treated to reduce to the maximum extent practicable the potential hazard from the nonradiological materials." The goal is twofold: to minimize the potential hazards to those persons handling the waste at each step of the disposal process, and to minimize the potential impact on the biosphere.

22.2.1 Reducing Biological Hazards

The authorized investigator shall ensure that radioactive waste containing hazardous biological, pathogenic, or infectious material is treated to reduce the hazard from non-radiological materials to the maximum extent practicable. Potentially infectious material shall be chemically disinfected or autoclaved prior to placing it into radioactive waste containers. Liquid waste shall be treated to prevent or inhibit biological growth. Autoclaving is generally not recommended for radioactive wastes because of the potential for contaminating equipment and generating radioactive vapors. Contact ORS before generating mixed infectious/radioactive waste for guidance in its handling.

22.2.2 Reducing Physical Hazards

Radioactive waste shall be treated to reduce to the maximum extent practicable the physical hazards from needles, broken glass, and other sharp objects. Needles and other sharp objects shall be collected only in appropriate sharps containers and shall not be placed loose into radioactive waste containers.

22.2.3 Reducing Chemical Hazards

Radioactive waste shall be treated to reduce chemical hazards to the maximum extent practicable. ORS strongly encourages you to use experiment procedures that do not generate mixed chemical and radioactive waste. Carcinogens, reproductive toxins, and other highly toxic materials shall be treated to reduce their hazards to the maximum extent practicable, however be aware that EPA restrictions on treatment in the laboratory may severely limit your options. Neutralizing inorganic acids is one of the few approved treatments. Contact ORS for approved treatment procedures. Extraordinary costs related to disposal of mixed waste may be charged back to the user.

22.3 Radiation Protection

Radioactive waste containers may be significant sources of contamination and external dose. Authorized investigators shall take appropriate steps to ensure that the collection and storage of radioactive waste is done safely and in accordance with all applicable policies and procedures. These guidelines will help reduce the hazards from your radioactive wastes:

- Use the strategies of time, distance, and shielding. Keep radwaste containers close to the radiation work area and away from desks and other frequently occupied areas. Shield wastes just as you would shield your stock materials; use high-density shields for gamma emitters and plastic shields for beta emitters. Shield benchtop waste collection apparatus.
- Control volatility. Airborne radioactive material may be a problem with radioiodine, sulfur-labeled amino acids, metabolic products in animal experiments, liquid scintillation media, and

other wastes. Control volatility in liquid radioiodine wastes by adding a solution of 0.1 M sodium hydroxide, 0.1 M sodium iodide, and 0.1 M sodium thiosulfate. Collect dry wastes with volatile components in tightly sealed plastic bags before putting them into radwaste drums. Keep all containers tightly closed. If wastes are stored in fume hoods, keep the waste in the rear of the hood, in small containers. Do not freeze sodium iodide, because the evolution of volatile components may increase when it is thawed. Do not store volatile wastes in laminar flow cabinets or biological safety cabinets or any location where potentially contaminated air is recirculated into the room. Store liquid scintillation media in a well-ventilated area.

- Control contamination. Protect work surfaces under waste containers. Do not invert lids on dry waste containers. Do not set equipment on top of waste containers. Securely bag dry waste being carried to the dry-waste container. Use secondary containers when carrying liquid wastes to the waste container. Do not overfill containers. Use a funnel with liquid wastes. Use protective gloves every time containers are handled. Perform routine contamination checks. Use strong, leakproof plastic bags for animal carcasses.
- Needles and other sharps contaminated with radioactive material shall be collected in puncture-resistant containers. Needles and needles attached to syringes (even if they are capped) shall not be placed loose in radioactive waste containers. To prevent puncture wounds from contaminated needles, recap or remove them *only* when no alternative is feasible. Any recapping or removal should be accomplished through the use of a mechanical device or a one-handed technique.
- Use protective clothing and equipment. Always wear lab coats, gloves, and eye protection when handling radioactive waste.
- If you were issued a dosimeter, wear it.
- Report all spills and injuries that occur when handling radwaste.

22.4 Radwaste Record Keeping

Authorized users and radiation workers shall maintain written records of activity for each radionuclide consigned to waste. These records should be decay-corrected. You should be able to account for all activity in your inventory. ORS reviews records of radionuclide use and performs independent analysis of radionuclides in waste containers to ensure that record keeping is accurate. Wastes that do not conform to record-keeping requirements may not be accepted for disposal. Two forms are used for radionuclide record keeping:

- ORS issues the Radionuclide Inventory form for each shipment of radioactive material to the laboratory. Radiation workers shall use it to record activity disposed as waste. Accurate record keeping on this form will help you estimate activity in waste containers. Keep records of activity in uCi or mCi or their SI equivalents (becquerels).
- The Radioactive Waste Card shall be attached to each liquid waste container, each dry waste container (including nonstandard containers), each collection of five or fewer trays of scintillation vials or each box of mini vials, each container of uranyl acetate, and each bag of animal carcasses. The only acceptable units of activity on a waste card are microcuries (uCi), millicuries (mCi), or their SI equivalents (becquerels). Activity concentration values are not acceptable.

Investigators shall maintain a written record of the waste placed into each container. It could be a separate log, however the information shall be available at all times and shall be transcribed onto the waste card prior to pickup.

22.5 Uranyl Acetate and Staining Solutions

Dry uranyl acetate shall be collected and disposed of as radioactive waste. Record the total number of grams of uranyl acetate in the container. Never combine uranyl acetate with any other chemical waste, such as lead citrate. Aqueous uranyl acetate solutions may be poured down the drain provided they do not contain any hazardous chemicals.

22.6 Chelating Agents

The presence of high concentrations of chelating agents in the radwaste may have an effect on waste-site stability. The radioactive waste card shall indicate the name and weight percentage of any chelating agents that are present in excess of 0.1% by weight. Chelating agents are amine polycarboxylic acids (e.g., EDTA, DTPA) and hydroxy-carboxylic acids (e.g., citric acid, carbolic acid, and glucinic acid) used for the purpose of binding (i.e., to stabilize radioactive materials).

22.7 Mixed Wastes

Mixed waste contains radioactive material and one or more hazardous chemical components. Most chemicals classified by the EPA as hazardous under the Resource Conservation and Recovery Act (RCRA) may not be released to water, air, or landfill. Hazardous waste contractors will not accept radioactive material. Therefore, mixed wastes become “orphan” wastes with no disposal options. To avoid conflicts between regulatory requirements and prudent safety and health practices, avoid generation of mixed radioactive and RCRA hazardous waste. Prevent cross-contamination of radioactive and nonradioactive components. Substitute non-radioactive materials or non-hazardous chemicals in your processes. Do not place lead pigs, other elemental lead or lead-containing materials into radioactive waste containers.

22.8 Biohazard Bags

The use of bags bearing the word "biohazard" or the biohazard symbol for the collection of radioactive waste is prohibited. For legal reasons and for the protection of waste handlers, these two waste streams may not be mixed. As previously stated, mixed biohazardous and radioactive waste must be treated to reduce the nonradiological hazard to the maximum extent practicable. After this is done, the material is no longer biohazardous and the biohazard bag is no longer appropriate. Bags that once contained mixed biohazardous and radioactive waste that has been autoclaved should be overbagged with an opaque bag before the waste is placed in radioactive waste containers.

22.9 Radwaste Labels

Each container of radioactive waste shall bear a label or tag identifying the contents at all times; identifying the nuclide in the container is essential. All labels, tags, tape, stickers and markings that indicate the presence of radioactive material or bear the radiation warning symbol shall be removed or defaced before they are placed in radwaste containers.

22.10 Requests for Pickup

ORS picks up radioactive waste on request. Call ORS at 3-8300 (Chicago campus) or 1-5581 (Evanston campus) and report the types of containers and radionuclides to be picked up. Waste must be placed in standard containers, accessible and ready for pickup at the time of the call. Radioactive waste cards shall be completely filled out at the time of the call. Unless requested otherwise, ORS will replace your full containers with empty ones. ORS is not obligated to remove improperly filled waste containers or containers for which the radioactive waste card has not been properly completed. Waste will be picked up *only* when all packaging and record-keeping requirements have been met. Provide the following information when you call:

- Authorized investigator's name.
- Caller's name.
- Location of the waste.
- Caller's telephone number.
- Number and size of each container to be picked up.
- Nuclide(s) in each container
- Any special instructions (such as whether the laboratory will be locked).

22.11 Radwaste Containers

ORS supplies a variety of standard radioactive waste containers at no charge. The standard containers shall be used for final disposal unless permission to use other containers has been granted by ORS. ORS attaches “caution, radioactive material” labels to each container which shall not be removed or defaced. These containers are recycled; please do not write on them or apply stickers or tape.

- Dry-Waste Containers. Fiberboard containers are available in 10-gallon and 22-gallon sizes. These containers have metal tops with spring closures, plastic liners, appropriate labels, and a pocket for the waste card.
- Liquid-Waste Containers. Plastic carboys are available in 1-gallon and 5-gallon sizes. Each carboy has appropriate labels and a pocket for the waste card.

22.12 Liquid Radioactive Waste

Separate handling is required for the two types of liquid radioactive wastes, aqueous and nonaqueous.

22.12.1 Aqueous Waste

Aqueous waste denotes any solution of which the primary constituent is water and any soluble organic and inorganic constituents, all present in quantities and forms that do not result in phase separation or precipitation. Depending on the quantity of organic or inorganic components, aqueous waste may also be defined as a mixed waste. Even small amounts of substances, when combined with nonhazardous materials, may result in mixed wastes. For example, a solution of 6% methanol in water is a mixed waste. Consult ORS before adding any organic material to aqueous wastes. Aqueous waste shall be collected separately from nonaqueous waste. The following guidelines apply:

- No more than two radionuclides shall be collected in any one container. See Table 22.1.
- The pH of aqueous wastes shall be adjusted as close to neutral as possible, and pH shall be within the range pH 5 to pH 9. Solutions should be buffered if necessary to maintain pH in the acceptable range. ORS personnel may check the pH before removing waste from the laboratory.
- Wastes shall be treated to reduce the nonradiological hazards and inhibit bacterial growth.
- Do not overfill containers. Leave at least three inches of space at the top of the container.
- Records shall be maintained of radionuclides and activity in the waste. A properly filled-out radioactive waste card shall be attached to each container. Acceptable units of activity are total uCi or mCi or their SI equivalents (becquerels) in the container. Activity concentration values are not acceptable.
- Aqueous wastes containing I-125 should be neutral or basic, securely capped, and stored in a well-ventilated area. Volatility in liquid radioiodine wastes may be controlled by adding a solution of 0.1 M sodium hydroxide, 0.1 M sodium iodide, and 0.1 M sodium thiosulfate.

Table 22.1 Acceptable Radionuclide Combinations in Liquid Radwaste

	H-3	**C-14**	**P-32**	**P-33**	**S-35**	**Ca-45**	**Cr-51**	**Rb-86**	**I-125**	**I-131**
H-3	X	X	X	X	X		X	X		X
C-14	X	X	X	X	X		X	X		X
P-32	X	X	X	X	X	X	X	X	X	X
P-33	X	X	X	X	X		X	X		X
S-35	X	X	X	X	X		X	X		X
Ca-45			X			X		X		X
Cr-51	X	X	X	X	X		X	X		X
Rb-86	X	X	X	X	X	X	X	X	X	X
I-125			X					X	X	X
I-131	X	X	X	X	X	X	X	X	X	X

22.12.2 Organic Liquid Wastes

Organic liquid waste is any solution of which the primary constituents are organic chemicals. They may contain water or other organic and inorganic constituents, in quantities and forms that do not result in precipitation. Examples of organic liquid radwaste are bulk liquid scintillation fluid, HPLC fluid, and chloroform. Organic liquid radwaste shall be collected separately from aqueous liquid radwaste.

- Acceptable combinations of radionuclides. See Table 22.1 for acceptable combinations.
- Chemical composition. The radioactive waste card shall describe the chemical constituents of the waste as well as all other required information.
- Flammable radioactive waste. Bulk flammable liquids shall be stored in approved flammable material storage cabinets or, if quantities are less than 10 gallons, in safety cans.
- Hazard reduction. Organic liquid radwaste shall be treated to reduce to the maximum extent practicable the hazards from the nonradioactive components. The generator shall inform ORS of the presence of any hazardous, nonradioactive component.
- Record keeping. Records shall be maintained of radionuclides and activity in the waste. A properly filled-out radwaste card shall be attached to each container. Acceptable units of activity are total uCi or mCi or their SI equivalents (becquerels) in the container. Activity concentration values are not acceptable.
- Do not overfill containers. Leave at least three inches of space at the top.
- Control volatility. Organic wastes may give off vapors that are both chemical and radiation hazards. Securely cap containers and store them in well-ventilated areas. If wastes are stored in a fume hood, use small containers located in the rear of the hood.

22.12.3 Phase Separation and Precipitation

Investigators shall identify each phase chemically and radiologically if phase separation occurs. Investigators should also be aware that precipitates may contain significant amounts of radioactive material that cannot be identified by analysis of the liquid fraction. Liquid wastes containing precipitates may not be picked up for disposal until the precipitate and activity in the precipitate are identified by the investigator.

22.13 Dry Radioactive Waste

- Acceptable radionuclide combinations. Only one radionuclide shall be placed in any dry-waste container for P-32, P-33, S-35, Cr-51, I-125 and any other radionuclide with a half-life of less than 90 days.
- No liquids allowed. No liquids of any kind shall be placed in dry-waste containers, with the exception of residual liquid in emptied vessels or equipment and very small quantities (such as one milliliter or less) in microfuge tubes and other small vessels.
- Remove lead pigs. All lead shall be removed from dry waste and stored separately for pickup.
- Remove labels. All labels, tags, signs, and stickers indicating the presence of radioactive material or bearing the radiation warning symbol shall be removed or defaced before waste is put into the container.
- No loose needles or unprotected sharps allowed. Needles and other sharp objects shall be collected in puncture-resistant containers.

- Treat waste to reduce nonradiological hazards. Waste potentially contaminated with pathogenic organisms shall be treated by autoclaving or chemical disinfection. Carcinogens, teratogens, other highly toxic materials, and physical hazards shall also be treated.
- Record keeping. Records shall be maintained of radionuclides and activity in waste. A properly filled-out radwaste card shall be attached to each container. Acceptable units of activity are uCi or mCi or their SI equivalents (becquerels).
- Containers. Dry waste shall be collected in the standard fiberboard containers provided by ORS. Very small volumes of dry waste may be collected in strong, tightly sealed plastic bags, which in turn are placed in closed cardboard boxes to which a standard waste card is attached. When standard containers are full, seal the plastic liner with a twist tie and replace and seal the metal top. Do not overfill containers.

22.14 Liquid Scintillation Vials/Bulk LSC Fluid

Solvent-based liquid scintillation media (LSC fluid) is a mixed waste containing hazardous chemical components and a radioactive component. The guidelines for collecting organic liquid radwaste apply to LSC fluids which are collected in the laboratory in bulk. The following guidelines apply to LSC fluids that are collected in the original vials. All LSC waste shall be disposed of through ORS. Disposal of any radioactive material by generators is prohibited. This includes so-called biodegradable LSC waste.

- Vials containing H-3 and/or C-14 shall be segregated from other vials and shall bear a separate radioactive waste card.
- Return standard vials to their vial trays. Return minivials to original boxes. Ideally, vials should be kept vertical during collection and storage to avoid leakage. If vials are collected in plastic bags, the bags must be chemically compatible, strong enough to contain any leakage and securely tied. Ordinary trash bags are not adequate. Do not use biohazard bags. Bags of vials shall be placed in closed boxes for pickup. Boxes and bags of vials shall have waste cards attached. An appropriate "caution, radioactive material" tape, sticker, label, or marking must appear on the box or bag.
- Vials shall not be combined with any other waste (e.g., gloves, stock vials, etc.)
- Guard against spillage. Make sure vials are securely capped. Handle glass vials carefully to avoid breakage.
- Minimize nonradiological hazards. The chief nonradiological hazard is evolution of solvent vapors. Make sure vials are securely capped, kept from breaking, and stored in well-ventilated areas in small quantities. Always wear protective clothing--gloves, lab coat, and protective eyewear--when working with LSC media.
- Record keeping. Record keeping is one of the most important aspects of LSC waste disposal. LSC waste is a waste category for which the generator should be able to determine the activity with a high degree of confidence because all vials are analyzed in the laboratory.

LSC waste is divided into two waste streams based on the radionuclides present and the average activity per gram of media: (1) H-3 and C-14 waste with an average activity of less than 0.05 uCi per gram of media (330,000 Bq per gram), and (2) all other LSC waste. Make estimates of activity based on calculations from actual vial counting or product yields, labeling efficiencies, analysis of aqueous wastes, fractionation of activity into different process streams and so on. The following sample calculation illustrates the standard method of determining the activity in a set of vials. Determine counting efficiency by counting a standard of known activity and similar composition and dividing counts per unit time (cpm) by activity of the standard (dpm).

Equation 22.1 Activity in LSC Vials

$$\textit{Total uCi} = \frac{\textit{(average cpm per vial) (total number of vials)}}{\textit{(counting efficiency) (} 2.22 \times 10^6\textit{)}}$$

Example:

average net cpm per vial = 1,100 cpm
counting efficiency = 0.4 cpm/dpm (40%)
total number of vials = 500

$$\frac{(1{,}100 \text{ cpm}) (500 \text{ vials})}{(0.4 \text{ cpm/dpm}) (2.22 \times 10^6)} = 0.62 \text{ uCi}$$

An average of 0.05 uCi per gram of media amounts to about 250 microcuries per case of standard 20 milliliter vials (500 vials). It is very unlikely that activity concentrations this high are routinely used in normal laboratory procedures. Generators should be prepared to justify--with supporting calculations or printouts--LSC waste activity that exceeds 100 microcuries per case of standard vials, per bag or box of minivials, or per container of bulk LSC fluid. If activity on waste cards exceeds 100 uCi of H-3 and/or C-14 and supporting documentation is not provided, ORS may request it. It is important to have a realistic assessment of activity in these wastes.

22.15 Biological Waste

Biological waste consists primarily of animal carcasses and animal bedding. It may also include specimens in vials or other containers.

- Place carcasses and tissues in strong, tightly closed, leakproof plastic bags at the conclusion of the procedure.
- Do not put nonbiological material in these bags. Collect paper, plastic, foil, syringes, absorbent, and so forth separately as dry waste and treat it, if necessary, to reduce nonradiological (primarily pathogenic) hazards.
- Freeze carcasses while awaiting pickup.
- Collect contaminated bedding in strong, tightly closed, leakproof plastic bags, place in a dry-waste drum and add lime (available from ORS). Note appropriate waste card information.
- A completed radioactive waste card shall be attached to each bag of carcasses. Record the radionuclide and the total amount of activity in the bag. Acceptable units of activity are uCi or mCi or their SI equivalents (becquerels).
- Needles and other sharps shall not be placed in bags with animal carcasses.
- Tissue samples shall be drained and consolidated and then collected in strong, tightly closed, leakproof plastic bags. Freeze them while awaiting pickup and attach a radioactive waste card. Do not dispose of tissue samples with LSC vials.
- Eggs must be collected separately as biological waste.

23.0 Radioactive Materials in Experimental Animals

23.1 General Responsibilities

ORS and the Center for Experimental Animal Resources (CEAR) cooperatively oversee safety and regulatory aspects of projects involving animals treated with radioactive materials. CEAR facilities are considered an extension of the investigator's laboratory for the purpose of controlling radioactive materials, so the same radiation safety precautions and record-keeping requirements apply. There are additional requirements, however, because multiple investigators may share CEAR facilities and CEAR personnel may help care for the animals.

23.2 Animals Housed in CEAR Facilities

Investigators proposing to treat animals with radioactive materials and house them in CEAR facilities must (1) contact CEAR for acquisition and housing of the animals and fulfillment of CEAR and Animal Care and Use Committee (ACUC) requirements, and (2) obtain authorization from the Radiation Safety Committee for the radionuclide, activity, and proposed use.

Obtain the form Protocol for Radioactive Materials in Experimental Animals from ORS. CEAR may also require the Application for Containment Facility Usage form. Submit the Protocol to ORS at least 2 weeks prior to initiating the experiment. ORS will review the Protocol and may make specific recommendations to the investigator and CEAR regarding radiation safety and compliance with program requirements including but not limited to:

- Record keeping.
- Radioactive waste pickup coordination.
- Personnel dosimetry.
- Protective clothing and equipment.
- Radiation safety surveys.
- Radiation safety practices during administration of the radioactive material.
- Continuing responsibilities for animals not sacrificed at the end of the experiment.

The investigator shall notify CEAR and ORS at least five days prior to administration of radioactive materials to animals that are to be housed in CEAR facilities. ORS may then supply appropriate waste containers, dosimeters, etc., to the investigator and/or CEAR personnel. Investigators shall keep records of estimated activity excreted and consigned to waste containers. The investigator usually is responsible for handling of contaminated bedding and cage cleaning. Authorized investigators are responsible for ensuring compliance with all radwaste requirements.

The investigator shall notify ORS when animal housing in CEAR facilities is concluded. If animals are sacrificed, carcasses shall be bagged, tagged, and frozen while awaiting pickup. ORS will pick up carcasses and waste and will survey equipment and facilities. Decontamination of cages, facilities, and equipment is the responsibility of the authorized investigator.

If animals are not sacrificed and are still excreting activity, all animal care and radiation safety protocols continue as before, until the animals are sacrificed or until activity is no longer excreted. If animals are not sacrificed and activity is not being excreted, ORS will pick up waste if necessary and survey equipment and facilities.

Incineration of animal carcasses containing radioactive materials, regardless of whether activity was still being excreted at the time of sacrifice, is prohibited in University facilities unless specific permission has been granted by ORS. Do not place carcasses containing radioactive materials into the CEAR carcass freezers.

23.3 Animals Housed in the Laboratory

University policy requires that animals be housed in CEAR facilities. Authorized users shall obtain approval from the ACUC to house any animals outside of CEAR facilities for periods greater than 12 hours. In addition, CEAR and ORS shall be notified at least five working days prior to commencement of such a project. See the *Animal Care and Use Training Handbook* or call CEAR for detailed information. Cages potentially contaminated with radioactivity or chemicals shall be stored in the laboratory with appropriate precautions and shall be decontaminated before being returned to CEAR.

23.4 Record Keeping

Investigators are expected to be sufficiently knowledgeable about the radionuclide kinetics in the animals with which they work to make reasonable estimates of the amount of activity that will be excreted (and by what routes) and the amount of activity, if any, that will remain in the carcass if sacrificed. Waste containers placed in CEAR facilities shall be assigned to a single investigator, and it is that investigator's responsibility to complete waste card information.

23.5 Radiation Safety

Several investigators may share a single CEAR facility, and CEAR personnel as well as the investigators' employees and students may be involved. Key safety considerations are:

- Use appropriate personal protective clothing and equipment including gloves, gowns or lab coats, and eye protection.
- Use appropriate dosimeters.
- Use time, distance, and shielding strategies to minimize dose during administration of radionuclides, housing animals in CEAR, and housing animals in the laboratory.
- Practice contamination control at the point of administration, in CEAR and in laboratories.
- Survey administration areas to identify contamination and promptly clean it up.
- Handle sharps safely. Prevent puncture wounds from contaminated needles by recapping or removing them only when no alternative is feasible. Accomplish any recapping or removing by use of a mechanical device or a one-handed technique. Never place loose needles, whether capped or not, in radioactive waste containers.

24.0 Irradiators

24.1 General

Two department-owned gamma irradiators are available for use by all investigators with permission of the owner and authorization from the Radiation Safety Committee. Contact the Microbiology-Immunology Department for permission to use the irradiator on the Chicago campus. On the Evanston campus, contact the Biochemistry, Molecular Biology, and Cell Biology Department.

24.2 Authorization

When you have secured permission to use the irradiator, obtain an application from ORS. The Radiation Safety Committee must approve the application. Irradiator applications stand alone; applicants do not need to have a radioactive materials authorization, and the application procedure is separate from any radioactive materials application.

24.3 Training

Each user must register as a radiation worker. Each user, including the applicant, shall be trained in irradiator procedures and radiation safety by ORS prior to first using the irradiator. It is the responsibility of the authorized user to ensure that radiation workers receive this training, which is separate from any other radiation safety training. Use of the irradiator by any person who has not had specific training provided by ORS is prohibited.

24.4 Dosimetry

Each user shall have and correctly use appropriate personnel dosimetry (e.g., body badge) when operating the irradiator. It is the responsibility of the authorized user to ensure that radiation workers register, and obtain and use appropriate dosimeters.

24.5 Inspection and Calibration

ORS tests gamma irradiators for leakage and safety features at least semiannually. Dose calibration, routine maintenance and repair are the responsibility of the respective owners. ORS is available to consult and advise on these activities. IDNS inspects irradiator records annually.

24.6 Site-Specific Instructions for Chicago Irradiator

- Call ORS to schedule training and dosimetry after authorization is granted by the Radiation Safety Committee and prior to using the equipment.

- ORS distributes keys to the facility and irradiator to authorized investigators. Authorized investigators are responsible for key control and ensuring that only those radiation workers who have met the training and dosimetry requirements use the equipment.
- The door to the facility shall be kept locked at all times except when loading and unloading samples.
- Persons using the irradiator shall wear appropriate personnel dosimeters (body badges).
- In the event of irradiator malfunction or unusual occurrence:
  - ⇒ Turn off the machine, if possible.
  - ⇒ Leave the room and lock the door.
  - ⇒ Call ORS at 3-8300 or call University Police at 456 and ask them to page ORS.
  - ⇒ Follow ORS instructions and prohibit access to the room.
- Each user shall sign the logbook located in the facility prior to each use of the equipment. ORS inspects the logbook at frequent intervals.

24.7 Site-Specific Instructions for Evanston Irradiator

- Call ORS to schedule training and dosimetry after approval has been granted by the Radiation Safety Committee and prior to using the equipment.
- Access to keys is provided following training. Authorized investigators are responsible for key control and ensuring that only radiation workers who have met the training and dosimetry requirements use the irradiator.
- The facility door shall be kept locked at all times unless facility is occupied by a trained user.
- Persons using the irradiator shall wear appropriate personnel dosimeters (body badge).
- In the event of a malfunction or unusual occurrence:
  - ⇒ Turn off the machine, if possible.
  - ⇒ Leave the room and lock the door.
  - ⇒ Call ORS at 1-5581 (Evanston), or call University Police at 456.
  - ⇒ Follow ORS instructions and prohibit access to the room.
- Each user shall sign the logbook located in the facility prior to each use of the equipment. ORS inspects the logbook at frequent intervals.

25.0 X-Ray Producing Equipment

25.1 General Considerations

Research and medicine utilize numerous types of X-ray equipment including analytical, medical, dental, fluoroscopic, veterinary, cabinet systems and electron microscopes. All units are registered under one of three state registrations maintained by ORS. In this section, the term “registrant” refers to the equipment owner or the person with official responsibility for the equipment. The term “operator” refers to any person actually using the equipment. All operators except for electron microscope users are radiation workers and shall register with ORS prior to using the equipment.

Regulations vary according to the type of X-ray equipment, so the following information--which includes most of the regulations--is grouped by type. Operators are expected to understand and follow the regulations for the type of equipment used. You may view or obtain a copy of the regulations in the ORS office on either campus.

25.2 Analytical X-Ray

The predominant X-ray-producing equipment used for nonmedical purposes is analytical X-ray. It produces intense beams of low-energy X-rays that can cause severe and permanent bodily injury to exposed persons. Because of the equipment configuration, most exposures are to the fingers and hands. Exposure of the lens of the eye may occur if visual alignment is performed while the equipment is operating. Despite the low energy of the X-rays, beam intensities up to 40,000 roentgens per minute may be possible. Radiation hazard is not restricted to the primary beam because ill-fitting or defective equipment may produce leakage or scatter radiation. Analytical samples or other material in the beam may give off secondary radiations, and diffracted beams are emitted at almost any angle from the primary beam.

25.2.1 Dosimetry

ORS provides ring dosimeters for all operators. Each operator shall obtain and properly use dosimeters. On most equipment, interlock mechanisms or other design features prevent exposures during routine operation; however, unnecessary exposure is possible during beam alignment or sample manipulation so dosimeters always should be worn when working around energized equipment. If an exposure is suspected, safeguard the dosimeters to prevent loss.

25.2.2 Required Training

Registrants or facility supervisors shall provide operators with specific written instructions. Complete instructions shall include notice of radiation hazards; safe work practices; symptoms of acute, localized exposure to radiation; and procedures for reporting actual or suspected radiation exposure. Registrants and supervisors shall provide operators with specific instructions for the equipment they will use. Each operator also shall view the training videotape before first operating the equipment. Schedule viewing by calling ORS in Evanston at 1-5581.

25.2.3 Required Postings

The registrant shall post the following documents near the controls of each analytical X-ray unit:

- Specific written instructions (see section 25.2.2)
- Analytical X-Ray Emergency Procedure (see section 25.2.8)
- Symptoms of Injury from Acute Local Exposure to Radiation (see section 25.2.9)
- Radiation Hazards from Analytical X-Ray Units (see section 25.2.10)
- Safe Working Practices for Analytical X-Ray (see section 25.2.11)

25.2.4 Required Labels

The registrant shall place the following labels and signs on analytical X-ray equipment:

- A label bearing the words "Caution--Radiation--This Equipment Produces Radiation When Energized" shall be placed near any switch that energizes a tube. You may obtain this label from ORS.
- A sign bearing the words "Caution--High-Intensity X-Ray Beam," or words having a similar intent, shall be placed in the area immediately adjacent to each tube head. The sign shall be located so that it is clearly visible to any person operating, aligning, or adjusting the unit or handling or changing a sample.

25.2.5 Required Indicators

The registrant shall provide the following indicators that signal whether the beam is on or off and whether safety features are engaged. Such indicators should never be defeated or tampered with.

- A clearly visible indication of the presence of an X-ray beam shall be provided on or immediately adjacent to each tube head.
- A clearly visible indication of the status of each shutter (i.e., open or closed) shall be provided.

25.2.6 Required Interlocks and Safety Devices

Registrants shall ensure that the following rules for interlocks and safety devices are followed:

- In cases where the primary X-ray beam is not intercepted by the experimental apparatus under all conditions of operation, protective measures such as auxiliary shielding shall be provided to avoid exposure to the primary X-ray beam.
- Whenever possible, an interlocking device shall be provided that prevents the entry of any portion of an individual's body or extremities into the primary beam, or causes the primary beam to shut off upon any entry into its path.
- If for any reason it is necessary to alter safety devices temporarily, such as bypassing interlocks or removing shielding, such action shall be (1) specified in writing; (2) posted near the X-ray tube housing so that other persons will know the current status of the machine; and (3) terminated as soon as possible.
- Unused tube ports shall be closed so that accidental opening is not possible.

25.2.7 Required Monthly Checklist

Each registrant or supervisor shall submit the Monthly Analytical X-Ray Safety Checklist to ORS. Obtain the form from ORS.

25.2.8 Analytical X-Ray Emergency Procedure

Equipment involved in an accidental exposure must be secured against use. It must be inspected by ORS before operation can resume. In case of accidental exposure to the primary beam or scattered radiation, either suspected or actual:

- Turn off power to unit.
- Notify Research Safety by calling 1-5581 (Evanston) or 3-8300 (Chicago).
- If you are unable to reach ORS at these numbers, call the University Police emergency number 456 and ask them to page Research Safety.
- Notify Division of Safety and Loss Prevention at 1-3253.

25.2.9 Symptoms of Injury from Acute Local Exposure to Radiation

Dose Received: 200 - 300 rad
Equivalent thermal burn: first
Symptoms: *Erythema* (redness of the skin). Possible reaction within hours of exposure. Sensations of warmth and itching. Major redness may appear two or three weeks after exposure, with the elapsed time dependent on the dose received. Epilation (hair loss) is possible two to three weeks after exposure.

Dose Received: > 1,000 rad
Equivalent thermal burn: second
Symptoms: *Transepidermal injury*. Wet or dry dermatitis. Wet or dry blisters occurring within one or two weeks of exposure. Blisters usually break open, leaving them vulnerable to infection. Epilation is possible and may be permanent.

Dose Received: > 5,000 rad
Equivalent thermal burn: third
Symptoms: *Severe transepidermal injury*. Resembles intense scalding or chemical burn. Immediate onset of intense pain. Epilation is permanent.

Ocular Effects: >200 rad
Symptoms: Conjunctivitis (inflammation of the eye). At acute, lower doses. Chronic exposures can lead to cataracts.

25.2.10 Radiation Hazards from Analytical X-Ray Units

- The primary beam is the most obvious source of possible exposure from an analytical X-ray unit. Typical dose rates may approach 40,000 R/minute. This beam, however, is usually of low energy and can be attenuated with approximately a millimeter of lead. Beams generated from targets composed of material with higher atomic number (such as Mo versus Cu) yield more penetrating X-rays.
- Leakage of the primary beam may be a significant source of unwanted radiation. Shutters and collimators must be properly coupled and unused ports secured to prevent accidental opening. Remember to use an adequate beam stop and to collimate the beam to reduce its cross section.
- Other radiation hazards are associated with analytical X-ray units as well. Significant exposure rates are possible from radiation scatter, and shielding against this may be

necessary. Also, ancillary equipment may contribute to significant levels of unwanted radiation (e.g., gassy rectifiers in the high-voltage supply may need replacement or shielding).

25.2.11 Safe Working Practices for Analytical X-Ray

A. Beam Alignment

1. Wear a dosimeter.
2. Use long handles on fluorescent screens, heavily leaded glass plugs, or electronic alignment where possible.
3. Only authorized persons are permitted to align an analytical X-ray unit. Authorized persons are those individuals who have completed courses offered by the Materials Science and Engineering Department and/or have been specifically trained by the supervisor of the facility.
4. If safety interlocks are being bypassed, post a sign indicating the status of the safety switch.

B. Sample Changing

1. Monitor the analytical X-ray unit with appropriate radiation detection equipment before changing a sample.
2. Use the shutter to stop X-rays during a sample change. There must be a visible signal (color marking or light) indicating the status of the shutter.
3. Be aware of the operational status of the analytical X-ray unit at all times, especially during sample change.

C. General Equipment Operation

1. Post a sign if the safety interlock is bypassed.
2. Terminate the safety interlock bypass as soon as possible.
3. Monitor the analytical X-ray unit as often as necessary.
4. Only trained individuals are to operate an analytical X-ray unit.
5. Wear a dosimeter when operating an analytical X-ray unit
6. Do not deliberately expose dosimeters.
7. Perform monthly safety checks.
8. Replace burned-out light bulbs.
9. If the experimental design does not fit the enclosure, the analytical X-ray unit must comply with standards applicable for an unenclosed unit.
10. Make no assumptions regarding your analytical X-ray unit; units left unattended, especially for a prolonged absence, should be monitored upon return. Contact ORS at 1-5581 if you have questions regarding safety.

25.3 Diagnostic X-Ray

Obtaining optimum diagnostic information from X-ray examinations goes hand in hand with minimizing exposure to both patient and radiological personnel. Doses to X-ray machine operators typically are among the lowest of all radiation workers. The radiation health practices responsible for keeping worker doses low should also help keep doses to patients ALARA. Although technical advances have resulted in systematic dose reductions to patients, poorly operating equipment, a lack of attention to detail, and inadequate operator training can negate these gains. Following are six ways to minimize doses to both X-ray operators and patients:

- Training and certification. Proper training covers technique factors; time, distance, and shielding strategies; quality assurance; personnel dosimetry; and minimizing retakes. Operators require state certification.
- Time, distance, and shielding. Minimizing the time of exposure to a beam of radiation, increasing the distance from the beam, and using appropriate shielding will reduce doses. Patients undergoing examination shall be provided with protective aprons or shields to minimize unnecessary dose. If it becomes necessary for operators to hold children or animals during X-ray treatment, they shall wear leaded gloves and aprons. Shielded collimators that restrict the beam size shall always be used.
- Quality assurance. The objective of minimizing patient dose while obtaining maximum diagnostic information also is met effectively by maintaining a program that stresses consistency. High-quality radiographs are consistent with reduced doses and fewer retakes. Diagnostic equipment operators should be familiar with daily, weekly, or other periodic quality-assurance procedures. These procedures include routine exposure of control X-ray film, measurement of developer temperature, checking chemical activity of the developer and fixer, and routine cleaning and mechanical inspection.
- Dosimetry. Each operator is required to use personnel dosimeters (body and/or ring badges) unless control panels are permanently mounted behind fixed barriers and area monitoring dosimeters are in place.
- Inspections. ORS arranges for annual inspection of diagnostic equipment for proper operation and compliance with state regulations.
- Justification. Medical personnel always must be prepared to justify the need for particular X-ray exams. Although X-ray operators may have little say in the decision to administer an exam, they should be prepared to recommend alternative exams or techniques. Frivolous use of X-ray machines is discouraged.

25.3.1 Dosimetry

Each operator is required to use personnel dosimeters (body and/or ring badges) unless control panels are permanently mounted behind fixed barriers and area monitoring dosimeters are in place. All operators of diagnostic X-ray equipment are radiation workers and must register with ORS. In most cases operators wear body badge dosimeters. Always wear assigned dosimeters during examinations. Store them in a safe place away from sources of radiation. Never wear another person's dosimeter; dosimetry records are a permanent, legal record of an individual’s occupational dose.

If a lead apron is worn and two dosimeters are used, wear one dosimeter at the collar above the apron and the other dosimeter on the torso underneath the apron. If only one dosimeter is used, wear it exposed at the outside of the apron collar.

25.3.2 Records

Registrants shall maintain records of maintenance, repairs, and modifications performed on each X-ray machine, including the name of the individual who performed the service and the date performed.

Registrants shall maintain a current staffing plan with the names of all operators and a definition of their duties. The staffing plan shall include, in writing, the qualifications of the operators. Registrants or supervisors shall have a copy of current certificates of accreditation issued by IDNS to X-ray technologists operating medical equipment.

25.3.3 Training

Annual inservice training in radiation safety is required for all operators of diagnostic X-ray equipment. Licensed practitioners are exempt from the training requirement. Registrants shall keep a record of all training that operators receive, including the date and content. Operators shall sign the training record. The training must include the following:

- Operating and emergency procedures for the machines.
- Use of employee and patient protective devices, including lead aprons, thyroid shields, lead screens, and structural shielding.
- Procedures to minimize patient and employee exposure.
- Use of personnel dosimeters (body badges).
- Film processing procedures.

25.3.4 Written Policy Statement

Regulations require providing each X-ray machine operator with a written policy statement outlining the institution's radiation safety practices and policies. This handbook provides the required information.

25.3.5 General Equipment and Operating Requirements

25.3.5.1 Audible Signal

Certified X-ray machines shall emit an audible signal when the exposure has ended, and the exposure shall cause automatic resetting of the timer to the initial setting or zero.

25.3.5.2 Technique Chart

A technique chart shall be posted at the control panel or exposure switch and shall specify routine exams including the following:

- The patient's anatomical size relative to technique factors used (centimeter measurement of part to be X-rayed, or area of interest, such as incisor, molar, or bitewing).
- The type (film speed) and size of film or film/screen combination.
- Distance between the X-ray tube and the film.
- The appropriate exposure detectors and density setting for each radiographic exam for automatic exposure control (AEC) systems.

25.3.5.3 Manual Film Processing

Manual film processing shall be monitored to assure the following:

- Use of a dedicated darkroom timer with adjustable preset function.
- Use of a dedicated darkroom thermometer.
- Use of a film processing guide indicating the processing time for various solution temperatures (as recommended by the processing chemical manufacturer).
- Replenishment of processing chemicals at an interval no less than that recommended by the chemical manufacturer.

25.3.5.4 Automatic Film Processing

Automatic film processing shall be monitored to assure the following:

- Temperature of the processing chemicals is appropriate for the type of film being processed at the film transport speed selected. Consult chemical manufacturer recommendations.
- Chemicals used and replenishing rate are appropriate for the film transport speed selected.
- Safelight illumination is adequate for the film speed and darkroom operating procedures used. Consult film manufacturer recommendations.

25.3.6 Required Postings

The registrant shall post IDNS form KLA.001, "Notice to Employees" in a sufficient number of places so operators can see them at any work location. ORS provides the form. Form KLA.001 describes where operators may see the following documents:

- IDNS statutes and regulations.
- The University's Certificate of Registration.
- Any notice of violations and related correspondence.

25.4 Fluoroscopy

Fluoroscopy of humans is not permitted in University facilities at this time. The University's fluoroscopy machines are used for research and demonstration purposes only.

25.4.1 Dosimetry

Registrants shall ensure that each operator of a fluoroscopy machine and each assistant and observer shall register with ORS and obtain and use appropriate personnel dosimetry. This may include both body badges and extremity TLD dosimeters.

25.4.2 Siting

ORS certifies fluoroscopes for specific sites. Users shall contact ORS before placing a fluoroscope in operation so that necessary inspections and surveys may be carried out.

25.4.3 Required Postings

Each room in which fluoroscopy is conducted shall be posted with the appropriate caution sign. ORS will post the sign.

25.4.4 Training

Before the fluoroscope can be used the registrant is required to train each operator in the basic principles and practices of radiation protection, operation of the fluoroscope, and emergency procedures.

25.4.5 Lead Aprons

A lead apron of at least 0.25 mm lead equivalent shall be worn by each operator. A lead apron of at least 0.25 mm lead equivalent shall be worn by each assistant and observer, unless a whole-body protective barrier is provided.

25.4.6 Beam Limitation

Whenever possible, the beam shall be limited by adjustable shutters.

25.4.7 Primary Barrier and Interlock

The fluoroscope shall function so that the entire cross section of the useful beam is intercepted by the primary protective barrier of the fluoroscopic image assembly at any source-image receptor distance.

The fluoroscopic tube shall be interlocked to prevent the unit from producing X-rays unless the primary barrier is in position to intercept the useful beam at all times.

25.5 Cabinet X-Ray Systems

25.5.1 Regulations

Illinois regulations define a cabinet X-ray system as follows: "A cabinet X-ray system is a system with the X-ray tube installed in an enclosure which, independent of existing architectural structures except the floor on which it may be placed, is intended to contain at least that portion of a material being irradiated, provide radiation attenuation, and exclude personnel from its interior during generation of X-radiation." "Cabinet Radiography" is defined as "industrial radiography conducted in an enclosure or cabinet so shielded that radiation levels at every location on the exterior meet the limitations specified in 32 IAC Part 340.1050."

25.5.2 Operating and Emergency Procedures

Cabinet X-ray systems designed to exclude individuals are exempt from X-ray regulations except for operating and emergency procedures. The registrant's operating and emergency procedures shall include instructions in at least the following:

- Security of the X-ray system when not in use.
- Biological effects of ionizing radiation.
- Radiation hazards associated with the X-ray system.
- Safety practices.
- Procedure for notifying proper supervisory personnel in the event of an emergency.
- Maintenance and repair procedures.
- Personnel monitoring (dosimeters) and the proper use of monitoring devices (body and extremity dosimeters).

No one shall be permitted to operate a cabinet X-ray system without first being instructed in the operating and emergency procedures for the unit and demonstrating competence in its use. The registrant shall maintain records for ORS inspection demonstrating compliance.

25.6 Veterinary X-Ray

25.6.1 Regulations

Many of the regulations governing diagnostic X-rays for human use also apply to veterinary machines. Among other requirements are the following:

- A technique guide shall be posted in the vicinity of the X-ray system's control panel.
- Film processing systems shall be monitored.
- If a patient must be held, individuals who are in the room with the patient shall be positioned so that they are shielded from the useful beam or from scatter radiation by either protective apparel or a protective barrier.
- The room or area shall be posted with the appropriate caution sign. ORS will post the sign.

25.6.2 Dosimetry

Each operator is required to use personnel dosimeters (body and/or ring badges) unless control panels are permanently mounted behind fixed barriers and area monitoring dosimeters are in place. All operators of diagnostic X-ray equipment are radiation workers and must register with ORS. In most cases operators wear body badge dosimeters. Always wear assigned dosimeters during examinations. Store them in a safe place away from sources of radiation. Never wear another person's dosimeter; dosimetry records are a permanent, legal record of an individual's occupational dose.

25.7 Mobile/Portable X-Ray Systems

Many of the regulations pertaining to diagnostic systems, as well as the general provisions for all X-ray systems, apply to mobile and portable systems, depending on the system's use:

- The exposure control switch shall be arranged so that the operator can stand at least six feet from the patient and X-ray tube and well away from the useful beam.
- The useful beam shall be limited to the area of clinical interest.
- A timer that terminates the exposure at a preset interval is required. The unit must be inoperable when the timer is set to a zero or off position.
- All operators shall wear protective aprons of not less than 0.25 mm lead equivalent.
- Each operator, assistant, and observer shall be provided with appropriate personnel dosimetry. All operators of diagnostic X-ray equipment are radiation workers and must register with ORS. In most cases operators wear body badge dosimeters. Dosimeters should always be worn during examinations.

25.8 Electron Microscopes

Each microscope shall bear the following labels:

- A label bearing the words "Caution--Radiation--This Equipment Produces Radiation When Energized" shall be placed near any switch that energizes a tube.
- A sign bearing the words "Caution--High-Intensity X-Ray Beam," or words with similar intent, shall be placed in the area immediately adjacent to each tube head. The sign shall be located so that it is clearly visible to anyone operating, aligning, or adjusting the unit or handling or changing a sample.

26.0 Lasers

26.1 General Information

The University has established a Laser Safety Committee responsible for formulating policy and guidelines related to the safe use of lasers. Safety training and compliance with safety and health regulations are the responsibility of investigators who own and use lasers.

26.2 Registration

The University requires the registration of all laser-producing devices. Investigators acquiring lasers shall notify ORS of the acquisition.

26.3 Safety

All laser users should be familiar with ANSI publication Z136.1-1986, "American National Standard for the Safe Use of Lasers." This standard is on file for viewing in ORS. State law requires the reporting of any injuries sustained while using laser systems (including nonbeam injuries). Call ORS when an injury occurs. Report any injuries to Risk Management/Division of Safety and Loss Prevention.

26.4 Signs and Labels

Warning signs must be posted at entrances to some laser facilities. These may be obtained from ORS. Labels and signs within laser facilities are the responsibility of the principal investigator.

Appendix A: Commonly Used Radionuclides

Tritium (H-3)

Half-Life:	12.26 years
Major Radiations:	Beta, 0.0186 MeV (100%) maximum
Shielding:	None required
Bioassay:	Urinalysis; H-3: Within 1 week of use of 10 mCi per week or procedure; H-3 thymidine: Within 2 weeks of use of 1 mCi per week or procedure

- Tritium is not an external exposure hazard in any quantity because the low-energy beta radiation is too weak to penetrate the skin.
- Tritium is undetectable with conventional survey instruments.
- Tritiated water, if taken into the body, becomes rapidly and completely mixed with all body water. Other tritiated compounds, such as DNA precursors, may be more toxic.
- Use protective clothing and equipment: skin protection (laboratory coats and gloves), eye protection, and a chemical fume hood if gases or vapors are present. Change gloves

frequently. Tritium may migrate through gloves and be absorbed by skin as a result of prolonged contact.

- Monitor the work area using wipe tests counted in liquid scintillation. Clean up any contamination immediately.

Carbon 14 (C-14)

Half-Life:	5,730 years
Major Radiations:	beta, 0.157 MeV (100%) maximum
Shielding:	Thin plastic or wood; none required for mCi quantities.
Bioassay:	Urinalysis; Within 1 month of use of 3 mCi per week or procedure

- Carbon-14 is not an external exposure hazard in millicurie quantities because the low-energy beta radiation will not penetrate the gloves and skin.
- Use protective clothing and equipment: skin protection (laboratory coat and gloves) and eye protection. Change gloves if they become contaminated.
- Monitor the work area frequently with a GM survey instrument. If such an instrument is not available, perform wipe tests counted in liquid scintillation. Clean up contamination immediately.

Sodium 22 (Na-22)

Half-Life:	2.62 years
Major Radiations:	gamma, 1.275 MeV (100%), 0.511 Mev (180%) beta, 0.545 MeV (9.8%), 1.820 MeV (0.05%)
Shielding:	HVL 6.5 mm lead; Exposure rate from 100 uCi @ 1 cm = 1,200 mR/hr
Bioassay:	Contact Office of Research Safety

- Store Na-22 behind lead shields.
- Personnel dosimetry (body badge and ring) is required when using this radionuclide. Use time, distance, and shielding when working with Na-22. Use remote handling instruments and shield all containers.
- Monitor the work area with either a GM or scintillation detector. Clean up contamination immediately. Monitor the hands frequently for contamination.
- Wear protective clothing: laboratory coat, gloves, and eye protection.
- Shield waste containers and use time, distance, and shielding to reduce doses from waste materials.

Phosphorous 32 (P-32)

Half-Life:	14.28 days
Major Radiations:	beta, 1.71 Mev (100%) maximum
Shielding:	Layered, with low-density shield such as plastic, wood, or other low-atomic-number material on the inside next to the source and high-density shield such as lead on the outside away from the source
Bioassay:	Urinalysis; Within 1 week of use of 600 uCi or more

- Store stock solutions, process vessels, and waste materials behind appropriate shields. Use time, distance, and shielding to minimize doses from all materials in use.
- Personnel dosimetry (ring badge) is required when working with this radionuclide. Never handle stock solutions or process vessels with the hands. Use remote handling tools.
- Wear protective clothing: laboratory coat, gloves, and eye protection.
- Do not work over open containers. The hands or face may receive large doses.
- Avoid direct contact with the skin. Dose rates may be extremely high at contact.
- Monitor the work area frequently with a GM survey instrument. Check the hands frequently and discard contaminated gloves promptly. Clean up contamination immediately. If quantities of activity are used for which bioassay is required, a survey meter should be available in the laboratory at all times.

Phosphorous 33 (P-33)

Half-Life:	24.4 days
Major Radiations:	beta, 0.248 MeV maximum
Shielding:	Thin plastic or wood; none required for mCi quantities
Bioassay:	Urinalysis; Within 1 week of use of 7 mCi or more

- Phosphorous-33 does not present an external exposure hazard in mCi quantities because the low-energy beta radiation will not penetrate the gloves and skin.
- Use protective clothing and equipment: laboratory coat, gloves, and eye protection. Change gloves if they become contaminated.
- Monitor the work area frequently with a GM survey instrument. If such an instrument is not available, perform wipe tests counted in liquid scintillation. Clean up contamination immediately.

Sulfur 35 (S-35)

Half-Life:	87.9 days
Major Radiations:	beta, 0.167 MeV (100%) maximum
Shielding:	Thin plastic or wood; none required for mCi quantities
Bioassay:	Urinalysis; Within 2 weeks of use of 5 mCi per week or

	procedure

- Sulfur-35 is not an external exposure hazard in millicurie quantities because the low-energy beta radiation will not penetrate the gloves and skin.
- Use protective clothing and equipment: laboratory coats, gloves, and eye protection. Change gloves if they become contaminated.
- Monitor the work area frequently with a GM survey instrument. If such an instrument is not available, perform wipe tests counted in liquid scintillation. Clean up contamination immediately.
- Methionine may be volatile and should be opened and used only in a fume hood.

Calcium 45 (Ca-45)

Half-Life:	165 days
Major Radiations:	beta, 0.252 MeV (100%) maximum
Shielding:	Thin plastic or wood; none required for mCi quantities
Bioassay:	Urinalysis; Monthly, for use of 3.0 mCi or more per week or procedure

- Calcium-45 does not present an external exposure hazard in mCi quantities because the low-energy beta radiation will not penetrate the gloves and skin.
- Use protective clothing and equipment: laboratory coat, gloves, and eye protection. Change gloves if they become contaminated.
- Monitor the work area frequently with a GM survey instrument. If such an instrument is not available, perform wipe tests counted in liquid scintillation. Clean up contamination immediately.

Chromium 51 (Cr-51)

Half- Life:	27.8 Days
Major Radiations:	gamma, 0.320 MeV (9%)
Shielding:	HVL 1.7 mm lead; TVL 7.0 mm lead; Exposure rate @ 1 cm from 1.0 mCi (unshielded): 180 mR/hr
Bioassay:	Urinalysis; Within 2 weeks of use of 4.0 mCi per week or procedure

- Millicurie quantities of activity should be stored behind lead shields.
- Personnel dosimeters (body badges) should be worn when using millicurie quantities.
- Use the strategies of time, distance, and shielding to minimize doses from stock solutions, process vessels, and waste materials.
- Use protective clothing and equipment: laboratory coat, gloves, and eye protection. Change gloves if they become contaminated.

- Monitor the work area with a scintillation survey instrument. If no survey instrument is available, the wipe test method may be used, although gamma radiation typically has low counting efficiency in liquid scintillation counters.

Iodine 125 (I-125)

Half- Life:	60.2 Days
Major Radiations:	gamma 0.035 MeV (7%); X-ray 0.027 MeV (113%); X-ray 0.031 MeV (25%)
Shielding:	HVL 0.02 mm lead; Unshielded exposure rate @ 1 cm from 1 mCi: 1.4 mR/hr
Bioassay:	Thyroid Counting; See the Bioassay section for detailed information.

- Radioiodine is volatile. Estimates of volatility range from much less than 1% to more than 4% of activity in stock solutions each time the vial is opened. Use radioiodine only in a properly functioning fume hood. Observe the posted maximum hood window opening. Place your equipment so that you work at least six inches behind the plane of the sash.
- Store radioiodine at room temperature if possible. Freezing may result in increased volatility upon thawing.
- Avoid creating acidic solutions that can increase volatility.
- Store waste in sealed containers, preferably in well-ventilated areas.
- Sodium iodide can pass through gloves and skin. Skin absorption may be a significant route of uptake. Wear two pairs of gloves. If the outer pair becomes contaminated, remove and discard them.
- Use a scintillation survey instrument to monitor for contamination. Use it throughout iodination procedures to check for contamination on hands and equipment.
- Wear protective clothing: laboratory coat with long sleeves, gloves, and eye protection. Do not expose bare skin to radioiodine.
- Engineering controls are preferable to thyroid blocking agents, which are not recommended. If blocking agents are used, this should be under the supervision of a physician and shall be reported to ORS before iodinations are conducted.
- Stabilize wastes and spills with a solution of 0.1 M NaOH, 0.1 M NaI, and 0.1 M $Na_2S_2O_3$ to minimize the evolution of volatile species.

Emergency Procedure for Sodium Iodide Exposure

If you are exposed to radioactive sodium iodide through a needlestick or other puncture wound or through a cut, skin contact, or inhalation, it is important to act quickly. Blocking agents that prevent uptake of the iodine by the thyroid are available. Such agents are safe when prescribed by a medical professional. In order to be effective, they must be used as soon as possible following exposure. Notify your supervisor, then report the incident to ORS at 1-5581 (Evanston) or 3-8300 (Chicago). After hours or anytime you are unable to reach ORS call University Police at 456 and ask them to page Research Safety.

Glossary

absorbed dose The energy imparted to matter by ionizing radiation per unit mass of irradiated material. The common unit of absorbed dose is the rad, and the SI unit is the Gray.

absorption The process by which radiation imparts some or all of its energy to material through which it passes.

activity The number of nuclear transformations occurring in a given quantity of material per unit time.

ALARA **A**s **L**ow **A**s **R**easonably **A**chievable. Philosophy of dose limitation.

alpha particle A charged, strongly ionizing particle emitted from the nucleus during radioactive decay, having a mass and charge equal to a helium nucleus (two protons and two neutrons, and a charge of +2).

atomic number The number of protons in the nucleus of an atom.

authorized investigator Any person whom the Radiation Safety Committee has granted authorization to possess and use radioactive material.

background radiation Radiation from cosmic rays and natural and man-made radionuclides and sources in the environment.

becquerel The SI unit of activity. One becquerel is equal to one transformation per second. Abbreviated Bq.

beta particle Charged particle emitted from the nucleus of an atom, having a mass and charge equal in magnitude to that of the electron.

body badge Dosimeter used for the approximate measurement of radiation dose for personnel monitoring purposes.

bremsstrahlung Electromagnetic radiation associated with the deceleration of charged particles passing through matter.

Ci See Curie

contamination Deposition of radioactive material in any place where it is not desired, particularly where its presence may be harmful. The harm may merely interfere with an experiment or procedure or may constitute an actual hazard to personnel.

cosmic rays High-energy particulate and electromagnetic radiations that originate outside the earth's atmosphere.

curie The common unit of activity. One curie (Ci) equals 3.7×10^{10} disintegrations per second.

decay, radioactive Transformation of the nucleus of an unstable atom by the spontaneous emission of charged particles and/or photons.

declared pregnant woman Any woman who has voluntarily informed her employer, in writing, of her pregnancy.

deep dose The dose equivalent at a depth of approximately 1 cm in soft tissue.

dose A general term denoting the quantity of radiation or energy absorbed. For special purposes it must be appropriately qualified, e.g., absorbed dose.

dose equivalent The absorbed dose multiplied by a modifier to express the radiation dose on a common scale. The special unit of dose equivalent is the rem, and the SI unit of dose equivalent is the sievert (Sv).

dosimetry Measurement or calculation of the amount of energy absorbed in matter.

electron volt A unit of energy equivalent to the energy gained by an electron in passing through a potential difference of one volt. Abbreviated eV. Larger units are keV, for thousand electron volts, and MeV, for million electron volts.

erythema A transient reddening of the skin as a result of exposure to radiation.

eV See Electron volt.

exposure A measure of the ionization produced in air by X or gamma radiation. The unit of exposure is the roentgen (R).

extremity A hand, elbow, arm below the elbow, foot, knee, and leg below the knee.

gamma ray Very penetrating electromagnetic radiation of nuclear origin.

genetic effect Heritable effect of exposure to ionizing radiation.

genetically significant dose The dose equivalent to the gonads, weighted for age and sex; used for expressing genetic risk.

GM detector Geiger Mueller detector. A versatile radiation detection device, suitable for detecting alpha, beta, and gamma radiation, that operates on the gas ionization principle.

gray The SI unit of absorbed dose. One gray (Gy) is equal to one joule per kilogram, or 100 rads.

ground state The state of a nucleus, atom, or molecule at its lowest energy.

Gy See Gray.

half-value layer The thickness of a specified material that will reduce the intensity of a given beam of radiation by half.

half-life, biological The time for the body to eliminate one-half of an administered dose of any substance by the regular processes of elimination. Approximately the same for both stable and radioactive isotopes of the same element.

half-life, effective Time required for a radioactive element in the body to diminish by 50 percent as a result of the combined action of radioactive decay and biological elimination. Effective half-life = (biological half-life x radioactive half-life)/(biological half-life + radioactive half-life)

health physics The science devoted to the protection of people and the environment from the harmful effects of radiation.

HVL See Half-value layer.

I See Intensity.

intensity The energy per unit time that crosses a unit area at right angles to a beam of radiation.

inverse square law The intensity of radiation at any distance from a point source varies inversely with the square of that distance.

ion Atomic particle, atom, or chemical radical bearing an electric charge, either negative or positive.

ionization The process by which a neutral atom or molecule acquires either a negative or positive charge.

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 (hence the same atomic number) but differing in the number of neutrons (and therefore mass numbers). Chemical properties are virtually identical for all isotopes of a given element.

keV 1,000 electron volts.

linear attenuation coefficient The fractional number of photons removed from a beam per unit thickness of material through all absorption and scattering processes.

mass number The number of protons and neutrons in the nucleus of an atom.

mCi See Millicurie.

member of the public Anyone other than individuals performing assigned duties for the licensee or registrant that involve exposure to sources of radiation.

MeV Million electron volts.

microcurie A submultiple of the common unit of activity, the curie. One microcurie is equal to one thousandth of a millicurie, or 3.7×10^4 transformations per second.

millicurie A submultiple of the common unit of activity, the curie. One millicurie is equal to one thousandth of a curie, or 3.7×10^7 transformations per second.

milliroentgen A submultiple of the special unit of exposure, the roentgen, equal to one thousandth of a roentgen. Abbreviated mR.

minor An individual younger than 18 years of age.

mR See milliroentgen.

neutron An elementary nuclear particle that is electrically neutral and has a mass close to that of the proton.

nuclide An atom characterized by the constitution of its nucleus, as specified by the number of neutrons, protons, and energy content.

occupational dose The dose received by an individual in the course of employment in which the individual's assigned duties for the licensee or registrant involve exposure to sources of radiation. Occupational dose does not include dose received from background radiation, as a medical patient, from voluntary participation in medical research programs, or as a member of the public.

OSL dosimeter Optically Stimulated Luminescence dosimeter, wherein laser stimulation of an aluminum oxide layer causes luminescence in proportion to the amount of radiation having struck the dosimeter.

photon A quantity of electromagnetic energy. Has both wave and particle characteristics.

positron A particle equal in mass to the electron and having an equal but opposite charge.

proton An elementary nuclear particle with a positive charge and a mass of approximately 1 atomic mass unit. The total number of protons is the atomic number of an element.

QF See Quality factor.

quality factor A modifying factor by which the absorbed dose in rad (or gray) is multiplied to obtain, for radiation protection purposes, the dose equivalent in rem (or sievert).

R See Roentgen.

rad The common unit of absorbed dose, equal to 100 ergs of energy deposited in the material of interest.

radiation The emission and propagation of energy in the form of waves or particles.

radionuclide A nuclide that spontaneously emits radiation in the form of electromagnetic or particulate radiation.

registrant Any person who registers an X-ray producing device.

rem The common unit of dose equivalent. The dose in rem is numerically equivalent to the dose in rad multiplied by an appropriate modifier (such as the quality factor).

restricted area Any area to which access is limited by the licensee or registrant for purposes of protecting individuals against undue risks from exposure to sources of radiation.

roentgen The unit of exposure. Equal to 2.58×10^{-4} coulombs per kilogram of air.

scattering Change in direction of particles or photons as a result of collisions or interactions in matter.

scintillation A radiation detection process whereby radiation interacting with a crystal emits light in proportion to the energy of the radiation.

sealed source Any device--containing radioactive material to be used as a source of radiation--that has been constructed in such a manner as to prevent the escape of any radioactive material.

shallow dose The dose equivalent at a depth of approximately .007 cm in soft tissue.

sievert The SI unit of dose equivalent. One sievert is the dose in gray multiplied by a quality factor. Abbreviated Sv. Equal to 100 rem.

somatic effect Nonheritable effect of biological exposure to ionizing radiation.

specific ionization The number of ion pairs produced per unit track length of an ionizing particle.

Sv See Sievert.

tenth-value layer The thickness of a specified substance that will reduce the exposure rate of a beam of photons by a factor of 10. Abbreviated TVL.

thermoluminescent dosimeter A radiation-sensitive phosphor, usually CaF or LiF, used for measuring dose. Abbreviated TLD.

TLD See Thermoluminescent dosimeter.

tritium An isotope of hydrogen with a nucleus containing one proton and two neutrons. Symbol is H-3.

TVL See Tenth-value layer.

uCi See Microcurie.

whole body For purposes of external exposure, head, trunk (including male gonads), arms above the elbow, or legs above the knee.

X-rays Penetrating electromagnetic radiation having wavelengths shorter than visible light. Identical to gamma rays except for their extranuclear origin.