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UNIVERSITY OF OREGON
RADIATION SAFETY MANUAL

I. RADIATION SAFETY PROGRAM

A. PURPOSE

The use of radiation sources for research and education is allowed through the practice of established procedures and demonstration of compliance. The purpose of this manual is to provide the basic guidelines and procedures for safety that will protect workers, facilities, the general public and the environment. It also outlines the procedures necessary to demonstrate compliance with the University's license for use of radioactive materials and radiation-producing machines.

B. SCOPE

The provisions and requirements outlined in this manual are incorporated in the license issued to the University of Oregon by the Oregon State Health Division. Compliance with its provisions applies to all locations under University control where radioactive material or radiation-producing machines are used or stored. The program applies to all persons working at or frequenting these locations, regardless of their relationship to the University.

In certain instances, review and authorization by the Radiation Safety Committee is not required. For example, the following specific uses are exempted from the authorization process:

- Small quantities of naturally-occurring radioactive material in unprocessed form, such as ore samples, mineral specimens, etc.;
- Readily available commercial products containing small amounts of radioactive material, such as gas lantern mantles, smoke detectors, small static elimination devices for photo lab use, or thoriated welding rods. However, the radioactive material may not be separated or used for experimental purposes;
- Dental porcelain containing radioactive material;
- Optics containing thorium in anti-reflection coatings;
- Electron microscopes, electron-beam welders, and other similar devices as exempted under Oregon Administrative Rule (OAR) 333-101-010.

Note that these exceptions do not relieve an individual from complying with any applicable provisions of state or federal rules. The Radiation Safety Committee may evaluate specific uses and determine the appropriateness of this exemption.

C. ALARA – A Management Concept

The University of Oregon policy is to prevent unnecessary radiation exposures to persons and the environment and to reduce all exposures to as low as reasonably achievable (ALARA).

The basic principles of time, distance and shielding shall be used as required to maintain doses from external sources of radiation ALARA. Engineering controls such as filtration, ventilation and containment shall be used as necessary to maintain potential internal doses ALARA.

D. Organization and Responsibility

1. Radiation Safety Committee

The Radiation Safety Committee (RSC) is responsible for establishing policies governing the procurement, use, storage and disposal of radioactive materials and radiation-producing devices. The Committee includes individuals experienced in the use or application of radiation sources and provides a peer review of intended uses by researchers at the University. Radiation sources may be used only by, or under the direct supervision of, individuals approved by the Radiation Safety Committee. The Committee meets at least quarterly to review various aspects of the radiation safety program and to act upon applications or amendments for authorization.

2. Radiation Safety Officer

The Radiation Safety Officer (RSO) is responsible for implementing the radiation safety program and providing general surveillance of activities involving radiation sources. Other specific duties include: monitoring regulatory compliance; evaluating applications for authorization and advising the RSC of appropriate findings; package receipt and delivery; personnel monitoring; basic training of personnel; waste disposal operations; consultation on radiation protection matters; license administration; and incident response.

3. Authorized User

An Authorized User is a member of the University community who has been approved to direct a program in which radiation sources are used according to procedures approved by the Radiation Safety Committee. The Authorized User is responsible for ensuring that all personnel, particularly new personnel, who have access to radiation sources under his/her jurisdiction are properly instructed and that they possess the necessary skills and disposition to cope with radiation safely.

The Authorized User has the responsibility to ensure that the procedures for purchase, acquisition, use, and transfer of radioactive materials are followed in all work under his/her supervision. This includes keeping accurate records as required by University rules or State regulations.

4. Individual User

The Individual User or Radiation Worker is a person working under a specific authorization. Radiation Workers are responsible for complying with standard safety and operating procedures as well as working within the limits of their education, training and experience. The individual user is ultimately responsible for the safe use of the radiation sources to which s/he has access

II. USE AUTHORIZATION

A. University of Oregon License

The Radiation Safety Program is controlled by federal and state regulations. The program applies to all personnel who use, supervise or control radiation sources, or use radiation-producing machines regardless of intensity or quantity.

Each individual who requests to use ionizing radiation must recognize their responsibility in complying with these regulations. They also must understand any additional policies defined by the University of Oregon to demonstrate compliance with these regulations.

Due to the varied nature of research and the difficulty in defining specific procedures for the entire University, the Oregon Health Division has issued a license of Broad Scope to the University. The license, this manual and the Oregon Rules for the Control of Radiation shall govern the use of ionizing radiation on the University of Oregon campus.

It is important that all users realize that failure to demonstrate reasonable compliance with state regulations in any campus facility could trigger state enforcement action resulting in termination of all licensed radiation uses at the University of Oregon.

The license issued by the Oregon Health Division, Radiation Protection Services and applicable state regulations are available at Environmental Health and Safety.

B. Radioactive Materials Use

As a condition of the University's license, radioactive material may only be used by, or under the supervision of, individuals authorized by the Radiation Safety Committee.

Normally only members of the Academic or Research Faculties will be approved as Authorized Users of radioactive material. This includes individuals holding the title of Professor, Associate Professor, Assistant Professor, Instructor and Research Associate. The Radiation Safety Committee will consider exceptions to this policy on a case-by-case basis.

Use of radioactive material in a classroom situation requires extra consideration and will be reviewed by the Radiation Safety Committee. Therefore, application for classroom use must be made during the term before the intended use.

1. Application Procedure

The Principal Investigator initiates the process by contacting the Radiation Safety Officer (RSO) to arrange a consultation and obtain an Application for the Use of Radioactive Materials (RS-100).

The Principal Investigator completes the application (RS-100) and submits it to the RSO for review.

The Radiation Safety Officer will review the application and prepare a summary and recommendations for the Radiation Safety Committee. Additional information may be requested from the Principal Investigator.

The application, along with any recommendations, is submitted to the Radiation Safety Committee. Each application is approved, disapproved, or approved with special conditions by the RSC.

During the period between completion of the RSO review and final action by the RSC, the Committee Chair may grant interim authorization to an individual for use of radioactive material. The interim authorization may be for the full scope of use as requested or may be of limited applicability. The applicant should be aware that such an interim authorization is of a temporary nature and that the Radiation Safety Committee may request additional information or impose specific conditions of use.

Once the authorization or interim authorization is approved, Environmental Health and Safety personnel will post authorized rooms and storage locations with radioactive material signs and provide the laboratory with radioactive waste containers. In addition, the Authorized User will be given a notebook to use as a central file for all radioactive material records. This notebook, or its equivalent, must be available for review at all times.

Upon approval by the Radiation Safety Committee, the authorization is valid for a period of three years, after which it must be renewed.

2. **Human Uses**

The University of Oregon license does not authorize or permit the deliberate application of ionizing radiation to humans except by, or under the supervision of, licensed medical practitioners and performed for healing art purposes.

C. RADIATION-PRODUCING MACHINES

The approval process is essentially the same for radiation producing machines as it is for radioactive material. Therefore, the Application Procedure in Section II.B.1. is still applicable, substituting the application form for Radiation-Producing Equipment (RS-107).

The application must be approved or conditionally approve before commencing the use of any radiation producing equipment.

1. **Vendors and Service Consultants**

Each person who is engaged in the business of selling, installing or servicing radiation-producing machines shall have a license for such services prior to furnishing or offering to furnish any such services. The Oregon Health Division issues the license. The Radiation Safety Officer will verify the vendor has the appropriate license.

2. **Registration**

Radiation-producing machines must be registered with the Oregon Health Division. The Radiation Safety Officer will complete the application process with Radiation Protection Services. The Registration certificate will be displayed on or near the x-ray or other machine that is registered.

3. **Regulations**

The Radiation Safety Officer will provide a copy of the appropriate Oregon Health Division Rules that apply to a particular radiation-producing machine. These rules are specified in the Oregon Rules for the Control of Radiation, OAR Chapter 333, and the following divisions:

Division 105 Radiation Safety Requirements for Industrial Radiographic Operations

Division 106 X-rays in the Healing Arts
Division 108 Radiation Safety Requirements for Analytical X-ray Equipment
Division 109 Radiation Safety Requirements for Particle Accelerators

The Authorized User is responsible for assuring compliance with these rules. As stated in the rules, normal operating procedures shall be written and available to all workers.

4. **Human Use**

At no time shall radiation be intentionally applied to a human being without the prior written approval of the Radiation Safety Committee, and must be under the supervision of a person licensed to practice in the healing arts.

5. **Changes**

Environmental Health and Safety must be notified whenever there is a change in the authorized use, such as new equipment installed, change in the location of the equipment, or change in output of radiation or change in the system configuration.

6. **Security**

Security must be adequate to prevent unauthorized use of the machine. The machine must be disconnected, the machine room locked, or the area must otherwise be controlled when the equipment is not in actual use.

7. **Exemptions**

No individual shall bypass a safety device without obtaining prior approval of the Radiation Safety Officer. Modification to existing equipment or variance of Oregon Health Division rules requires a written request to the Division stating the nature and justification of the variance.

D. AMENDMENTS TO AN AUTHORIZATION

Whenever there is to be a substantive change in radionuclide use, it is necessary to amend the authorization.

Examples of such changes include the following: radioisotopes for which the user is not currently authorized, changes in radioiodinations, new room locations, or an extended leave of the Authorized User.

Request an Application for Amendment Form (RS-101) from Environmental Health and Safety to describe the change of authorization.

E. Authorization Renewals

An authorization to use radioactive material or radiation-producing machines must be renewed every three years. The Authorized User shall review the current research or instructional use. Procedures shall be verified and the annual audits reviewed by the RSO. The renewal application is presented to the Radiation Safety Committee for approval.

F. Termination of Authorization

In the event that an Authorized User (or any person working under the supervision of an Authorized User) demonstrates a flagrant disregard for any federal, state or university rules concerning the use of ionizing radiation, the authorization may be suspended by the Radiation Safety Officer. Upon review by the Radiation Safety Committee, the authorization may be revoked, modified and reissued, or reinstated.

An authorization will normally be terminated upon notification that a project has been completed and that no sources of radiation are to be retained by the Authorized User.

Upon notification of intent to terminate by an Authorized User, Environmental Health and Safety will collect all radioactive material for disposal or transfer to another Authorized User. Areas of authorized use shall be monitored and cleared for other uses by Environmental Health and Safety.

III. TRAINING OF PERSONNEL

Training of individuals working in radiation use areas is required by Oregon Administrative Rules.

A. Radiation Safety Training

Each individual working with radioactive material shall receive training on the potential hazards they may encounter and methods available to protect themselves.

Each individual shall register for basic radiation safety training with Environmental Health and Safety prior to commencing work.

Environmental Health and Safety shall provide basic radiation safety training and document satisfactory attendance.

Environmental Health and Safety shall provide periodic refresher training as necessary. Refresher training is required every three years.

B. Analytical X-ray Training

Each individual who intends to operate an analytical x-ray machine shall complete the tutorial provided by EHS prior to operational training.

A training checklist must be completed to document that the individual has received operating instructions for each machine that they are allowed to operate.

Environmental Health and Safety will maintain documentation of satisfactory completion of training.

C. Authorized User Training Responsibilities

The Authorized User is responsible for assuring that individuals working with radiation sources have received basic radiation safety orientation and any necessary refresher training.

The Authorized User shall be responsible for informing any individual working in or frequenting a controlled area of radiation safety issues. Workers shall be:

- Kept informed of the storage, transfer or use of radioactive material in the controlled area.
- Instructed in any safety practices relevant to the experimental procedures in the laboratory.
- Instructed to report promptly to the Authorized User any conditions that may lead to unnecessary exposure to radiation or radioactive materials.

IV. MANAGEMENT OF RADIOACTIVE MATERIAL

Radioactive material may be procured only by an Authorized User. In this context, "procurement" means purchase, receipt by transfer from another laboratory, receipt from outside the University as a gift or demonstration sample, or any other receipt of radioactive material regardless of whether any monetary transaction is involved.

A. Receipt

Environmental Health and Safety must approve all requests for radioactive material. A completed purchase order that includes: the authorization number, the isotope, the supplier and catalog number, and the activity for each container of radioactive material must be approved by EHS.

Environmental Health and Safety personnel will check the appropriate authorization to verify that the order is within the Authorized User's possession and order limits. EHS will retain an approved copy of the requisition.

Failure to obtain prior approval may delay or prevent delivery to the final user.

All radioactive material shall be shipped to:

Environmental Health and Safety
University of Oregon
1230 Franklin Blvd.
Eugene, OR 97403-5224

Environmental Health and Safety will receive the material, survey the shipment, record its arrival into the University's radionuclide inventory, and deliver the package to the Authorized User's laboratory. The material will be placed in the designated radioactive materials storage location. A designee of the laboratory must sign for receipt of the material.

B. INVENTORY

The Authorized User must maintain an inventory of all radioactive materials in their possession. Each use shall be dated and indicate the individual user.

The inventory should keep a running balance to permit totaling by radionuclide for accountability and to verify possessed amounts are below authorized limits. Indicate when each "stock vial" is emptied (none remaining).

After final use and disposal, send the original or a copy of the inventory form to EHS. A copy is retained in the laboratory, available for inspection, for a period of three years.

C. SECURITY

State law requires that licensed material must be under the immediate control and constant surveillance of the licensee, or otherwise be locked and secured to prevent tampering or unauthorized removal. Radioactive materials in storage or unattended should be kept in locked containers or in areas that are not readily accessible to unauthorized individuals.

When working with radioactive materials, the room must be secured whenever a radiation worker is not present, or the radioactive materials must themselves be secured. Refrigerators or cabinets containing radioactive materials that are located outside a lockable room must be locked to prevent access. **Any loss of radioactive materials must be reported to the Radiation Safety Officer immediately.**

The personnel present in the laboratory may provide security for radioactive materials by challenging unauthorized entry into the room.

D. Transfers of Radioactive Material

1. Intra-Laboratory Transfers

Transfer of radioactive material between Authorized Users must be reported prior to the transfer by telephoning the Radiation Safety Officer (6-2864).

All transfers of radioactive materials must be documented in Environmental Health and Safety's inventory database. In order to record a transfer, EHS will need the following information:

a) The original Ship Code number.
b) The Authorized User providing the material.
c) The Authorized User receiving the material.
d) The activity of the transfer.

A new Receipt and Disposal of Radioactive Materials form will be printed and delivered to the receiving laboratory for record keeping.

Radioactive materials must never be transferred to individuals who are not approved for the material and quantity.

2. Off-Campus Transfers

Environmental Health and Safety must approve and manage all transfers of radioactive material **to** or **from** the University of Oregon.

State law requires that the shipper obtain the receiver's approval and a copy of the respective radioactive materials license prior to the shipment of the radioactive material. All shipments must be in accordance with the packaging and labeling requirements set forth by the Department of Transportation.

E. General Rules for working with Radioactive Materials

These rules apply to ALL uses of radioactive materials at the University of Oregon unless specifically modified in writing as a condition of an individual Authorization to Use Radioactive Materials. These laboratory practices are intended to keep both internal and external exposures to ionizing radiation As Low As Reasonably Achievable (ALARA).

- A high standard of cleanliness and good housekeeping should be maintained in all laboratories.

- Personal belongings should not be brought into the laboratory where they may become contaminated.
- Eating, drinking, chewing gum and application of cosmetics is **forbidden** in any area where radioactive material is used or stored.
- Pipetting of radioactive solutions by mouth is **forbidden**.
- Protective clothing, appropriate for the work conditions, shall be worn when working with unsealed radioactive materials, which includes: a laboratory coat, gloves, and safety glasses. Appropriate footwear must also be worn (closed-toe shoes are required). Laboratory coats shall not be taken home to be laundered.
- Faucets, notebooks, calculators, drawer handles, etc., should not be handled when wearing gloves.
- Clearly designate work areas and, to the extent possible, isolate from the rest of the laboratory.
- Whenever possible, work with all equipment on easily cleaned trays.
- Cover work surfaces with absorbent paper, which should be changed regularly to prevent the build-up of contamination.
- Radiation sources shall be used and stored behind shielding of a type and amount appropriate to the radiation hazard involved.
- Processes that may release volatile components shall be performed in an approved fume hood.
- Radioactive solutions must be kept covered.
- Before leaving the laboratory, wash hands then check hands and shoes with an appropriate survey instrument.
- Check the laboratory frequently with an appropriate survey instrument or by taking paper smears. At a minimum, survey each day at the completion of a procedure.
- Decontaminate workspaces as soon as practical. Label potentially contaminated equipment.
- Food and beverages intended for human consumption must never be stored in the same refrigerator, freezer, or other container with radioactive material. This restriction applies both to the storage of “stock solutions” and of specimens or other items to which any quantity of radioactive material has been intentionally added.
- Any equipment used in an area authorized for radioactive material must be cleared by EHS prior to removal or maintenance.

V. RADIATION DOSE LIMITS

The Nuclear Regulatory Commission (NRC) has established dose limits for individuals working with ionizing radiation. The State of Oregon has adopted the NRC limits and rules for summing external and internal dose. The limits are set at a level where apparent injury due to ionizing radiation during a normal lifetime is unlikely. However, personnel should not disregard exposures at or below these limits and every effort should be made to keep all exposures as low as reasonably achievable.

A. Occupational Dose Limits

Part of the Body	Annual Adult (mrem)	Annual Minor (< 18 yr. of age) (mrem)
Whole Body, Head and Trunk, Active Blood Forming Organs **(TEDE)**	5,000	500
Lens of Eye **(LDE)**	15,000	1,500
Extremities **(SDE)** (Elbows, Forearms, Hands Knees, Lower Legs, Feet)	50,000	5,000
Total Organ Dose Equivalent **(TODE)**	50,000	5,000
Skin of Whole Body **(SDE)**	50,000	5,000

The dose limits are described in terms of *dose equivalents* or the product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. The unit of dose equivalent is the rem.

The annual dosimetry reports are expressed in mrem (millirem). Additional information on Dose equivalents may be obtained from Environmental Health and Safety.

B. Dose to an Embryo or Fetus

A limit of 500 mrem to an embryo or fetus during the entire pregnancy, due to occupational exposure of a declared pregnant woman has been set by state regulation. A declared pregnant woman is a woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception. A declaration form is available from EHS.

If a pregnant woman chooses not to declare her pregnancy, the appropriate dose limits listed in section V.A. above apply,

C. Dose Limits for Individual Members of the Public

Public exposure limits apply to any visitors to a laboratory, laboratory workers not trained in radiation safety, custodial or other maintenance staff.

Members of the general public must not receive a radiation dose in excess of two millirem in any hour or 100 millirem in a calendar year.

VI. MONITORING RADIATION EXPOSURE

A. External Radiation Monitoring

Personnel monitoring is required for all individuals likely to receive doses from external sources in excess of 10 percent of the applicable limits or for individuals entering a high radiation or very high radiation area.

1. Criteria for Requiring Personnel Monitoring

As a general policy, the University of Oregon issues dosimeters to individuals who work with the following types of radiation.

- Greater than 10 µCi Beta-emitters with average energy greater than 250 keV
- Greater than 10 µCi Gamma emitters with energies greater than 15 keV
- Open beam X-ray sources
- Neutron sources

Dosimetry devices are provided by EHS as appropriate for the type and configuration of radiation–producing equipment used.

Radiation detection dosimeters are not assigned for work with certain radionuclides, since the energies are beneath the detection limit of the badge. Examples of these radionuclides are ^{3}H, ^{14}C, ^{35}S, ^{33}P and ^{63}Ni.

Individuals not requiring external monitoring must still register with Environmental Heal th and Safety as a radiation worker and complete the appropriate training.

2. Arranging for Radiation Badge Service

One must visit the Environmental Health and Safety office to apply for radiation badges. EHS administers the program as the contact and distribution coordinator between individual users, the university and the vendor.

Notification must be made to EHS of any changes to an individual's monitoring requirements.

3. General Rules for Using Radiation Badges

- Whole body badges are to be worn at chest height or attached to the collar.
- Badges should be clipped to clothing so that the front stays upright and faces away from the body. Never allow clothing, buttons, pens, etc. to shield the front of the dosimeter.
- Ring badges (if issued) are to be worn on the *inside* of your glove, with the label turned to the inside of your finger. Be careful to not tear the glove when putting the glove on or taking it off. Also take care not to throw the ring away with the glove.
- The badge shall be worn ONLY BY THE PERSON TO WHOM IT IS ISSUED.
- Badges should be protected against damage from heat, moisture, pressure and contamination. Check your hands for contamination before removing your ring badge.
- Badges must <u>not</u> be worn during non-occupational exposure, such as during examinations with medical and dental X-rays.
- When not in use, badges should be stored away from sources of radiation.
- NOTIFY the Radiation Safety Officer if any dosimeter becomes contaminated, is damaged, lost or when an individual's personal dosimeter is no longer needed.

B. Prenatal Radiation Monitoring

Regulations allow a pregnant woman to decide whether she wants to formally declare her pregnancy to her employer, thereby taking advantage of the special dose limits provided to protect the developing embryo/fetus.

A woman may declare her pregnancy by providing, on the appropriate form, her name, a declaration that she is pregnant and the estimated date of conception (month and year). An individual may obtain a form from EHS.

C. Internal Radiation Monitoring

Individuals are monitored for internal exposure by means of bioassay, which is the analysis of the uptake of radioactive materials in the body by direct counting of the body or body parts (*in vivo*), or by the analysis of excreta (*in vitro*).

Bioassay is required whenever individuals work with greater than specified amounts of certain radionuclides, or if they are likely to receive, in one year, an intake greater than 10% of the applicable Annual Limit of Intake.

1. **Tritium (H-3)**

Urinalysis is required before and 2-24 hours after handling unsealed ^{3}H in any chemical form in a quantity of 100 mCi or more in any week.

2. **Iodine**

Each individual handling ^{125}I or ^{131}I labeled materials in an unsealed form and using an activity greater than or equal to that specified in the following table must undergo a thyroid bioassay between 6-72 hours following the use.

Activity Levels Above Which Bioassay for I-125 or I-131 is Necessary*

Type of Operation	Activity handled in Unsealed Form	
	Volatile	Bound to Non-volatile Agent (or RIA Kits)
Process in open room or bench	0.1 mCi	1 mCi
Process in fume hood of adequate design	1 mCi	10 mCi
Process in glove box	10 mCi	100 mCi

*From USNRC Regulatory Guide 8.20, as amended by 10 CFR 20

Before working with ^{125}I or ^{131}I in quantities equal to or in excess of the above activities, each individual must receive a baseline thyroid bioassay.

At the request of an individual or at the discretion of the RSO, thyroid bioassay may be performed at activity use levels less than those specified above.

D. Review of Exposures

The Radiation Safety Officer will review all exposure results. Exposures ≥ 50 mrem deep dose equivalent, ≥ 500 mrem shallow dose equivalent, or bioassays showing intakes greater than 1% of the annual limit will be investigated by EHS to determine the cause and to discuss how future exposures can be reduced.

Each monitored individual shall be advised annually in writing of their reported exposure to radiation or radioactive materials.

VII. LABORATORY SURVEYS

A. Definitions

Removable contamination can be readily removed using proper decontamination procedures. Removable contamination in any amount may present both an external and internal hazard because it can be picked up on the skin and possibly ingested.

Fixed contamination cannot be readily decontaminated. Fixed contamination generally does not present a significant hazard unless the material comes loose or is present in such large amounts that it presents an external radiation hazard.

Direct surveys, using Geiger-Mueller (G-M) detectors or scintillation probes, identify gross contamination (total contamination consisting of both fixed and removable contamination) but will detect only certain isotopes.

Wipe surveys are the most versatile and most sensitive method for detection of low-level radioactive contamination in the laboratory. Use of "wipes" counted on a liquid scintillation counter or a gamma counter can identify removable contamination only but will detect most isotopes used.

B. Daily Monitoring

Good lab practice dictates that users conduct contamination surveys before, during and after working with unsealed sources. While actively working with radioactive material (except H-3 or C-14), users shall have a survey meter turned on and immediately available. Hands should be checked frequently.

At the end of an operation or at the end of the day,

- Survey the work surfaces, the floor below, and any equipment used.

- Monitor hands, shoes and clothing, especially at the cuff of the sleeve.
- Discard any contaminated items as radioactive waste.
- Monitor bare hands and then wash hands.

If contamination is found, it must be cleaned up and the steps above repeated. Consider the cause of contamination and modify procedure as appropriate.

Consistent daily monitoring is the best defense against radiation exposure. Use the survey meter.

C. Periodic Laboratory Surveys

Each laboratory in which unsealed sources of radioactive material are present must conduct thorough surveys and **document** the results in order to evaluate external radiation levels and the effectiveness of the contamination control program.

A documented survey of authorized use areas must be conducted within each calendar month wherein unsealed radioactive material is handled. Additional documented surveys may be required as determined by your level of use, radiation hazard of the material used, or contamination control history. The survey must include a direct survey and a wipe survey if radionuclides other than ^3H have been used. Documented surveys for ^3H use must be by wipe method.

D. Environmental Health and Safety Surveys

Periodically, Environmental Health and Safety personnel shall survey the laboratories of Authorized User in order to monitor the laboratory's radiation safety program. Radiation exposure rates and contamination levels shall be measured and recorded. EHS will notify the Authorized User if excessive radiation levels are observed or contamination is detected. Annually, EHS personnel will conduct an audit of each Authorized User for compliance with University rules and good work practices.

E. Leak Test

Each sealed source containing licensed material (other than tritium) with a half-life greater than thirty days, and in any form other than gas, shall be periodically tested for leakage. EHS will perform these tests as needed and maintain records of the tests.

- Sources containing >10 µCi of an alpha emitting material must be leak tested at intervals of approximately three months.

- Sources containing >100 µCi of a beta or gamma emitting radionuclide must be leak tested at intervals of approximately six months.
- Sources placed in storage are exempt from the leak test requirement. Sources in storage must be leak tested prior to return to use.
- Sources exempt from leak testing shall be inventoried at intervals of approximately six months.

Principal Investigators must have approval to possess and use sealed radioactive sources. Users must have training, sources must be labeled, and security must be in place.

F. Survey Instrument Calibration

Radiation detection instruments used for contamination surveys must be operable and capable of detecting the radioisotopes used in the laboratory. Radiation detection instruments will be calibrated annually by EHS or EHS will arrange for the calibration.

EHS must be informed when a new instrument is purchased or repair of an existing meter is completed so that calibration may be achieved. Calibration is not required after changing batteries.

G. Removal of Laboratory Equipment

Any equipment in the laboratory that could have been contaminated with radioactive material must be surveyed prior to transfer to another laboratory, to a repair shop, or offered for disposal. Before the equipment is transferred and following a satisfactory survey, all warning signs and stickers must be removed.

Equipment needing repair or offered for disposal, must be surveyed by EHS and have a Request for Space / Equipment Clearance form attached.

EHS must be notified before disposing any equipment that may contain a radiation source or is a radiation producing machine, such as x-ray machines, liquid scintillation counters, gamma counters, etc.

H. Maintenance Work in Laboratories

Before allowing any maintenance work in a laboratory space, radiation sources must be removed from the equipment scheduled for servicing and any radioactive materials must be properly stored. The space must be surveyed for radiation levels and contamination. EHS must be notified prior to the start of work.

EHS will assess the laboratory before posting a Request for Space / Equipment Clearance form allowing the maintenance work to begin. Examples of situations that require these precautions include maintenance on fume hoods, plumbing systems, flooring, and workbenches.

I. Vacating Laboratory Spaces

EHS must be informed of all changes in authorized laboratory spaces, including relocations to new labs or departures from the University. The Authorized User is responsible for surveying all spaces and equipment and proper removal of all radioactive waste and radiation sources prior to the changes. Upon notification, EHS will complete a final clearance survey of the authorized spaces and remove posted warning signs.

VIII. POSTING AND LABELING

Warning signs and labels serve the purpose of immediately identifying potential hazards in an area. Radiation warning signs of the approved type are required where the potential for exposure to radiation exists.

A. Controlled "Radiation Use" Areas

A controlled area is a limited access area such as a laboratory in which licensed radioactive materials are used or stored. Requirements for a controlled area include:

1) Approval by the Radiation Safety Committee as an authorized location for work with radiation sources.

2) Restricted access (i.e. door locks or locked storage) to an area when unoccupied by authorized personnel.

3) Identification, with signs, of the area(s) with elevated radiation fields and/or the area where radiation sources are used or stored.

4) The Oregon Health Division "Notice to Employees" Form posted in a conspicuous location.

5) Emergency laboratory procedures and phone numbers posted in a conspicuous location.

B. Containers

Each vial or container containing greater than the quantities listed in 10 CFR Part 20 Appendix C (see UO Appendix B) must be labeled with the following information.

1) The radiation trefoil with text **"Caution - Radioactive Material"**,

2) Radionuclide present,
3) An estimate of the quantity of radioactivity,
4) The date for which the activity is estimated.

C. Equipment

Equipment routinely used in procedures using radioactive material should be labeled with the radiation trefoil and **“Caution - Radioactive Material”**. This includes any apparatus that will contain greater than three times background amounts of radioactivity left unattended either due to prolonged experimentation or due to contamination.

D. Sealed Sources

The source, its shield, or the apparatus in which the source is mounted must have a radiation warning sign containing the information listed in VIIIB.

E. Radiation-Producing Machines

Each area or room containing analytical X-ray equipment shall be conspicuously posted with the radiation symbol and “**Caution – X-ray Equipment**”.

IX. RADIOACTIVE WASTE DISPOSAL

A. General Considerations

All radioactive waste must be transferred to EHS for disposal.

No radioactive materials are permitted to be discharged into the sanitary sewer, released into the air, or disposed in regular trash.

When disposing of radioactive waste, recognize that other hazards can be present (e.g., biohazards, chemicals, sharps, etc.) and that each must be treated appropriately. Infectious substances must be disinfected, sharps deposited in sharps container, and certain chemicals neutralized. Special waste should be described during the authorization process for approval.

Other hazardous waste such as lead “pigs” shall not be mixed with radioactive waste.

Only waste containers provided or approved by EHS that are chemically compatible with the material being collected shall be used.

All radioactive material labels shall be removed or completely defaced from non-radioactive materials/packages that have been surveyed and cleared before they are placed in the ordinary trash receptacle.

B. Waste Labeling

Each container must have a completed WASTE DISPOSAL RECORD affixed before the waste can be collected.

C. Liquid Waste

Liquid radioactive waste includes radioactive solutions and any subsequent rinses of each container or process that contain detectable activity (greater than 2 times background when counted by liquid scintillation). Liquid scintillation vials and liquid is collected separately.

Collect liquid waste in the 4-liter plastic containers provided by EHS.

Segregate liquid waste according to nuclide.

Aqueous and water-soluble materials must be collected in separate containers from non-aqueous materials, because of varying disposal site requirements.

All liquid waste containers must be placed in secondary containers (e.g., plastic tubs) of sufficient size and composition to contain all of the liquid in the bottle in case of breakage or leakage. Liquid waste containers must be double contained at all times.

Do not fill jugs more than 90% full.

Maintain a complete list of chemical constituents for each liquid waste stream, including the concentration of each constituent.

Remove funnels from liquid waste container and securely cap the container when not actively filling.

D. Solid Waste

All solid radioactive waste must be placed in plastic-lined containers authorized by EHS.

Place sharp objects in a labeled heavy-wall plastic container before placing in the dry waste container. Do not use a biohazard sharps container unless collecting biohazard sharps. Notify EHS as biohazards must be collected separately.

Consult EHS if the radioactive waste is a dry powder.

Do **not** place any scintillation vials, cocktail or other liquids in these containers

Segregate dry solid waste according to half-life. Collect those with nuclides with a half-life of 90 days or less separately from those with half-lives greater than 90 days.

E. SCINTILLATION VIALS

Keep the vials separate from all other types of waste.

The liquid should remain in the vials and the vials securely capped.

Collect the vials in a container approved by EHS.

Specify the brand name of the scintillation cocktail used.

F. ANIMAL WASTE

Special arrangements must be specified on the application for authorization and disposal methods approved prior to commencing work. The application process must estimate the concentration (µCi/gm) for each form and nuclide.

G. LEAD WASTE

Lead pigs and other lead used for shielding will be collected by EHS for survey and recycling.

Every attempt should be made to prevent contamination of lead objects. Lead is a hazardous waste and cannot be disposed with the usual radioactive waste.

H. MIXED BIOHAZARDOUS/RADIOACTIVE WASTE

Biohazardous Materials are hazardous biological materials or organisms, and include: a) infectious organisms (bacteria, fungi, parasites, prions, rickettsias, viruses, etc.) which can cause disease in health humans and/or significant environmental or agricultural impact; b) human or primate tissues, fluids, cells, or cell culture; c) recombinant DNA; and d) animals known to be vectors of zoonotic diseases.

Waste must be disinfected and kept separate from other waste.

Notify EHS if research will generate Biohazardous Mixed waste.

I. Mixed Radioactive/Chemical Waste

Hazardous chemicals are those that are flammable, corrosive, toxic, oxidizers, or reactive. They present special disposal problems when mixed with radioactive material.

If the chemical waste is compatible with the containment described for radioactive waste, the container used for radioactive waste should be used. If not, select a suitable container for the chemical and obtain EHS approval.

Notify EHS if research will generate Mixed Chemical waste.

J. Waste Collection

To request a waste collection, call EHS at 6-3192.

You will be asked to provide information on the number of containers for each waste type, the authorized user, waste location, and your name and phone number. Note any special request for the pick-up.

EHS will replace the types of containers requested for pick-up.

Waste is normally picked-up within 1-2 working days of the request.

X. RECORDKEEPING

All users of radioactive materials are required to maintain certain records. These include complete and accurate radioactive inventory records, and records of radiation safety surveys. Records must be maintained in the lab until their disposition is authorized by EHS.

A. EHS Records

The RSO is responsible for the maintenance and control of all central record keeping requirements. This includes the University’s license to use radioactive material, an inventory of radioactive materials, radioactive waste disposals, inspection reports, monitoring reports, and other records maintained to demonstrate compliance with State regulations.

B. Authorized User Records

Each Authorized User must maintain certain records in a laboratory binder, which shall be available for inspection by EHS or the Oregon Health Division Radiation Protection Services.

1. **Authorization**

A copy of the approved Application for the Use of Radioactive Materials (or Analytical X-ray Equipment) and any amendments to that application shall be available. A list of individuals authorized to work with radioactive material under the authorization and their training dates shall be kept current.

2. **Materials Receipt and Usage Records**

Radioactive materials receipt records that show the use of the material shall be maintained in the laboratory binder for a period of three years following disposal. A copy of the completed record is sent to EHS.

3. **Records of Surveys**

Records of all surveys requiring documentation per Section VII.B. and any follow-up surveys resulting from clean up actions shall be retained for five years.

4. **Liquid Waste Composition**

Maintain an accurate list of the chemical composition of each radioactive stream. Indicate each component as percent by volume of the waste container.

XI. ACCIDENTS AND EMERGENCY PROCEDURES

In the event of an accident involving radioactive materials, the immediate objective is to stabilize the scene. As with any emergency, protect personnel from injury and hazards, quickly identify and treat exposed personnel and obtain the necessary assistance.

A general emergency procedure is posted in each room where radioactive materials are used. The purpose of this general procedure is to reach the point where the situation is under control and assistance is on the way.

A. General Objectives in Emergency Situation

- Prevent or reduce personnel contamination or injury.
- Confine the contaminant.
- Prevent or reduce damage to equipment.
- Decontaminate the area.

The RSO shall be notified immediately of any accidents involving:

- Significant skin contamination.

- Ingestion of radioactivity by personnel.
- Unexpected personnel exposure.
- Severe contamination of Equipment.
- Spread of contamination, or difficulty in cleaning up a contaminated area.
- The loss of radioactive materials or radiation-producing machines.

B. Initial Action

The general procedures in the event of an emergency involving radioactive material are as follows:

1. **Notify** all persons in the area that a spill or incident has occurred.
2. **Assist Injured –** If an individual is injured, administer immediate first aid as appropriate. Instruct someone to call Department of Public Safety. Do not let the possibility of radioactive contamination hinder first aid efforts. Decontamination can always be done after the patient's condition has been stabilized. Notify first responders of the potential for radioactive contamination so appropriate measures can be taken.
3. **Remove Persons** from the area. Hold them nearby until they can be checked for contamination and provide assistance as necessary.
4. **If Fire is involved –** Immediately call Department of Public Safety ***ext. 6-6666***.
5. **Confine the Spill –** If liquid, drop absorbent paper on the area of the spill. If solid, drop damp absorbent paper on the area of the spill. If airborne contamination may have occured, turn off fans, hood, and ventilation and close windows and doors.
6. **Determine Level of Emergency –** At this point, some decision has to be made as to the level of the emergency. The following criteria are offered as guidelines only. If you have any doubt as to the seriousness of the situation, consider the emergency a major spill.

   Minor Spill – No personnel contamination.
   – Less than 100 microcuries of ^{3}H, ^{14}C, ^{32}P, ^{35}S.
   – No radiation hazard to personnel.

Major Spill – Personnel are contaminated or injured.
– Quantities greater than 100 microcuries of any nuclide.
– Any quantity of ^{125}I.
– Large volumes even if they are less than 100 microcuries.
– Accidents involving airborne contaminates

C. Notification and Reports

All radiation emergencies, except minor laboratory contamination emergencies, will be documented as a radiation event or if appropriate, a radiation incident. All Authorized Users involved in the emergency will receive a copy of the report for review prior to review by the Radiation Safety Committee and if applicable, prior to submission to the Oregon Health Division, Radiation Protection Services.

XII. DECONTAMINATION PROCEDURES

Contamination control is one of the most important aspects of radiological protection. It is important for all employees to recognize potential sources of contamination as well as methods to remove the contamination.

To properly decontaminate an area, it is necessary to first define the areas of contamination by means of a proper survey. In general decontamination is then accomplished from the outside to the middle or from top to bottom.

1. **Methods for Decontamination**

   a. **Liquid Radioactive Decontaminant:** Concentrated liquid decontaminating agents are commercially available. This detergent is diluted with water and rapidly and easily cleans radioactive contamination without excessive effort. Note that these detergents may contain chemicals of a hazardous nature and the user should read the Material Safety Data Sheet prior to use. In dilute liquid form, radioactive decontaminates do not present a significant hazard to handlers unless ingested or splashed in eyes.

   b. **Foam Spray Decontaminant:** A variety of foam spray decontamination products are available which are marketed as radioactive decontaminates. However, many other foam cleaning products may accomplish decontamination just as effectively. These are marketed as bathroom or kitchen cleaning agents.

c. **Soap:** Lukewarm water and a mild-cleaning agent, such as soap should be available for cleaning the surface of the skin. Do not rub hard or scrub with abrasives. A cream hand cleaner, which contains no abrasives, may also be used.

d. **Other Decontaminating Agents:** Many other agents will work to clean radioactive contamination that has been resistant to the usual methods. Contact EHS for assistance with particular decontamination problems.

2. **Personnel Decontamination**

- **Monitor** the person carefully to determine the level and location of contamination, noting the time of initial survey.
- Remove contaminated **clothing** and place in a plastic bag.
- Decontamination of **wounds** must be accomplished under the supervision of a physician. In this situation, the only step you should take is to flush the wound profusely with tepid water.
- For **skin** contamination, wash the contaminated area for 2-3 minutes using a mild soap and water. Work into a good lather. Pay particular attention to areas between fingers or around fingernails. Survey and repeat lathering procedure up to three times unless the skin starts to turn red. Do <u>Not</u> abrade the skin. Avoid spreading the contamination to unaffected areas.
- Contact the RSO as soon as possible.

3. **Facilities Decontamination**

- Block off the area and establish the control zone between the contaminated area and clean areas. Post the area with appropriate signs to keep people out.
- At the perimeter of the spill area, lay down something to step on, such as plastic sheeting, laboratory paper or a large piece of cardboard.
- Plan decontamination procedures. Get together any equipment any equipment and supplies you will need. This may include –
  - Heavier protective gloves.
  - Disposable shoe covers. (available at EHS)
  - Lab coat or overalls (preferably disposable).
  - Second survey meter.
  - Filter paper for wipe samples and vials.
  - Waste container, lined with plastic bag.

  - Decontamination solution (Count-Off®, Radiac Wash®)
  - Bucket
  - Sponges and absorbent towels.

- Don the protective clothing.
- Proceed from the outermost edges of the spill boundary and work inward.
- As you move inward, use the meter to carefully monitor the area. Be alert for splash points.
- When you find contamination, use a dry paper towel to absorb as much free liquid as possible. Discard this paper towel in a plastic bag. Repeat until the area is dry. The idea is to “lift” up the material. When all free liquid is absorbed, dampen a paper towel with decon solution and wipe the spot. Survey to see if residual contamination remains. If so, conduct a wipe survey on the spot to check for removable contamination. Try to completely decontaminate each spot before moving further.
- If contamination remains, use liquid or foam decontaminate directly onto the spots and allow the solution to set for a few minutes, then repeat removal process.
- Repeat this process as you work towards the center of the spill.
- If you must leave the contaminated area at any time, strip off gloves and disposable shoe coverings. Survey your hands and feet. Wash your hands.
- When only fixed contamination remains, resurvey the entire spill area. With a permanent marker, circle any hot spots and record the readings on a contamination survey log. Mark the spots with Caution-Radioactive Materials tape indicating nuclide, dpm and date.
- Dispose of all clean up materials and disposable personal protective equipment as radioactive waste.
- Complete a survey report that includes a discussion of the cause of the spill and actions taken to prevent a recurrence. Provide a copy to EHS.
- Request that EHS conduct a follow up survey of the area.

XIII. APPENDIX

A. Basic Definitions and Units

Absorbed dose: The amount of energy imparted by ionizing radiation per unit mass of irradiated material at the place of interest. The units of absorbed dose are the gray (Gy) and the rad.

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

ALARA: The acronym for the radiation protection philosophy that radiation exposures should be maintained "As Low As Reasonably Achievable".

Alpha particle (α): Electrically-charged particle emitted from a nucleus. These are equivalent in mass [approx. 4 atomic mass units (amu) and charge (2 positive units)] to helium nuclei.

Annual Limit of Intake (ALI): The annual intake of a given radionuclide by "Reference Man" which would result in either a committed effective dose equivalent of 5 rem (0.05 Sv) or a committed dose equivalent of 50 rem (0.5Sv) to an organ or tissue.

Attenuation: The process by which a beam of radiation is reduced in intensity as it passes through material.

Authorized User: A member of the University community who has been approved by the Radiation Safety Committee to use or supervise the use of radioactive material or radiation-producing equipment consistent with conditions specified in an application for authorization. All transactions involving radioactive material must be made in the name of an Authorized User.

Background radiation: Radiation from cosmic sources and naturally occurring radioactive material in the environment and human body.

Becquerel (Bq): SI unit of radioactivity. One Bq equals one nuclear transformation/second. One microcurie is equivalent to 37,000 Bq.

Beta particle (β): Electrically-charged particle emitted from a nucleus and it is identical to an orbital electron in mass (1/1840 amu) and charge (1 negative unit).

Bremsstrahlung: Electromagnetic radiation produced when charged particles decelerate in matter. The production of bremsstrahlung is proportional to the energy of the particle and the atomic number of the absorber. This means that large activity, high-energy beta sources require shielding with sufficient thickness of low atomic number substances such as plastic. This is particularly important when working with nuclides such as ^{32}P and ^{90}Sr.

Calibration: To determine the response or reading of an instrument relative to a series of known radiation values over the range of the instrument.

Characteristic x-rays: Characteristic x-rays are produced when electron vacancies are produced in the inner orbital electron shells of atoms to which outer electrons can transfer. These x-rays have discrete energies.

Committed dose equivalent (CDE): The dose equivalent to organs or tissues of reference that will be received from an intake of radioactive material by an individual during the 50-year period following the intake.

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

Contamination (Radioactive): The deposition or presence of radioactive material in any place where it is not desired, and particularly in any place where its presence can be harmful. The harm may be a source of danger to persons in compromising the validity of an experiment or a procedure. Contamination can be divided into two types:

(a) Removable contamination may easily be transferred from one object to another by light rubbing or by the use of weak solvents such as water or alcohol. Removable contamination is evaluated and recorded in units of microcuries or dpm per unit area, e.g. dpm/100 cm^2.

(b) Fixed contamination is not easily transferred from one object to another and requires mechanical or strong chemicals to remove it from its current location. Fixed contamination is evaluated and recorded in units of dpm (low activity) or mR/hr (high activity).

Curie (Ci): A unit of quantity of radioactivity. One Curie (Ci) is that quantity of radioactive material that decays at the rate of 3.7×10^{10} transformation per second (2.22×10^{12} per minute). The Curie is a relatively large unit; most of the quantities of radioactive used on campus are at the millicurie (mCi) or microcurie (µCi) level. (i.e., 1/1000th or 1/1,000,000th of a Curie).

Declared pregnant woman: A woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception.

Deep dose equivalent (DDE): The dose that applies to external whole body exposure. It is the dose equivalent at a tissue depth of 1 centimeter (1000 mg/cm^2).

Derived air concentration (DAC): The concentration of a given radionuclide in air which, if breathed by Reference Man for a working year of 2,000 hours under conditions of light work, results in an intake of one ALI. The condition of light work is an inhalation rate of 1.2 cubic meters of air per hour for 2,000 hours in a year.

Dose equivalent: The product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. The units of dose equivalent are the rem and the Sievert (Sv).

Effective dose equivalent: The sum of the products of the dose equivalent to each organ or tissue and the weighting factor applicable to each of the body organs or tissues that are irradiated.

Effective half-life: The time required for the amount of a radioactive compound deposited in a living organism to be diminished 50% as a result of the combined action of radioactive decay and biological elimination.

Electron volt (eV): The unit of energy equivalent to energy gained by an electron passing through a potential difference of 1 volt (1 eV = 1.6×10^{-12} ergs).

Extremity: The hand, elbow, arm below the elbow, foot, knee, or leg below the knee.

Eye dose equivalent: The external dose equivalent to the lens of the eye at a tissue depth of 0.3 centimeters.

Gamma rays (γ): Electromagnetic radiation of short wavelength emitted from the nucleus.

Gas chromatograph source: Radioactive material (normally ^3H or ^{63}Ni) contained within a gas chromatograph detector cell (e.g. electron capture detector). Special restrictions apply to operating temperature, dismantling and cleaning, etc.

Gray (Gy): The SI unit of absorbed dose. One gray is equal to an absorbed dose of one joule per kilogram of absorber. 1 Gy is equivalent to 100 rad.

Half-life (T½): The half-life of a radionuclide is the period of time required for half of the atoms in a sample of that nuclide to undergo nuclear transformation.

Half-value layer (HVL): The thickness of a material, which if placed in a radiation beam, will reduce the intensity of the beam by half.

High radiation area: Any area, accessible to individuals, in which there exists radiation levels that could result in an individual receiving a dose equivalent in excess of 0.1 rem (1 mSv) in 1 hour at 30 centimeters from any source of radiation or from any surface that the radiation penetrates. High radiation areas must be posted and must be equipped with specified control devices, alarms, etc.

Internal dose: That portion of the dose equivalent received from radioactive material taken into the body.

Ionization: The process by which a neutral atom of a molecule acquires a positive or negative electrical charge.

Ionizing radiation: Any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, in its passage through matter. It includes alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons and protons, fission fragments and other subatomic particles; but does not include sound or radio waves, or visible, infrared or ultraviolet light.

Member of the public: An individual in an unrestricted area. However, an individual is not a member of the public during any period in which the individual receives an occupational dose.

Monitoring: The periodic or continuous determination of the levels of radiation or radioactivity present in a region.

Neutrons: Electrically neutral particles with a mass of approximately 1 amu. They may be produced from nuclear interaction when high-energy particles interact with nuclei or by nuclear fission.

Nuclear Regulatory Commission (NRC): Federal agency established by the Atomic Energy Act of 1954 and the Energy Reorganization Act of 1974 to regulate the use of radioactive material through its licensing, inspection and enforcement and Standards development activities.

Nonstochastic effect: A health effect the severity of which varies with the dose and a threshold is believed to exist. “Deterministic effect” is an equivalent term.

Occupational dose: The dose received by an individual in a restricted area or in the course of employment in which the individual’s assigned duties involve exposure to sources of radiation. Occupational dose does not include dose received from background radiation, as a patient from medical practices, from voluntary participation in medical research programs, or as a member of the public.

Oregon Health Division (OHD): The administrative agency that regulates the use of radioactive material in Oregon. Specific responsibility is delegated to Radiation Protection Services.

Positrons: Positively charged beta particles (equivalent in mass to electrons), emitted from the nucleus in the same manner as negatively charged electrons.

Quality Factor (QF): Number by which the absorbed dose is multiplied to obtain the dose equivalent for radiation protection purposes. It is a quantity that expresses on a common scale the radiation harm incurred by exposed persons. Quantitatively, QF is related only to linear energy transfer of the radiation. The QF for x-rays, gamma rays and beta particles is one.

Rad: The unit of absorbed dose. One rad is the dose when any ionizing radiation deposits 100 ergs per gram in any material.

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

RAM: An acronym for “Radioactive Material”.

Rem: The unit of dose equivalent that is used for radiation protection purposes. It is the product of the absorbed dose and a factor that relates it to the harmfulness to man. This latter factor is termed the Quality Factor (1 rem = 0.01 Sievert).

Roentgen (R): The special unit of exposure. The amount of x-ray or gamma radiation that will produce one electrostatic unit of charge (approximately 2 billion electrical charges of either sign) per cc of air at standard temperature and pressure. One roentgen equals 2.58×10^{-4} coulombs/kilogram of air.

Sealed source: Radioactive material permanently bonded or fixed in a capsule or matrix designed to prevent release and dispersal of the radioactive material under the most severe conditions which are likely to be encountered in normal use and handling.

Shallow dose equivalent (SDE): The dose equivalent that applies to the external exposure of the skin or extremity. It means the dose equivalent at a tissue depth of 0.007 centimeter (7 mg/cm^2) averaged over an area of 1 square centimeter.

SI: Abbreviation for the International System of Units.

Sievert: SI unit of absorbed dose to the human body in terms of biological effect. The Sievert is equal to the absorbed dose in gray multiplied by the quality factor (1 Sv = 100 rem).

Stochastic effect: A health effect that occurs randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a linear function of dose without threshold. Hereditary effects and cancer incidence are examples of stochastic effects. "Probabilistic effect" is an equivalent term.

Survey: An evaluation of the radiological conditions and potential hazard incident to the production, use, transfer, release, disposal, or presence of sources of radiation. When appropriate, such evaluation includes, but is not limited to, testing, physical examination, and measurements of levels of radiation or concentrations of radioactive material present.

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

Total organ dose equivalent (TODE): The sum of the deep dose equivalent and the committed dose equivalent to the organ receiving the highest dose.

Weighting factor: The proportion of the risk of stochastic effects resulting from irradiation of that organ or tissue to the total risk of stochastic effects when the whole body is irradiated uniformly.

X-rays: A form of electromagnetic radiation very similar to gamma rays, except x-rays are emitted from orbital electron energy transitions.

B. Excerpt from 10 CFR 20 Appendix C

Quantities of Licensed Material Requiring Labeling

Radionuclide	Quantity (µCi)*
Hydrogen – 3	1,000
Carbon – 14	100
Phosphorus – 32	10
Phosphorus – 33	100
Sulfur – 35	100
Chlorine – 36	10
Calcium – 45	100
Chromium – 51	1,000
Iron – 55	100
Nickel – 63	100
Iodine – 125	1
Iodine – 131	1

* To convert µCi to kBq, multiply the µCi value by 37.

Additional values and information available at Environmental Health & Safety.

C. Sources of Additional Information

1. Environmental Health and Safety
   5224 University of Oregon
   72 Onyx Bridge
   1230 Franklin Blvd.
   Eugene, OR 97403-5224
   346-3192

2. Oregon State Department of Human Services
   Health Services Division
   Radiation Protection Services
   800 NE Oregon Street, Suite 640
   Portland, OR 97232
   971-673-0490

3. U.S. Nuclear Regulatory Commission
   One White Flint North
   11555 Rockville Pike
   Rockville, Maryland 20852-2738
   301-415-7000

800-368-5642

D. Conversion Factors

Multiply number of ⟶	by ⟶	to obtain number of
becquerel	2.703×10^{-11}	curies
curies	3.700×10^{10}	dis/sec (dps)
curies	2.220×10^{12}	dis/min (dpm)
curies	10^{3}	millicuries (mCi)
curies	10^{6}	microcuries (µCi)
dis/min (dpm)	4.505×10^{-10}	millicuries
dis/min	4.505×10^{-7}	microcuries
dis/sec (dps)	2.703×10^{-8}	millicuries
dis/sec	2.703×10^{-5}	microcuries
gray	100	rad
microcuries	3.700×10^{4}	dis/sec
microcuries	2.220×10^{6}	dis/min
millicuries	3.700×10^{7}	dis/sec
millicuries	2.220×10^{9}	dis/min
Roentgen	2.58×10^{-4}	Coulombs/kg of air (STP)
sievert	100	rem
to obtain number of ⟵	**by ⟵**	**Divide number of**

Correcting for Radioactive Decay

$$A = A_0 e^{-\lambda t}$$

Where:
- A = Activity remaining after time interval t
- A_0 = Activity in sample at some original time
- e = Base of natural logarithm; 2.718
- λ = Decay Constant for a particular radionuclide = $0.693/T_{1/2}$
- $T_{1/2}$ = Half life (in the same units as elapsed time t)

E. SELECT RADIONUCLIDE INFORMATION

1. RADIATION SAFETY DATA – Hydrogen-3 (^{3}H) (Tritium)

Tritium (^{3}H) is widely used in life sciences research. A wide range of tritium-labeled compounds are available, at moderate specific activity, and forms with uniform labeling or selective parts of the molecule labeled are often available. The moderate half-life permits the use of chemically stable isotope batches over a period of years. The very low beta energy emission limits some applications and makes the detection of spills more difficult, but is an advantage in cytological localization studies. The very low beta energy results in no external hazard, but internal health hazards are significant if taken into the body.

Physical Data

Radiation:	Beta emission to ^{3}He (stable)
Energy:	Max.: 18.6 keV; Average 5.7 keV
Physical half-life:	12.3 years
Biological half-life:	10-12 days
Effective half-life:	10-12 days*

* Large liquid intake (3-4 liters/day) reduces effective half-life by a factor of 2 or 3. (Relatively easy to flush out of system with fluids.)

Maximum Beta range in air:	6 mm = 0.6 cm = 0.25 inches
Maximum Beta range in water:	0.006 mm = 0.0006 cm = 3/10,000 inch
Penetrability in matter or tissue:	Insignificant (No ^{3}H betas pass through dead layer of skin)

Radiological Data

	Least radiotoxic of all radionuclides.
Critical Organ:	Body water or tissue
Routes of Intake:	Ingestion, inhalation, puncture, , wound, skin absorption
Radiological hazard:	External exposure from weak ^{3}H beta is not a concern. Internal exposure and contamination are primary concern.

Committed Dose Equivalent(CDE):	Ingested:	64 mrem/mCi
	Inhaled:	64 mrem/mCi
Committed Effective Dose Equivalent (CEDE):	Ingested:	90 mrem/mCi
	Inhaled:	63 mrem/mCi
Annual limit on intake	Ingestion:	80 mCi
	Inhalation:	80 mCi
Skin Contamination Exposure Rate:	57,900 mrad/hr/mCi (contact)*	

*Exposure rate to dead layer of skin only.
*Skin contamination of 1.0 µCi/cm^2 = 0 mrad/hr dose rate to basal cells

Some special cases exist, notably tritiated thymidine, which can result in higher doses to the cell nucleus due to its specific incorporation into DNA. Since DNA has low turnover, tritium residence time is longer, resulting in damage to the genetic material.

Common hazards – Precautions

A major problem with tritium is the difficulty of detection and measurement of uncontained material. Portable survey instruments are unable to detect the low-energy beta spectrum, so contamination must be detected by counting swipes by liquid scintillation or in a windowless gas-flow counter. Liquid scintillation counting efficiency approaches 60%.

No film badge or finger badges are required due to zero external hazard. Survey meters are not required and not useful.

No shielding is required during tritium use.

Contamination with tritium can be harder to avoid compared with other isotopes.

a) At some sites in molecules (electron-deficient sites that permit exchange of acidic protons with the solvent), tritium can become equilibrated with the aqueous solvent, resulting in the generation of volatile tritium from non-volatile labeled compounds. Thus, gaseous release must always be considered.

b) Some compounds can release tritium gas on acidification or heating; sodium Borotritide and other hydrides used in organic syntheses are common examples. Work with such compounds must be in a properly functioning fume hood.

c) Under some conditions – when handling > 10 mCi of compounds with readily exchangeable protons – tritium compounds can penetrate gloves, move through plastic containers, across lab bench covering, migrate out of vials along screwcap threads, etc. This presumably occurs by movement of tritiated water vapor or condensate after exchange with environmental water. Refrigerators used for storage can become contaminated by tritium movement out of containers. Storage areas holding >10 mCi should be monitored for contamination routinely; one less obvious technique is to sample ice or frost for liquid scintillation counting.

d) Vacuum systems used in handling high activity tritiated materials often become contaminated internally. Pump exhausts should be properly vented, and oil monitored before disposal or pump repair.

Some older style electron capture detectors coupled to gas chromatographs contain very large amounts (0.25-1 Ci) of titanium or scandium tritide. To prevent release of tritium and ruin of the sources, maximum temperatures are limited to 225ºC for titanium tritide and 325ºC for scandium tritide. Such gas chromatographs must be fitted with automatic temperature limiting devices and must be properly vented.

Liquid waste must be stored in appropriate containers with properly fitting screwcaps supplied by the Radiation Safety Office, and these containers must be inside a secondary container capable of holding the entire fluid in the event of bottle rupture. Volatile compounds must be stored in a fume hood and vented extensively before disposal.

For tritiated compounds that are classified toxic or carcinogenic, including organic solvents, care must be taken to segregate waste and declare it as mixed waste.

2. RADIATION SAFETY DATA – Carbon-14 (^{14}C)

^{14}C is widely used in life sciences research. A wide range of ^{14}C-labeled compounds are available, but only rather low specific activities are attainable; forms with uniform labeling or selective parts of the molecule labeled are often available. The very long half-life means that isotope levels do not change significantly over decades. The low beta energy emission makes ^{14}C safe to handle (unless volatile), yet permits some detection with a hand-held monitor and very efficient detection by liquid scintillation counting.

<u>Physical Data</u>

Radiation: Beta emission to ^{14}N (stable)
Energy: Max.: 156 keV; Average 49 keV
Physical half-life: 5730 years
Biological half-life: 12 days
Effective half-life: 12 days (bound); 40 days (unbound)
Maximum Beta range in air: 24 cm = 10 inches
Maximum Beta range in water/tissue: 0.28 mm* = 0.012 inches
*~ 1% of ^{14}C betas transmitted through the dead layer of skin, i.e. 0.007 cm depth
Maximum Beta range in Plexiglas: 0.25 mm = 0.010 inches

<u>Radiological Data</u>

Critical Organ: Fat tissue
Routes of Intake: Ingestion, inhalation, puncture, , wound, skin absorption
Radiological hazard: External exposure from weak ^{14}C beta is not a concern. Internal exposure and contamination are primary concern.
Committed Dose Equivalent(CDE): Ingested: 2.08 mrem/mCi
Inhaled: 2.09 mrem/mCi
Committed Effective Dose Equivalent (CEDE): Ingested: 1.54 mrem/mCi
Annual limit on intake: Ingestion: 2 mCi (labeled organic compound)
Inhalation: 2000 mCi (carbon monoxide)
Inhalation: 200 mCi (carbon dioxide)
Skin Contamination Dose Rate: 1090-1180 mrem per1.0 µCi/cm^2 (7 mg/cm^2)

Common Hazards – Precautions

Detection of contamination is difficult using portable survey instruments, and necessitates the use of swipes counted by liquid scintillation. Liquid scintillation counting efficiency approaches 95%. Typical efficiency for a pancake GM probe at ½" is ~2-3%.

No film or finger badges are required due to minimal external hazard. Survey meters are required when handling > 10 µCi amounts.

No shielding is required during ^{14}C use.

A special problem associated with ^{14}C use is that many compounds are metabolized to release $^{14}CO_2$. Bicarbonate, especially, which is frequently used for biomass productivity studies, readily releases CO_2 on acidification. All such applications resulting in gaseous ^{14}C must be carried out with adequate venting. Released CO_2 can be trapped with highly alkaline solutions, but liquids with pH > 12.5 cannot be disposed as general liquid radioactive waste.

For ^{14}C-labeled compounds that are classified toxic or carcinogenic, including organic solvents, care must be taken to segregate waste and declare it as mixed waste.

3. RADIATION SAFETY DATA – Phosphorus-32 (^{32}P)

Phosphorous-32 is used extensively in life sciences research. It is easily detected and measured, available in a wide variety of radiochemicals, and relatively inexpensive.

Physical Data

Radiation:	Beta emission to ^{32}S (stable)
Energy:	Max.: 1.709 MeV; Average 690 keV
Physical half-life:	14.3 days
Biological half-life:	1155 days (bone); 257 days (whole body)
Effective half-life:	14.1 days (bone); 13.5 days (whole body)
Maximum Beta range in air:	610 cm = 240 inches = 20 ft.
Maximum Beta range in water/tissue:	0.76 cm = 1/3 inch
Maximum Beta range in Plexiglas:	0.61 cm = 3/8 inch

Radiological Data

Critical Organ:		Bone (soluble forms) Lung (inhalation of insoluble or non-transportable compounds) G.I. Tract (ingestion of insoluble or non-transportable compounds)
Routes of Intake:		Ingestion, inhalation, puncture, , wound, skin absorption
Radiological hazard:		External and internal exposure
Committed Dose Equivalent (CDE):	Ingested:	32 mrem/mCi
	Inhaled:	96 mrem/mCi (Class W/lungs)
	Inhaled:	22 mrem/mCi (Class D/ bone marrow)
Committed Effective Dose Equivalent (CEDE):	Ingested:	7.5 mrem/mCi (WB)
	Inhaled:	5.55 mrem/mCi (Class D)
	Inhaled:	13.22 mrem/mCi (Class W)
Annual limit on intake:	Ingestion:	0.6 mCi
	Inhalation:	0.9 mCi (Class D)
	Inhalation:	0.4 mCi (Class W)
Skin Contamination Dose Rate:		8700-9170 mrem/mCi/cm^2 (7 mg/cm^2)

ICRP 30 shows that for most phosphorous intake into the body, about 15% is excreted with half-life of about 1/2 day; 15% goes to intracellular fluids with half-life of about two days, 40% goes to soft tissue with half-life of about 19 days, and 30% is retained in the bone permanently. Intake of 1 µCi, resulting in 0.33 µCi to bone, will produce a dose equivalent of ~9 mrem.

Common Hazards – Precautions

Personal radiation monitors (whole body and finger rings) are required when handling ^{32}P.

Researchers accustomed to handling ^{3}H, ^{14}C and ^{35}S often receive high body doses and higher hand doses when working with ^{32}P. In contrast to the first three isotopes, which produce no external doses, ^{32}P produces high radiation doses through walls of shipping vials, at distances from open containers, etc., and can cause appreciable x-ray secondary radiation (bremsstrahlung) from glass or metal. For instance, dose rates to hands holding a shipping vial or a syringe containing 1 mCi ^{32}P in 1 ml liquid is several rem per hour if the container is plastic, and could be several tens of rem per hour if the container is glass or thin metal. Doses to body, eyes, etc., when working a batch of ^{32}P on a bench or in a hood can easily be tens to hundreds of mrem/hr if shielding is not used.

Shielding is often misunderstood. Bremsstrahlung production increases rapidly as the atomic number (z number) of the target material increases. Hence, shielding for beta radiation should be Lucite, wood or other low-z material. In contrast, shielding for x-rays and gamma rays should be of high-z material for most efficient absorption. For ^{32}P work body shields are often needed. Shields of 1/2" thick lucite will stop the ^{32}P betas, can be seen through, and are reasonably easy to move. Use lead sheets or foil to shield Bremsstrahlung x-rays only after low density Plexiglas/acrylic/wood shielding.

Distance is important, particularly when dealing with small volumes of high activity material. Generally, gloved hands should be kept at least four inches from the container. Pliers, forceps, tongs, or similar devices must be used for removing vial tops, etc. "Moving fast" is simply not adequate.

Never work directly over an open container; avoid direct eye exposure from penetrating ^{32}P beta particles.

An operable survey meter must be present whenever working with more than a few µCi of ^{32}P. Simple Geiger-Mueller (GM) type survey instruments can easily detect quite small amounts of ^{32}P. Typical efficiency for a pancake GM probe at ½" is ~25%. LSC efficiency is ~95%. Routine instrument surveys must be made to locate contamination so that it can be cleaned, and to locate unexpected radiation levels so that they can be shielded or marked to prevent unneeded personnel doses.

4. RADIATION SAFETY DATA – Phosphorus-33 (^{33}P)

Phosphorous-33 is used in the life sciences research. It is easily detected, measured, and is widely available in a variety of radiochemicals. ^{33}P is used in a similar manner to ^{32}P, but has a lower energy beta emission and a longer half-life.

<u>Physical Data</u>

Radiation:	Beta emission to ^{33}S (stable)
Energy:	Max.: 0.249 MeV; Average 85 keV
Physical half-life:	25.4 days
Biological half-life:	1155 days (bone); 257 days (whole body)
Effective half-life:	24.9 days (bone)
Maximum Beta range in air:	89 cm = 35 inches = 3 ft.
Maximum Beta range in water/tissue:	0.11 cm = 0.04 inch
Maximum Beta range in Plexiglas:	0.089 cm = 0.035 inch

<u>Radiological Data</u>

Critical Organ:	Bone (soluble forms) Lung (inhalation of insoluble or non-transportable compounds) G.I. Tract (ingestion of insoluble or non-transportable compounds)
Routes of Intake:	Ingestion, inhalation, puncture, , wound, skin absorption
Radiological hazard:	External and internal exposure

Committed Dose Equivalent (CDE):	Inhaled:	0.5 mrem/mCi
Annual limit on intake:	Ingestion:	6.0 mCi
	Inhalation:	8.0 mCi (Class D)
	Inhalation:	3.0 mCi (Class W)
Skin Contamination Dose Rate:		2,910 mrem/hr/μCi/cm^2 (7 mg/cm^2)

ICRP 30 shows that for most phosphorous intake into the body, about 15% is excreted with half-life of about 1/2 day; 15% goes to intracellular fluids with half-life of about two days, 40% goes to soft tissue with half-life of about 19 days, and 30% is retained in the bone permanently. Intake of 1 μCi, resulting in 0.33 μCi to bone, will produce a dose equivalent of ~9 mrem.

<u>Common Hazards – Precautions</u>

Personnel dosimeters (XBG body badge and TLD finger rings) are not necessary due to the low energy of the beta emission. However, the beta is of sufficient energy to be easily detected using a thin-window GM survey instrument. A GM pancake probe should be used to survey the work area following use of ^{33}P.

5. RADIATION SAFETY DATA – Sulfur- 35 (^{35}S)

^{35}S has become widely used in molecular biology due to the combination of moderate beta energy emission and high attainable specific activity. The low beta energy emission makes ^{35}S safe to handle (unless volatile), yet permits some detection with a hand-held monitor and very efficient detection by liquid scintillation counting.

Physical Data

Radiation: Beta emission to ^{35}Cl (stable)
Energy: Max.: 0.167 MeV; Average 53 keV
Physical half-life: 87.4 days
Biological half-life: 623 days (unbound); 90 days (bound)
Effective half-life: 44-76 days (unbound)
Maximum Beta range in air: 26 cm = 10.2 inches
Maximum Beta range in water/tissue: 0.32 mm = 0.015 inch
Maximum Beta range in Plexiglas: 0.25 mm = 0.01 inch

Radiological Data

Critical Organ: Testis
Routes of Intake: Ingestion, inhalation, puncture, , wound, skin absorption
Radiological hazard: External exposure from weak beat is not a concern Internal exposure and contamination are the primary concerns.
Committed Dose Equivalent (CDE): Ingested: 10.0 mrem/µCi
Committed Effective Dose Equivalent (CEDE): Ingested: 2.6 mrem/µCi*
*Assumes a 90 day biological half-life
Inhaled: 2.48 mrem/µCi
Annual limit on intake: Ingestion: 10 mCi (inorganic compounds)
Ingestion: 6 mCi (elemental sulfur)
Inhalation: 10 mCi (vapors)
Inhalation: 20 mCi (sulfides and sulfates)
Skin Contamination Dose Rate: 1,170 - 1,260 mrem/µCi/cm^2 (7 mg/cm^2)

Common Hazards – Precautions

Detection of contamination is difficult using portable survey instruments, and necessitates the use of swipes counted by liquid scintillation. Liquid scintillation counting efficiency approaches 95%. Typical efficiency for a pancake GM probe at ½” is ~2-3%.

No shielding is required during ^{35}S use.

No film or finger badges are required due to minimal external hazard. Survey meters are required when handling > 10 μCi amounts.

Some ^{35}S-labelled compounds (notably methionine and cysteine, but not thio-nucleotides) generate volatile decomposition products, which are released during lypholization, incubation, or after storage. Storage containers should always be opened in the fume hood to vent any volatiles. Activated charcoal present during storage or incubations (available in paper form in various sizes from Schleicher & Schuell: β-*Safe*) can absorb such volatiles. Such an absorber should be present in incubator chambers when large-scale incubations with ^{35}S-labeled amino acids are carried out [refer to Meisenhelder and Hunter, *Nature* 335(1988):120].

6. RADIATION SAFETY DATA – Iodine-125 (^{125}I)

^{125}I is mostly used in labeling proteins to high specific activity, a use that has declined with the development of alternative detection methods. As an x-ray/gamma emitter, a specialized gamma counter is required for efficient counting. The volatility of many forms, high penetration of the released x-rays, and strong concentration in the thyroid gland can make work with ^{125}I hazardous.

Physical Data

Radiation: Electron capture to ^{125}Te (stable)
Gamma 35.5 keV (7% abundance/93% internally converted)
X-ray 27.0 keV (113% abundance)
Gamma Constant: 0.27 mR/hr per mCi @ 1.0 meter
Physical half-life: 60.1 days
Biological half-life: 120-138 days (unbound iodine) – thyroid elimination
Effective half-life: 42 days (unbound iodine) – thyroid gland

Radiological Data

Critical Organ: Thyroid
Routes of Intake: Ingestion, inhalation (most probable), puncture, wound, skin absorption
Radiological hazard: External and internal exposure and contamination concerns exist.
Committed Dose Equivalent (CDE): Ingested: 1185 mrem/mCi (thyroid/Class D)
Inhaled: 814 mrem/mCi (thyroid/NaI form)
Committed Effective Dose Equivalent (CEDE): Inhaled: 24 mrem/mCi (whole body)
Annual limit on intake: Ingestion: 0.04 mCi (Class D)
Ingestion: 0.1 mCi (thyroid)
Inhalation: 0.06 mCi (Class D)
Inhalation: 0.2 mCi (thyroid)

Common Hazards – Precautions

The penetrating ability of the released x-rays makes shielding in all directions important.
Detection of contamination requires a portable survey instrument fitted with a thin-crystal scintillation probe appropriate probe. Efficiency for a 1 mm thick by

1 in diameter probe is ~8%. Swipes may be counted by gamma counter (~80% efficiency) or LSC (efficiency approaches 80%).

Although ^{125}I emits x-ray radiation, which is generally more penetrating than beta radiation, the low energy of emission means relatively thin shields of high-density materials (lead or steel) provide adequate shielding. First half-value layer for shielding is 0.02 mm lead.

^{125}I is or can become volatile in many forms.

Persons working with more than 100 µCi of ^{125}I must have thyroid counts before initial use and after each run. Contact the Environmental Health and Safety Office to arrange for these scans.

Film and finger badges are required for individuals working with ^{125}I. Survey meters equipped with a thin-crystal scintillation probe are required when handling >10 µCi.

Work with more than a few µCi must be performed in an operating fume hood.