

UCLA Radiation Safety Manual

(This is an abridged version for the web site. Contact the RSD for a complete, printed version)

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Chapter 1: Introduction

A. GENERAL INFORMATION

The Chancellor is responsible for maintaining a Radiation Safety Program to ensure the safe use of ionizing radiation on the UCLA campus. The Radiation Safety Manual is a formal statement of policies and procedures pertaining to radiation safety. It has the concurrence and support of the Radiation Safety Committee and the Medical Radiation Safety Committee. The Vice Chancellor, Research Programs, appoints the committee chairs and members and assures that the overall radiation safety policy is being executed. The California Department of Health Services issues a license to UCLA that contains many special requirements. This license, along with applicable State laws and regulations, governs the use of ionizing radiation at UCLA.

This Radiation Safety Manual replaces all previous manuals that have been distributed to persons who are engaged in work with radioactive material and radiation-producing machines.

Uses of radiation for treatment, diagnosis, or research on humans must be reviewed and approved by the Medical Radiation Safety Committee. All other uses are reviewed and approved by the Radiation Safety Committee.

The Radiation Safety Division is responsible for providing a radiation safety program that preserves the environment and health of the campus community and assures that personnel radiation exposures at UCLA are maintained as low as reasonably achievable (ALARA). This is accomplished with the concurrence of the Radiation Safety Committee or the Medical Radiation Safety Committee through the application of recommendations of the National Council on Radiation Protection and Measurements, the American National Standards Institute, and adherence to other accepted practices not clearly required by license provision.

B. DISTRIBUTION OF MANUAL

This document is intended to be a source book for all radiation workers and is an adjunct to radiation safety training. Each authorized user is assigned a copy of this manual.

A copy of the manual must be available in the laboratory for reference and inspection purposes.

This manual may undergo periodic revisions that can be incorporated by replacing original pages of the manual. Such revisions will be routinely issued to each official manual holder.

C. SCOPE

This manual is the principal document governing all radiation use at UCLA and is required in order for UCLA to possess a broad scope, type A, Radioactive Material License with the California Department of Health Services. The authority for the Radiation Safety Program flows directly from the University of California Board of Regents and is delegated to the Chancellor, Vice Chancellor of Research Programs, and ultimately to the Radiation Safety Committee and Medical Radiation Safety Committee.

Chapter 2: Authority and Responsibilities

A. CHANCELLOR

In accordance with state and federal laws and UCLA's broad scope radioactive material license, the chancellor has delegated to the research and administrative vice chancellors the authority to administer the radiation safety program. Routine administration of the program is delegated to the Radiation Safety Division, with oversight from the Radiation Safety Committee and the Medical Radiation Safety Committee.

B. VICE CHANCELLORS

The complementary roles of the research and administrative vice chancellors are, respectively, to provide management structure for the establishment of policy, and operational capability to the Radiation Safety Division, as outlined below.

The research vice chancellor appoints the members of the Radiation Safety Committee and the Medical Radiation Safety Committee. These bodies establish policy for the use of ionizing radiation on the UCLA campus.

The administrative vice chancellor is responsible for the operational aspects of the radiation safety program performed under the auspices of the Radiation Safety Division.

C. RADIATION SAFETY COMMITTEE

The Radiation Safety Committee is required by state regulations. It is responsible for maintaining UCLA personnel radiation exposures as low as reasonably achievable (ALARA) and for activities at UCLA involving the use of radioactive material and radiation-producing machines. The Committee develops campus policy concerning radiation safety.

The chairperson and members of the Radiation Safety Committee are selected from faculty who are knowledgeable in radiation safety and the use of radioactive material and radiation-producing machines. The term of membership is one year and is renewable. The Radiation Safety Committee has the authority to evaluate and authorize research, development, or educational use of radioactive material or radiation-producing machines. The Committee may suspend or revoke an authorization for the use of radioactive material or the operation of a radiation-producing machine. The committee meets quarterly to carry out the responsibilities outlined in the bylaws.

D. MEDICAL RADIATION SAFETY COMMITTEE

The Medical Radiation Safety Committee is required by regulation and reviews proposed uses involving the administration of radioactive material or external ionizing radiation to human subjects.

The chairperson and members are selected from UCLA faculty who are knowledgeable in radiation safety and the human use of radioactive material and radiation-producing machines. The term of membership is one year and is renewable. The Medical Radiation Safety Committee has the authority to evaluate and authorize human-use research and development involving radioactive material or radiation-producing machines. The committee may suspend or revoke a human-use authorization for the use of radioactive material or the operation of a radiation-producing machine. The committee meets at least once annually to carry out the responsibilities outlined in the bylaws.

E. OFFICE OF ENVIRONMENT, HEALTH & SAFETY

The Office of Environment, Health & Safety (EH&S) is responsible for assuring that all UCLA facilities are operated in a safe manner and comply with the requirements of governmental agencies and University of California policies. EH&S provides guidance and services to ensure a safe working environment at UCLA.

EH&S activities are carried out by professionals in safety engineering, industrial hygiene, sanitation, biological and chemical safety, emergency planning, fire safety, and radiation safety. The EH&S Director serves on various safety committees.

F. RADIATION SAFETY DIVISION

The Radiation Safety Division is the operational unit for the radiation safety program and is managed by the Radiation Safety Officer (RSO). The RSO is designated by name and position as a broad scope license condition and is an ex-officio member of the Radiation Safety Committee and the Medical Radiation Safety Committee.

The Radiation Safety Division manages the operational aspects of the radiation safety program and provides technical guidance and information to the committees. Division personnel include health physicists, technologists, and administrative staff. Radiation Safety Division responsibilities include:

1. Regulatory functions such as the administration of the radioactive material and X-ray machine authorization programs; survey and audit functions; and assuring compliance with state, federal, and local radiation control regulations.
2. Educational functions to support and train radiation users and to provide community outreach activities.
3. Service functions to supply client needs such as radioactive waste disposal, instrument calibration, and emergency response.

G. AUTHORIZED USER

The authorized user (AU) assures that activities under the radiation use authorization are conducted in accordance with radiation safety requirements and good practices, as presented in this manual and in other reference material available from the Radiation Safety Division. In addition, the AU must maintain records demonstrating compliance with radiation safety laws, regulations, and University policy concerning personnel training and safety when using radioactive material or radiation-producing machines.

H. RADIATION WORKERS

Radiation workers are responsible for complying with conditions of the radiation use authorization, radiation safety requirements, and good practices as presented in this manual and in other reference material available from the Radiation Safety Division.

Chapter 3: ALARA and Quality Assurance

A. INTRODUCTION

Accepted good practice for the use of radioactive material and radiation-producing machines results in personnel radiation exposures being reduced to values as low as reasonably achievable (ALARA). In 1973, the International Commission on Radiological Protection (ICRP) published guidelines for maintaining radiation doses at ALARA levels.

“As any exposure may involve some degree of risk, and thus some detriment, the comprehensive system of dose limitation is aimed at the following principal objectives:

- a. to ensure compliance with the dose limits;
- b. to avoid the use of unnecessary sources of exposure;
- c. to provide for operational control of specific procedures, both individually and in combination, so that the resulting doses are as low as is reasonably achievable, economic and social considerations being taken into account; and
- d. to provide a general framework to ensure that these doses are justifiable in terms of benefits that would not otherwise have been received.”

Federal regulations require a formal ALARA program. UCLA is expected to set investigation levels of dose well below the established limits, develop records of investigations and engineering or administrative corrections, and assure involvement by management.

These requirements suggest the need for a quality assurance (QA) program as a standard management tool to evaluate the required ALARA program. The ALARA principle does not mandate radiation exposure minimization. It means that unnecessary exposures are avoided, with economic and social factors considered.

B. OBJECTIVE OF RADIATION PROTECTION

At UCLA the authorized user (AU) and the Radiation Safety Division share responsibility for QA. The AU has primary responsibility for safety in the workplace. The Radiation Safety Division's role includes the development of policies and procedures which facilitate research and development while maintaining the principles of ALARA.

C. RADIATION PROTECTION PROGRAM

The responsibilities for the development and implementation of the ALARA program are outlined below.

1. Authorized users shall:
 - a. Consult with, and receive the approval of, the Radiation Safety Division before using radioactive material in a new procedure.
 - b. Evaluate procedures before using radioactive material, to ensure that radiation exposures will be kept ALARA, using trial runs, as necessary.
 - c. Explain the ALARA principle to all persons under their supervision.
 - d. Ensure that persons who are subject to occupational radiation exposure are trained in good health physics practices, including the ALARA concept.

2. Radiation Workers shall:
 - a. Be familiar with the ALARA principle and its application to working procedures and conditions.
 - b. Be aware of measures taken to assure that exposures are maintained ALARA.
 - c. Perform consistent and systematic radiation surveys to minimize contamination.
 - d. Follow established practices in the use of personnel radiation monitoring devices, participation in bioassay programs, and maintenance of safety equipment (e.g. chemical hood flow rates, iodination hood filters, and electrical interlocks installed for access control).
 - e. Maintain good housekeeping practices to minimize exposure to radioactive contamination in the workplace, and control the accumulation, packaging, and segregation of radioactive waste materials.

3. The Radiation Safety Division Staff shall:
 - a. Perform consistent and systematic radiation audits of UCLA work areas in support of the primary surveillance done by the AU.
 - b. Complete assigned surveillance, personnel monitoring, dosimetry, and bioassay functions in a timely fashion, and assure that findings are reported to the appropriate health physicist or state agency.
 - c. Perform laboratory surveys and calibrate survey instruments according to established procedures.
 - d. Perform dosimetry and bioassay procedures and review results for these programs.
 - e. Inspect safety devices and warning signs or posters in assigned areas.
 - f. Develop and maintain records and log books.

4. The Radiation Safety Officer or Designee shall:
 - a. Perform annual reviews of radiation safety programs to assure adherence to ALARA concepts.
 - b. Review external radiation exposure and bioassay results and identify trends in personnel exposure.
 - c. Ensure that radiation workers and other personnel exposed to radiation are instructed in the ALARA principle and its application in the workplace.
 - d. Maintain the Radiation Safety Manual and related documents (e.g., technical and administrative notices to AUs).
 - e. Assure that laboratory and survey instrumentation is maintained in working condition and properly calibrated.

Chapter 4: Management of Radioactive Material

A. INTRODUCTION

Radioactive isotopes are used in teaching, research and development and for the diagnosis or treatment of human ailments. Either the Federal government or the State of California regulates radioactive material use. Special administrative procedures for human use authorizations are given in Chapter 5. The acquisition of radioisotopes for any use must first be authorized by the Radiation Safety Division upon recommendation of the Radiation Safety Committee (RSC) or the Medical Radiation Safety Committee (MRSC).

B. PLANNING A PROJECT USING RADIOACTIVE MATERIAL

Each project must be planned by the authorized user (AU) to assure that all research activities are conducted safely. Planning assures the safety of both authorized radiation workers, nearby non-radiation workers, and members of the public. AUs must maintain radiation exposures at levels as low as reasonably achievable (ALARA). Inadequate planning may result in serious safety situations, unwanted radiation exposure, and non-compliance with applicable policies and regulations.

When planning for isotope use, the following factors must be considered:

1. Personnel

The proper training of people who are directly or indirectly involved with radiation and radioactive material is foundational to a good radiation safety program. At UCLA, training must be accomplished through a partnership between the Radiation Safety Division (RSD) and authorized users (AU). The program has three primary elements: initial training, continuing training, and performance-based review of laboratory activities. See Chapter 12 for training requirements.

2. Safety Procedures and Controls

a. Administrative Controls

Policies and procedures employed in the workplace must assure that radioactive material is used safely.

b. Physical Controls

Physical controls are engineered into the work area, as applicable. Engineered controls include shielding to reduce exposure to penetrating radiation and fume hoods and glove boxes to provide containment and to prevent exposure to airborne radioactive isotopes.

c. Environmental Considerations

Radioactive isotopes, as well as many chemical compounds, cannot be released to the environment without control. Uncontrolled release is contrary to conditions of the UCLA license, government regulations, and the ALARA exposure principle.

d. Animal Use

If the project involves the administration of radioactive material to live animals, the planned use must conform to the requirements of the Division of Animal Medicine and the Animal Research Committee, as well as the requirements of the Radiation Safety Division.

3. Records

Record keeping must be in accordance with policies and procedures developed by the Radiation Safety Division.

At a minimum, records must be maintained for the following:

- a. Isotope receipt
- b. Isotope inventory
- c. Isotope transfer/disposal
- d. Laboratory surveys

4. Quantities and Chemical Forms

The isotope quantities requested by an AU for a project should be limited only to those quantities needed. The principles of ALARA should always be considered. Requesting only needed materials will reduce exposure to personnel and minimize radioactive waste.

Limiting the isotope quantities to be acquired is especially important for projects in which radioactive material is likely to become airborne. Aerosols are easy to generate and become a personnel hazard and environmental control problem.

5. Radioactive Waste Management

The AU must provide appropriate radioactive waste containers and adequate storage of radioactive waste material prior to transfer to the Radiation Safety Division. Disposing of radioactive material in ordinary waste streams (i.e. sanitary sewer or ordinary trash) is a serious violation of UCLA's radioactive material license. See Chapter 10 for more detailed information on radioactive waste management.

6. Laboratory Layout

Authorized users should plan the layout of a radioactive material laboratory (i.e. equipment, storage facilities, benches, fume hoods, floor coverings) to simplify decontamination. When radioactive material use is discontinued in a laboratory, a thorough survey must be conducted and, if necessary, decontamination of areas having levels of contamination above limits specified in Chapter 9.

7. Lead Time

The AU must provide sufficient time for the required safety evaluation of proposed isotope use by the Radiation Safety Division and the Radiation Safety Committees.

C. OBTAINING A RADIATION USE AUTHORIZATION

Research, clinical, and instructional use of radioactive material must be authorized by the Radiation Safety Division with oversight from the Radiation Safety Committee or Medical Radiation Safety Committee.

1. Application for Approval of Isotope Project

The authorized user (AU) should complete the application as the first step in obtaining the authority for radioisotope use. Applications are available from the Radiation Safety Division.

2. Required Information

The authorized user must submit a training and experience form with the application. Anyone who works in a laboratory where isotopes are used must participate in initial training or demonstrate competency prior to being added to an isotope project.

3. Review by the Radiation Safety Division

The Radiation Safety Division makes an evaluation of the application. The incoming application is assigned an identification number. After review and approval by the Radiation Safety Division and Radiation Safety Committee, this number becomes the permanent authorization number.

The need for radiation monitoring, dosimetry, bioassays, survey instruments, swipe sampling (for the detection of radioactive contamination), and independent surveillance by the Radiation Safety Division, is determined during the review process.

Special conditions may be stipulated because of the review. Standard conditions applicable to all projects are not shown on the authorization. They are contained in this manual and general notices to all AUs issued by the Radiation Safety Division.

4. Review and Concurrence by the Radiation Safety Committee

After evaluation of the application by the Radiation Safety Division, a Radiation Use Authorization (RUA) is produced. The RUA is sent to the Radiation Safety Committee for final review.

The Radiation Safety Committee has oversight of all use of radioactive material at UCLA. Much of the authorization process, however, is delegated to the Radiation Safety Division. Committee involvement in the authorization process is based on the level of hazard. For new applications and renewals the project description and procedures may also affect Committee involvement.

5. Approved Project

After Committee approval, a copy of the authorization is sent to the AU. The RUA lists the authorized isotopes, acquisition limits, use limits, authorized uses, personnel radiation badge and bioassay coverage, and any special conditions applicable only to that authorization.

The approved authorization permits the AU to acquire and use the radioisotopes specified on the authorization subject to general radiation safety requirements indicated in this manual, in supplementary guidance distributed by the RSD, and special conditions stipulated in the authorization.

A copy of the RUA must be available in the laboratory, and workers should be familiar with its conditions.

6. Authorization Period

Every four (4) years the Radiation Safety Division will send a radiation use authorization renewal form to each AU. The purpose of this form is to determine the status of the project. If the AU wishes to continue working with radioactive material, all relevant information specified on the renewal form must be completed. The completed form must be returned to the Radiation Safety Division in the allotted time.

7. Amendment of Project Authorizations

A radiation use authorization may be amended before the expiration date. The AU applies for such changes through the Radiation Safety Division. Such requests must include sufficient information to enable an evaluation or referral to the Radiation Safety Committee.

Committee approval is not required for an amendment if the documents supplied by the AU and project audits show no major operational problems or changes. However, the Radiation Safety Officer may refer isotope projects with major or recurring operational problems to the chair of the Radiation Safety Committee for advice or action by the committee.

Amendments are needed for an increase in quantities of isotopes already approved for use, the addition of new isotopes, changes in quantity of an isotope used per procedure, significant changes in procedure, room changes, or personnel changes. The Radiation Safety Division must determine that there is no significant increase in hazard, as indicated by the safety index (SI) and recent performance. The Radiation Safety Division cannot amend Human Use Isotope Authorizations without prior approval from the Medical Radiation Safety Committee chair.

8. Reinstatement of a Suspended Project

An authorized project may be interrupted for any of several reasons. These may include extended absence or sabbatical leave by the AU, poor safety performance, or continued disregard for University procedures. The project may be reinstated following verification of corrective action and after consultation with the Committee Chair. In exceptional cases, safety violations and reinstatements may be a matter for consideration of the full committee.

D. SAFETY INDEX

The safety index is a calculated value employed by the Radiation Safety Division to assess the hazards associated with the laboratory use of radioactive material. Health physicists use the safety index to assess the risks from internal uptake and external exposure associated with radioactive material being used in laboratory experiments. The numerical value of the safety index determines the extent to which the Radiation Safety Committee becomes involved in the review of an application or amendment and the frequency and level of inspection by the Radiation Safety Division.

Review and approval by a single committee member is required for renewals and new projects if the SI is less than or equal to 25. If the SI is greater than 25, review by the Committee chair and at least one other committee member is required.

E. LABORATORY INSPECTION REQUIREMENTS

Routine radiation surveys of laboratory areas must be made by the AU or a qualified designee, and the surveys must be documented for audit by the Radiation Safety Division. See Chapter 9 for details regarding radiation surveillance of laboratories.

The documented inspection frequency for authorized user surveys is monthly. The frequency of inspection or audit by the Radiation Safety Division is based on the initial evaluation of the project and subsequent safety performance by the user. For authorizations with a safety index greater than twenty-five ($SI > 25$), the annual review process shall include a laboratory audit by the responsible health physicist or a qualified division representative.

F. ACQUISITION OF RADIOACTIVE MATERIAL

All acquisition, use, transfer (both on and off campus) of radioactive material, must be done in accordance with appropriate policies and procedures.

Some small quantities of isotopes are permanently installed in commercially-available devices, such as military compasses, luminescent signs, liquid scintillation counters, and gas chromatographs. While these sources are exempt from ordinary controls because of general license provisions in the California Radiation Control Regulations (17CCR), their acquisition and description must be reported to the Radiation Safety Division.

1. To acquire radioactive material, the AU must follow administrative procedures:
 - a. The acquisition must conform to both the quantity limitations and the chemical or physical form specified on the project authorization.
 - b. The shipping document must identify the name of the AU and the authorization number (e.g. LA000). This will ensure that the package will be assigned to the correct RUA and distributed in a timely manner.

2. Packages containing radioactive material must be shipped to the attention of the Radiation Safety Division. The Radiation Safety Division may grant specific pre-approved exceptions for direct shipment to the AU.
3. Packages addressed to the AUs are usually delivered to Medical Receiving.
 - a. The Radiation Safety Division receives and records the shipment and notifies the AU. Shipments which do not conform to the RUA are held.
 - b. Incoming shipments containing radioisotopes are examined for containment integrity and conformance to transportation regulations and are monitored for contamination.
 - c. The Radiation Safety Division notifies the AU of the receipt and advises the AU of excessive contamination. A contaminated package may be held until special arrangements can be made to help the AU in handling the isotope, or the vendor may replace the contaminated shipment. If the shipment is replaced, the Radiation Safety Division will return the radioisotope to the vendor or dispose of the contaminated package and radioisotope.
4. Cyclotron-produced isotopes at UCLA are transferred directly to authorized users without being routed through the Radiation Safety Division. The transfers of cyclotron-produced isotopes or labeled compounds can be made within the limits specified in the recipient's authorization and must be documented. Before initiating such a transfer, the AU must ascertain that the recipient is authorized to receive the isotopes, labeled compounds, and quantity to be transferred.
5. The receipt or discovery of unauthorized isotopes must be reported to the Radiation Safety Division immediately.
6. The transfer of isotopes to another AU can be made within the limits specified in the recipient's authorization and must be documented.
7. The shipment of radioactive material from any AU to another licensee outside UCLA is subject to strict Federal Department of Transportation regulations and requirements. The Radiation Safety Division is the only organization at UCLA that can authorize the transfer of radioactive material to off-campus locations. The AU must:
 - a. Obtain a copy of the recipient's license. This copy must be sent to the Radiation Safety Division to show that the recipient is authorized to receive the particular isotope and the quantity to be shipped.
 - b. Obtain guidance on packaging from the Radiation Safety Division for either common carrier or private vehicle transport.
 - c. Provide adequate shipping instructions (address of recipient, name of isotope, quantity, etc.).
 - d. Provide the Radiation Safety Division with a charge number to cover costs of the shipment.
8. Large sealed sources are leak tested semiannually, except those used in medical therapy. Unneeded sealed sources should be transferred to the Radiation Safety Division by special arrangement. Storage of unneeded sealed sources for long periods is not recommended.

G. CLOSE-OUT OF LABORATORY FACILITIES

Authorized radioactive material users may not remodel a laboratory, relocate to a different laboratory, or abandon the radiation use area without express written approval of the Radiation Safety Division. Abandoning a radiation use area without approval will subject the AU, department chair, or division head, as signatory of the original application, to payment of costly clean-up fees.

AUs wishing to remodel an existing radiation use area, relocate from one laboratory to another, or discontinue use of radioactive material in a laboratory must advise the Radiation Safety Division of the planned remodel, relocation, or termination of use to avoid the clean-up fees. Refer to Chapter 9 for more information.

Chapter 5: Human Medical Use of Radiation

A. INTRODUCTION

The broad scope license requirements, regulations of the California Department of Health Services (17 CCR), and federal regulations of the Food and Drug Administration govern activities involving the administration of radioisotopes and ionizing radiation to humans for medical purposes or research. Proposals for procedures directly or indirectly related to research must be reviewed and approved by the Medical Radiation Safety Committee (MRSC) and by the Radiation Safety Officer (RSO).

The MRSC is charged with reviewing and authorizing all applications that involve the exposure of humans to ionizing radiation for medical purposes, whether from radioactive material (radionuclides) administered internally or from external radiation sources. Committee members include faculty members with training in diagnostic radiology, nuclear medicine, radiation oncology, and internal medicine, as well as special competence in radiation biophysics, radiation safety, and radioactive pharmaceuticals. The committee has three subcommittees:

1. **Radiochemical/Radiopharmaceutical – Human-Use**

The Radiochemical/Radiopharmaceutical – Human-Use Subcommittee:

- a. Reviews all proposals for the direct and indirect research use of radiochemicals and radiopharmaceuticals in humans. The members of this subcommittee act as the Radioactive Drug Research Committee (RDRC), as required by United States Food and Drug Administration regulations, for the evaluation of radiopharmaceutical uses in humans for research purposes.
- b. Makes annual evaluations of projects approved under a. above.
- c. Provides a general radiation safety review of routine use of radioactive material in diagnostic and therapeutic procedures.

2. **Machine-generated Radiation**

The Machine-generated Radiation Subcommittee reviews research proposals involving the non-routine (i.e., volunteers, controls) purposeful exposures of humans to ionizing radiation from X-ray machines or other devices.

3. **Medical Surveillance**

The Medical Surveillance Subcommittee provides scientific expertise to the Radiation Safety Division on special radiation protection matters related to medical and occupational exposure, including bioassays.

B. Authorization of Radioisotope Use

The authorization for human research use requires that the responsible physician or faculty member must first obtain the approval of the MRSC and the Radiation Safety Division. As for all radioactive material use, the authorization must be secured prior to purchase, receipt, possession, and use of radioisotopes.

1. **Radioactive Material Use for Medical Research.** If the radioactive material is to be used to gather data on elemental distribution in the body, metabolism, kinetics, biochemistry, or other information of a physiological nature, the investigator or applicant must comply with applicable regulations of the United States Food and Drug Administration and the State of California. This information is reviewed by the MRSC. Note that the applicant also must submit the proposal to the Human Subject Protection Committee, which reviews all non-radiation aspects of the research project.

If the proposed study is not covered by an RDRC approval or other exemption, then, besides obtaining approval by the Medical Radiation Safety and the Human Subject Protection Committees, the applicant also must file a "Notice of Claimed Exemption for a New Drug (or Biologic)" (commonly known as an IND application) with the FDA. The applicant should consult with the Medical Radiation Safety Committee in

preparing the IND. This does not apply to positron emission tomography (PET) drugs or unlabeled indications of any approved drug or biologic, including all radiopharmaceuticals.

2. **Radiopharmaceuticals for Medical Use.** Radioactive material may be administered if, in the "best medical judgment" of the authorized user physician, it appears to be appropriate for the patient. No legitimate medical use (i.e., for the good of the individual patient) will be classified as a *research* project.

C. SUBMISSION OF PROPOSALS TO MEDICAL RADIATION SAFETY COMMITTEE

1. General Policy

- a. The Medical Radiation Safety Committee reviews the administration of radioactive material or external ionizing radiation to human subjects for medical purposes, but separate project applications are *not* necessary. They are only necessary for *research* purposes.
- b. Each application is evaluated in consideration as to safety to patients and investigators. Committee considerations and actions are based on: guidelines established by official agencies, such as California and Federal regulatory agencies, the National Council on Radiation Protection and Measurements, the International Commission on Radiation Protection, and other authoritative organizations, and Accepted good p practices.
- c. The minimum qualification for investigators intending to use radiopharmaceuticals in human subjects is Board Certification in Nuclear Medicine. For use of diagnostic radiation-producing machines, physicians must have appropriate State of California certification. Physicians who are Board Certified in Radiation Oncology may only perform radiation therapy in human subjects. Inexperienced investigators who need to use radioactive material or machines will be guided by the MRSC into collaborative programs with experienced investigators.
- d. Radiochemical and radiopharmaceutical control is essential during receipt of the incoming material by the investigator, in opening shipping containers, and making primary dilutions. The greatest hazard to patients or experimental subjects occurs in errors of dosage. The MRSC requires that all radiochemicals and radiopharmaceuticals for human use be sent to a central laboratory and dispensed from there after all calculations of isotope dilution have been checked by an authorized user physician or an authorized user nuclear pharmacist or their designee, a certified nuclear medicine technologist, or a pharmacy technician under the direct supervision of the nuclear pharmacist. For gamma-emitting isotopes, the activity will generally be checked in calibrated well-type ionization chambers, and the radioisotopic purity will be checked in a multichannel analyzer before being dispensed, unless it is verified by the manufacturer, a nuclear pharmacist, or an institutional nuclear medicine physician or his designee.
- e. Policies for normal research patients are consistent with the National Institutes of Health (NIH) policy on clinical research. The MRSC is specifically charged with evaluation of hazards of all clinical research under NIH guidelines.
- f. Proposals involving children or pregnant women are evaluated by the full Committee before approval.
- g. The MRSC may deny approval based on inadequate safety to investigators, patients, or research subjects, or inexperience.
- h. The full MRSC meets at least annually to review policy, activities of the subcommittees, and other matters set before the MRSC by the Chair. Interim meetings are held to resolve particular problems or projects.

2. Required Information

To simplify committee review, the following information should be submitted:

- a. Application for Use of Radioactive Material (Human Use);
- b. Application for Use of Radioactive Material (Non-routine Human Use);
- c. Pertinent protocol portion of the grant, contract, or proposal;
- d. Consent form must show estimated radiation dose to patient, preferably relative to dose from some common radiation exposure;
- e. Training and Experience Form (unless already submitted to the Radiation Safety Division);
- f. Radiation dosimetry calculations (MIRD method), or if another method, cite literature.

D. Machine-generated Ionizing Radiation

All machines that generate ionizing radiation, including those for either medical diagnostic or therapeutic purposes, must be registered with the State of California. Their installation and operation must be registered with the Radiation Safety Division.

Use of machines for medical or dental purposes, as opposed to research, either diagnostic or therapeutic, does *not* usually require review by the Medical Radiation Safety Committee.

Use of machines for any research involving the intentional irradiation of volunteer patients or control subjects *does* require the submission of an appropriate application submitted to the Radiation Safety Division.

Chapter 6: Management of Radiation-Producing Machines

A. INTRODUCTION

A radiation-producing machine is any high-voltage device that, during operation, can generate or emit ionizing radiation. This definition does not include machines that produce ionizing radiation solely by the use of radioactive material. Examples of radiation-producing machines include X-ray machines used in medicine, dentistry, and veterinary medicine; diffraction and fluorescence analyses; electron microscopy; cyclotrons; and other particle accelerators.

Over 300 radiation-producing machines are operated at UCLA both on and off campus. The Radiation Safety Division (RSD) controls the use of these machines. All persons proposing to use radiation-producing machines owned or operated under the direction of the RSD must comply with the provisions of this chapter and all applicable federal and state regulations. Most of the regulatory requirements that apply to radiation-producing machines are contained in Title 17 of the California Code of Regulations.

B. REQUIREMENTS FOR THE USE OF RADIATION-PRODUCING MACHINES

Registration: Radiation-producing machines must be registered with the California Department of Health Services (DHS). Pursuant to existing regulations they are renewed on a biennial basis. The Radiation Safety Division performs all required machine registration functions. The authorized user (AU) must supply registration information or an X-ray machine status change to the RSD. This can best be accomplished by contacting the RSD and completing the appropriate form. Once the RSD is in receipt of this information, it is forwarded to DHS for data entry.

Machine Authorization: In addition to registration requirements with DHS, all X-ray machines are required to have a current Machine Authorization (MA) issued by the RSD before they may operate at UCLA. Machine authorization applications, with instructions, are available from the RSD. The completed application must be submitted for review and approval to the RSD.

User Training: Only trained and authorized personnel may operate radiation-producing machines. Users must receive initial training and successfully complete a quiz prior to using X-ray equipment.

Initial and annual refresher training should include:

1. Review of radiation protection tenets of time, distance, and shielding;
2. UCLA Radiation Safety Division Policies and Procedures;
3. Regulatory requirements;
4. Dosimetry;
5. Site-specific information supplied by the AU such as safe operating procedures for X-ray Machines, safe use of X-ray Machines in the laboratory, and policies and procedures related to X-ray Machines used for experiments or for research purposes.

Peripheral Worker Training: Individuals who do not operate radiation-producing machines but are peripherally involved with the experiment or procedure, must receive training from the AU or RSD. Training topics should include ALARA principles, UCLA policies and procedures, regulations, and dosimetry requirements.

Annual Retraining: X-ray users who apply ionizing radiation to human beings and currently possess a valid license, certificate, or permit from the State of California or the Dental Board of California are not required to obtain annual retraining from RSD. Continuing education units required for renewal of these licenses, certificates, or permits satisfy the retraining requirements.

X-ray users who operate non-human use X-ray equipment and peripheral workers must receive at least one hour of retraining annually. The AU or RSD can provide appropriate training. Documentation must be submitted to the RSD.

Additional Training Requirements For Clinical Human Use: The Radiologic Technology Act requires anyone who administers or uses diagnostic or therapeutic X-ray on human beings to be certified or granted a permit (e.g. Certified Radiologic Technologist, Limited Permittee) and to act within the scope of that certification or permit.

1. Certificates/Permits for Radiologic Technologists and Limited Permit X-ray Technicians

Diagnostic Radiologic Technology Certificate. Individuals who possess this certificate are allowed to operate X-ray equipment for diagnostic purposes, other than mammography and fluoroscopy. These uses require additional certification as described below.

Mammographic Radiologic Technology Certificate: In addition to obtaining a Diagnostic Radiologic Technology Certificate, an individual who operates mammography X-ray equipment must be awarded a mammographic radiologic technology school graduation diploma or certificate and pass a DHS examination in mammography technology.

Radiologic Technologist Fluoroscopy Permit: DHS requires a Radiologic Technologist Fluoroscopy Permit of any Radiologic Technologist who exposes a patient to X-rays in the fluoroscopy mode or who does one or more of the following during fluoroscopy of a patient:

- a. Positions the patient.
- b. Positions the fluoroscopy equipment.
- c. Selects exposure factors.

Additionally, this individual must be supervised by a licentiate who possesses a valid Fluoroscopy Supervisor and Operator Permit.

Therapeutic Radiologic Technology Certificate: Individuals who possess this certificate are allowed to operate radiation therapy simulators (radiographic/fluoroscopic) if the intended use is solely for therapeutic purposes (e.g. port films).

Permits for Limited Permit X-ray Technicians. Limited Permit X-ray Technicians may work in facilities operated by the University. The categories and authorized uses are defined in Title 17.

2. Licentiate Certificates and Permits

Any licentiate of the healing arts who uses diagnostic, mammographic, or therapeutic X-ray on human beings must be certified and act within the scope of that certification. The following certificates and permits are applicable for licentiates:

- a. Licentiate Certificate:
Radiology Supervisor and Operator
(Radiologists only)
- b. Licentiate Permits:
Fluoroscopy Supervisor and Operator
Radiography Supervisor and Operator
Dermatology Supervisor and Operator

Fluoroscopy Supervisor and Operator: Licentiate Permits for fluoroscopy allow the individual to do any of the following:

- a. Actuate or energize fluoroscopy equipment.
- b. Directly control radiation exposure to the patient during fluoroscopy procedures.
- c. Supervise one or more persons who hold a Radiologic Technologist Fluoroscopy Permit.

Radiography Supervisor and Operator: Licentiate Permits for radiography allow the individual to do any of the following:

- a. Actuate or energize radiography X-ray equipment.
- b. Supervise one or more persons who hold a Radiologic Technologist Certificate.
- c. Supervise one or more persons who hold a limited permit.

3. Dental Licentiates and Operators

Dentists, Registered Dental Hygienists, and Registered Dental Assistants must hold a current license in order to use intraoral and extraoral X-ray equipment on human beings. Initial radiation safety training is required for all UCLA dental X-ray equipment operators; however, they are exempt from annual retraining.

C. PLANNING AND FACILITY DESIGN

It is important to properly plan the location where the X-ray machine will be used and ensure that the installation of the unit is designed with safety and compliance in mind. Pre-operational measurements and evaluation of installed shielding and operating procedures may be necessary before routine use of the machine can be authorized.

1. Shielding Considerations

X-ray shielding requirements are given by the California Code of Regulations (CCR) Titles 17 and 24. Technical guidance is contained in several publications such as the National Council on Radiation Protection and Measurements and the American National Standards Institute. The following shielding requirements and/or guidelines are provided:

- a. **Medical-Use Machines:** Permanent X-ray installations such as radiographic, fluoroscopic, linear/particle accelerators, mammographic equipment, etc., must contain shielding that is adequate to assure that radiation exposures do not exceed regulatory limits. Shielding plan check calculations for medical-use machines are performed either by the hospital health physicist or a consultant. Information such as operating parameters of the machine, primary beam direction, use factor, occupancy factor, workload (generally in milliamperere minutes per week), a representative room drawing (to scale) of the walls, floor, ceiling, etc., and building materials are needed in order to determine shielding requirements. If a machine is changed, upgraded, the workload increases, or the occupancy factor changes, the existing shielding may not be adequate and should be re-evaluated to determine if any applicable regulatory limits will be exceeded. The Radiation Safety Division is responsible for reviewing the completed shielding plan check calculations and determining final approval for installation.
- b. **Analytical Machines –** Analytical machines such as X-ray diffraction, X-ray fluorescence, electron microscopes, and cabinet units usually have integral shielding and require no additional shielding. Some of these machines utilize an intense X-ray beam with exposure rates in the primary beam of up to 10,000 R/min, and the AU must assure that they are operated in accordance with the manufacturer's specifications and specific safe operating procedures.
- c. **Special Facilities –** Shielding requirements for linear/particle accelerators, cyclotron units, CT/PET units, etc., can be quite complicated. The hospital health physicist or a consultant must perform the shielding plan check calculations on this equipment. Additionally, all ion particle accelerators require special access control, and effluent monitors for the monitoring and control of activation products. The completed calculations must be submitted to the Radiation Safety Division for final approval.

RESPONSIBILITIES

Authorized user: For the purposes of this chapter, the authorized user (AU) is defined as the individual who assures that all X-ray equipment listed on the Machine Authorization is in compliance and operated by qualified individuals in accordance with applicable regulations, UCLA Policies and Procedures, Safe Operating Procedures and standards of good practice. The term "authorized user" is further defined in the UCLA Medical Hospital Systems Policies and Procedures titled "Definition for Responsible Party/Authorized User for Human Use of Ionizing Radiation Machines and Sources." This definition is applicable only to authorized users that have oversight of human-use X-ray machines and are required to follow Medical Center policies and procedures.

The AU may designate another individual for the completion of certain tasks; however, the overall burden for assuring that radiation safety is achieved and maintained in the specified work area falls on the AU.

Specific responsibilities include, but are not limited to:

1. Assuring that all X-ray machines are operated safely and in accordance with all applicable regulations, policies and procedures;
2. Notifying the RSD upon receipt, disposal or transfer of any X-ray machine listed on the Machine Authorization (MA) or when any machine status changes;
3. Submitting MA application/renewal paperwork in a timely fashion in order to initiate or renew the authorization;
4. Assuring that all X-ray operators and peripheral workers have obtained proper radiation safety training;
5. Assuring that all human-use X-ray operators have a current State certificate or permit;
6. Assuring that all X-ray operators and peripheral workers have obtained individual monitoring devices, as applicable, and that such devices are used properly;
7. Assuring "As Low As Reasonably Achievable" (ALARA) principles are observed;
8. Assuring that new permanent X-ray installations have a shielding plan check performed by either the hospital health physicist or a consultant and that the completed plans are submitted to RSD for final approval;
9. Notifying RSD of any emergencies involving X-ray Machines or personnel;
10. Assuring that all pertinent radiation safety records are maintained; and
11. Notifying RSD of loss or theft of any X-ray Machine.

Radiation Safety Division: The role of the X-ray machine staff is to oversee the safe use of X-ray equipment pursuant to applicable laws, regulations, UCLA Policies and Procedures, and accepted radiation protection practices.

Specific responsibilities include, but are not limited to:

1. Advising and assisting the AU in matters of personnel training, operational procedures, and ALARA concerns;
2. Inspecting and surveying X-ray machines;
3. Assuring compliance with State machine registration requirements;
4. Assuring that all UCLA X-ray machines have been issued a current Machine Authorization;
5. Providing guidance and expertise to X-ray operators and peripheral workers relative to radiation protection issues and equipment performance standards;
6. Assisting the AU in assuring that occupational and non-occupational exposures are within regulatory limits;
7. Providing appropriate individual monitoring devices for X-ray use; and
8. Evaluating monthly and quarterly individual monitoring device results and assuring that the department representative receives these results.

X-RAY MACHINE CALIBRATIONS

The following information is provided as guidance to the AU:

1. *Medical Diagnostic Machines.* The Department of Radiological Sciences performs X-ray machine calibrations annually on medical diagnostic machines under the control of UCLA Hospital and Clinics to assure compliance with applicable rules and regulations contained in CCR Title 17 and Title 21, Code of Federal Regulations (CFR). Records of these findings must be made available during Radiation Safety Division audits.
2. *Medical Therapy Machines.* The complex requirements for these machines (linear/particle accelerators) require that beam calibrations be performed by a qualified Hospital Medical Physicist before initial operation and at intervals not to exceed twenty-four months. A radiation protection survey must be performed on all new and existing installations not previously surveyed, and spot checks must be performed at least once each week for therapy systems operating at potentials above 500 kVp. Records of these calibrations, spot checks, and surveys will be audited annually by the Radiation Safety Division.
3. *Dental X-ray Units.* RSD performs X-ray machine calibrations annually on all UCLA dental equipment. Additionally, quality assurance of the dental radiation safety program is evaluated during the annual machine calibration.
4. *Non-medical X-ray Equipment.* RSD performs annual machine surveys and quality assurance on all UCLA non-medical X-ray equipment, which includes X-ray diffraction units, X-ray fluorescence units, veterinary-use units, micro CT scanners, cabinet X-ray units, particle accelerators, and electron microscopes. The Radiation Safety Division will determine the eligibility of electron microscopes to be exempted under DHS Radiation Safety Advisory 90-4.

5. *Special Facilities.* These facilities include cyclotrons, Tokamaks, and any other devices that can produce significant levels of radiation. Initial and routine surveys of facilities are handled on a case-by-case basis.

Chapter 7: Technical Guidance to Radiation Safeguards

A. INTRODUCTION

Radiation exposure is controlled by operating procedures, training, mechanical interlocks, and physical structures (shielding). Controls that are used vary and are dependent on the characteristics of the isotope of interest. In addition, safe handling procedures may depend on the material quantity, chemical form, and containment.

This chapter provides elementary technical data as well as guidance on radiation physics, the characteristics of radiation, and radioisotopes commonly used at UCLA.

B. CHARACTERISTICS OF RADIOACTIVITY

Radioactivité, a word coined by Madame Marie Curie, describes a spontaneous energy-emitting change of one nuclide into a different isotope or isomer. **Radiation** is simply the emission and propagation of energy through space. The following terms describe the characteristics of radioactivity:

Half-life (T) is the time required for a given number of radioactive atoms of a specific radionuclide to decay to half its original number. This property is isotope specific and cannot be altered. For example, Hydrogen-3 (Tritium) has a half-life of 12.3 years. Thus, if we have a million atoms of H-3 today, one half million atoms will decay in 12.3 years. After an additional 12.3 years, only one quarter of the original atoms will remain.

Activity, the quantity of a radionuclide, is expressed as the number of radioactive decay events occurring per unit time. A basic unit of measure is the Curie (Ci). One Ci is equal to 37 billion (3.7×10^{10}) radioactive decay events per second. The Système International (SI) uses the Becquerel (Bq) as the unit of activity. One Bq is equal to one radioactive event per second.

Activity may be calculated as follows:

$$A = \lambda N$$

Where:

A = Activity

λ = Decay constant defined as $\ln 2/T$ or $0.693/T$

T = half-life

N = Number of atoms

C. RADIOACTIVE DECAY

Many isotopes commonly used in research have relatively short half-lives. Short-lived isotopes should be used when feasible to reduce radiation exposures and radioactive waste generation.

It may be necessary to account for radioactive decay when preparing for experimental, medical, and teaching procedures as well as when procuring isotopes and managing radioactive waste. The activity of a radioactive sample needs to be known to assure that a correct medical dose will be administered, an experimental procedure will be successful, a measurement will be properly interpreted, and that regulatory limits will not be exceeded.

The simple mathematical description of exponential radioactive decay is represented by:

Where:

$$A = A_{(0)} e^{(-\lambda t)} \quad (\text{or}) \quad A = A_{(0)} 0.5^{(n)}$$

- A = the activity remaining after a time interval (t)
- $A_{(0)}$ = the activity of the sample at some original time (t_0), in curies, dpm, or Bequerels (Bq)
- t = the elapsed time for decay
- λ = is the decay constant and defined as $\ln 2/T$, or $0.693 / T$ (half-life)
- T = the half life of the isotope
- n = number of elapsed half-lives (t/T)

Example: What is the remaining activity fifteen days after the time when a sample was known to contain 75 mCi of I-131?

We know $T = 8.04$ d for I-131 (Table 7.3).

Therefore:

Another method to determine remaining activity is shown in Table 7.1. To determine the remaining activity at any time, calculate the fraction t/T , elapsed time divided by the half-life, and then use the table to find the remaining fraction.

$$\lambda t = \frac{0.693 \times 15 \text{ d}}{8.04 \text{ d}} = 1.293$$

$$A = 75e^{(-1.293)} = 20.6 \text{ mCi}$$

(or)

$$\frac{15 \text{ d}}{8.04 \text{ d}}$$

$$n = \quad = 1.866$$

$$A = 75 \times 0.5^{(1.865)} = 20.6 \text{ mCi}$$

UNIVERSAL DECAY TABLE

t = elapsed time				T= half-life			
t/T	FRACTION REMAINING	t/T	FRACTION REMAINING	t/T	FRACTION REMAINING	t/T	FRACTION REMAINING
0	1.0000	0.52	0.6974	1.54	0.3439	3.80	0.0718
0.01	0.9931	0.54	0.6878	1.56	0.3392	3.90	0.0670
0.02	0.9862	0.56	0.6783	1.58	0.3345	4.00	0.0625
0.03	0.9794	0.58	0.6690	1.60	0.3299	4.10	0.0583
0.04	0.9727	0.60	0.6598	1.62	0.3253	4.20	0.0544
0.05	0.9659	0.62	0.6507	1.64	0.3209	4.30	0.0508
0.06	0.9593	0.64	0.6417	1.66	0.3164	4.40	0.0474
0.07	0.9526	0.66	0.6329	1.68	0.3121	4.50	0.0442
0.08	0.9461	0.68	0.6242	1.70	0.3078	4.60	0.0412
0.09	0.9395	0.70	0.6156	1.75	0.2973	4.70	0.0385
0.10	0.9330	0.72	0.6071	1.80	0.2872	4.80	0.0359
0.11	0.9266	0.74	0.5987	1.85	0.2774	4.90	0.0335
0.12	0.9202	0.76	0.5905	1.90	0.2679	5.00	0.0313
0.13	0.9138	0.78	0.5824	1.95	0.2588	5.10	0.0292
0.14	0.9075	0.80	0.5743	2.00	0.2500	5.20	0.0272
0.15	0.9013	0.82	0.5664	2.05	0.2415	5.30	0.0254
0.16	0.8950	0.84	0.5586	2.10	0.2333	5.40	0.0237
0.17	0.8888	0.86	0.5510	2.15	0.2253	5.50	0.0221
0.18	0.8827	0.88	0.5434	2.20	0.2176	5.60	0.0206
0.19	0.8766	0.90	0.5359	2.25	0.2102	5.70	0.0192
0.20	0.8706	0.92	0.5285	2.30	0.2031	5.80	0.0179
0.21	0.8645	0.94	0.5212	2.35	0.1961	5.90	0.0167
0.22	0.8586	0.96	0.5141	2.40	0.1895	6.00	0.0156
0.23	0.8526	0.98	0.5070	2.45	0.1830	6.20	0.0136
0.24	0.8467	1.00	0.5000	2.50	0.1768	6.40	0.0118
0.25	0.8409	1.02	0.4931	2.55	0.1708	6.60	0.0103
0.26	0.8351	1.04	0.4863	2.60	0.1649	6.80	0.0090
0.27	0.8293	1.06	0.4796	2.65	0.1593	7.00	0.0078
0.28	0.8236	1.08	0.4730	2.70	0.1539	7.20	0.0068
0.29	0.8179	1.10	0.4665	2.75	0.1487	7.40	0.0059
0.30	0.8123	1.12	0.4601	2.80	0.1436	7.60	0.0052
0.31	0.8066	1.14	0.4538	2.85	0.1387	7.80	0.0045
0.32	0.8011	1.16	0.4475	2.90	0.1340	8.00	0.0039
0.33	0.7955	1.18	0.4414	2.95	0.1294	8.20	0.0034
0.34	0.7900	1.20	0.4353	3.00	0.1250	8.40	0.0030
0.35	0.7846	1.22	0.4293	3.05	0.1207	8.60	0.0026
0.36	0.7792	1.24	0.4234	3.10	0.1166	8.80	0.0022
0.37	0.7738	1.26	0.4175	3.15	0.1127	9.00	0.0020
0.38	0.7684	1.28	0.4118	3.20	0.1088	9.20	0.0017
0.39	0.7631	1.30	0.4061	3.25	0.1051	9.40	0.0015
0.40	0.7579	1.32	0.4005	3.30	0.1015	9.60	0.0013
0.41	0.7526	1.34	0.3950	3.35	0.0981	9.80	0.0011
0.42	0.7474	1.36	0.3896	3.40	0.0947	10.00	0.0010
0.43	0.7423	1.38	0.3842	3.45	0.0915	10.50	0.0007
0.44	0.7371	1.40	0.3789	3.50	0.0884	11.00	0.0005
0.45	0.7320	1.42	0.3737	3.55	0.0854	11.50	0.0003
0.46	0.7270	1.44	0.3686	3.60	0.0825	12.00	0.0002
0.47	0.7220	1.46	0.3635	3.65	0.0797	12.50	0.0002
0.48	0.7170	1.48	0.3585	3.70	0.0769	13.00	0.0001
0.49	0.7120	1.50	0.3536	3.75	0.0743	14.00	0.0001
0.50	0.7071	1.52	0.3487	3.80	0.0718	15.00	0.0000

D. BETA EMISSION

In one type of radioactive decay, a beta particle (electron) is ejected from the atomic nucleus. Beta particles are emitted with a continuous energy distribution ranging from zero to a maximum value determined by mass-energy considerations for a particular nuclear transformation. The average beta energy is about 30-40% of the maximum energy. Unless otherwise specified, the energy of a beta emitter given in literature is the maximum energy.

Beta radiation penetrates matter to varying depths. Beta emitters may pose an external exposure hazard. The degree of hazard depends on the activity, beta energy, chemical form, and type of containment, if any, of the beta emitter.

Energetic beta emitters require considerations for handling and shielding that differ from that of gamma rays or X-rays. Beta emitters with energies less than 200 keV, such as H-3 (tritium), S-35, and C-14, have very limited ranges in tissue and are not considered to be external radiation hazards. Table 7.2 gives physical parameters of five commonly-used beta emitters.

High-energy beta emissions, such as the beta particles emitted from P-32 and Y-90, traverse several meters in air. However, these high-energy beta particles are easily shielded by (1) cm of water. Typically, Plexiglas™ at a thickness of at least (1) cm is used for beta shielding at UCLA. This is a sufficient thickness to absorb the maximum beta energies emitted from P-32, as well as lower energy beta emitters.

TABLE 7.2
COMMON BETA EMITTERS^a

Parameter	H-3	C-14	S-35	P-33	P-32
Half Life	12.28y	5730y	87.4d	25.4d	14.29d
Max Energy (MeV)	0.019	0.156	0.167	0.249	1.71
Average Energy (MeV)	0.006	0.049	0.049	0.077	0.695
Range in Air (cm)	0.5	23	26	49	610
Range in H ₂ O (cm)	<0.0001	0.029	0.04	0.06	0.8
Fraction through skin ^b	negligible	0.11	0.16	0.37	0.95
Dose Rate, mrad/h ^c	negligible	1.1	1.2	4.0	9.2

- a. Shapiro (1990)
- b. Fraction through the "standard" dead layer of skin, 7 mg/cm².
- c. Dose rate to basal cells of epidermis from 1 nCi/cm² deposited on skin surface.

The maximum range of a beta with a maximum energy, E, where 0.01 < E < 2.5 MeV:

$$R = 412E^{1.265 - 0.09454 \ln E}$$

Where:

R = Range in mg/cm²

E = Maximum energy in MeV

Example 1: What thickness of Lucite/Plexiglas is suitable for shielding Ca-45 betas, E_{max} = 0.257 MeV?

From the formula above,

$$R = 62 \text{ mg/cm}^2$$

Density of Plexiglas 1.18 g/cm³

Answer: 0.053 cm

Example 2: What thickness of Lucite/Plexiglas is suitable for shielding P-32 betas, E_{max} = 1.71 MeV?

From the formula above,

$$R = 790 \text{ mg/cm}^2$$

Density of Plexiglas 1.18 g/cm³

Answer: 0.67 cm

High-energy beta particles are reduced in kinetic energy by ionizing or exciting atoms along their path or by photon emission as the particles are deflected by electric fields of nuclei. The later (photon emission) is called **bremstrahlung** (“braking radiation”). Photon emission increases with the square of the atomic number of the absorber. Thus, bremstrahlung can be significant for high-energy beta particles incident on high Z-material such as lead. Therefore, only light Z-materials such as water, plastic, and aluminum are considered proper for beta shielding. When betas of 1 to 2 MeV pass through light materials such as water, aluminum, or glass, less than 1% of their energy is dissipated as bremstrahlung.

The potential external exposure hazard from contamination of beta emitters on the skin may be significant (see bottom line of the Table 7.2). Except for H-3 contamination, the dose rate to the basal cell layer of the skin is in the range, 2.6 – 5.9 mrad/hr, for a moderate skin contamination of (1) nCi/cm².

Another type of decay is the beta-plus or positron decay. When positrons have lost most of their kinetic energy, they combine with negatively-charged electrons in a process termed **annihilation**. The original positron and electron disappear and are replaced with two 0.511 MeV photons. Positron emitters, such as F-18 and C-11, are used with positron emission tomography procedures in nuclear medicine and various research studies. Exposure controls associated with annihilation photons should be considered when handling positron emitters.

E. GAMMA RAY EMISSIONS

Gamma rays are electromagnetic photons that originate in the nucleus. The properties of the emitted photons are determined by their frequency/wavelength. Gamma rays interact with matter by photoelectric, Compton, and pair production processes. A lengthy explanation is beyond the scope of this chapter, but note that these processes yield energetic electrons that ionize or excite atoms. Such interactions determine the shielding material necessary to attenuate the exposure rate from an X-ray or a gamma-ray source to some acceptable value.

Technically, **exposure (X)** refers to the ionization of air. It is defined as the absolute value of the total charge dQ of the ions of one sign produced in air when all the electrons (negatrons and positrons) liberated by photons in the air are completely stopped in air. The special unit of exposure, **roentgen (R)**, is given as 2.58 x 10⁻⁴ Coulombs kg⁻¹.

Dose is the energy imparted to matter by ionizing radiation per unit mass. The unit of absorbed dose is the **Rad**. **Dose equivalent** expresses all types of radiation on a common scale for calculating effective absorbed dose. The unit of dose equivalent is **Rem**. The **effective dose equivalent** is defined as the sum of the products of the dose equivalent to the organ or tissue and the weighting factors applicable to each body organ or tissues that are irradiated. The International Commission on Radiological Protection (ICRP) defines this as the **effective dose**.

For practical applications:

$$(1) \text{ Roentgen} = (1) \text{ Rad} = (1) \text{ Rem for beta, gamma and X-rays}$$

The geometry of a particular exposure situation (i.e., the relation of source to detector) determines the exposure rate at specified distances. For example, for a *point* source, where the source dimensions are small compared to the distance from the source, the inverse square rule applies.

Inverse square law for point sources:

$$\dot{X}_a d_a^2 = \dot{X}_b d_b^2$$

(or)

$$\dot{X}_b = \dot{X}_a \left(\frac{d_a}{d_b} \right)^2$$

Where:

X_a = Exposure rate at distance, a

X_b = Exposure rate at distance, b

d_a = Distance, a, from point source

d_b = Distance, b, from point source

To determine an exposure rate (X) at distance, (d), from a point source; apply the gamma constant (Γ) as follows:

$$X = \frac{A \Gamma}{d^2}$$

Where:

- X = Exposure rate at distance, d, in R/hr
- A = Activity in mCi
- Γ = Gamma constant from Table 7.3 (R-cm²/hr-mCi)
- d = distance from the point source in cm

Note that the positron-emitter C-11 is included in Table 7.3. The use of positron emitters in medical research has increased greatly at UCLA. The gamma-ray emission rate from C-11 is typical, and the estimated Γ constants for C-11, N-14, O-15 and F-18 are all in the range 5.7 to 5.9 R-cm²/hr-mCi.

Half value layer (HVL) is the thickness of a material required to reduce the intensity of a given radionuclide to 50% of its original value. Similarly, **tenth value layer (TVL)** is the thickness of a material required to reduce the intensity of a given radionuclide to 10% of its original value. Table 7.3 provides HVL and TVL data for lead shielding.

TABLE 7.3
GAMMA SOURCE DATA

NUCLIDE	G ^a	T Physical Half Life	Shielding Factors		NUCLIDE	G ^a	T Physical Half Life	Shielding Factors	
			I/I ₀ in cm Lead					I/I ₀ in cm Lead	
			0.5 (HVL)	0.1 (TVL)				0.5 (HVL)	0.1 (TVL)
Barium-133	2.4	10.4 years	0.1	0.5	Molybdenum-99	1.8	66.7 hours	0.65	0.255
Beryllium-7	0.3	53.3 days	0.5	1.5	Oxygen -15	5.9	122.2 sec.	0.55	1.6
Carbon-11	5.9	20.3 min.	0.55	1.6	Palladium-103	0.86	16.97 days	0.0008	0.003
Cesium-137	3.3	30.0 years	0.8	2.4	Potassium-42	1.4	12.4 hours	1.7	5.2
Chromium-51	0.16	27.7 days	0.2	0.7	Potassium-43	5.6	22.4 hours	0.5	1.8
Cobalt-57	0.9	270 days	0.01	0.05	Radium-226	8.25	1600 years	1.4	4.6
Cobalt-60	13.2	5.26 years	1.5	4.50	Rubidium-86	0.5	18.6 days	1.4	4.1
Fluorine-18	5.7	109.7 min	0.55	1.6	Scandium-47	0.56	3.40 days	0.05	0.17
Gallium-67	1.1	78.8 hours	0.1	0.5	Selenium-75	2.0	120 days	0.1	0.5
Gold-198	2.3	2.69 days	0.33	1.1	Sodium-22	12.0	2.60 years	0.9	3.6
Indium-111	3.24	2.81 days	.023	0.2	Sodium-24	18.4	15.0 hours	1.8	5.7
Indium-113m	1.77	99.4 min.	0.2	0.9	Strontium-85	3.0	65.1 days	0.1	1.1
Iodine-123	0.67	13 hours	0.04	0.2	Tantalum-182	6.8	115.0 days	1.2	4.0
Iodine-125	2.7	60.2 days	0.002	0.006	Technetium-99m	0.7	6.30 hours	0.02	0.08
Iodine-131	2.2	8.04 days	0.3	1.1	Tin-113	1.7	115 days	0.001	0.004
Iridium-192	4.8	74.2 days	0.3	2.0	Thallium-201	0.447	73.1 hours	0.03	0.1
Iron-59	6.4	45 days	1.5	4.5	Xenon-133	0.14	5.31 days	0.003	0.015
Manganese-54	4.7	312 days	1.1	3.2	Zinc-65	2.7	245 days	1.4	4.1

a. $G = R \cdot cm^2/hr \cdot mCi$

F. PROTECTION AGAINST RADIATION EXPOSURE

The radiation worker can control and limit his/her exposure to penetrating radiation by taking advantage of *time*, *distance*, and *shielding (TDS)*. By reducing the *time* of exposure to a radiation source, the dose to the worker is reduced in direct proportion with that time. By increasing his/her *distance* from the source, the dose is reduced inversely proportional to the square of that distance.

Time directly influences the dose received: if you minimize the time spent near the source, the dose received is minimized. This idea involves planning a work procedure, following the procedure, and often performing a "dry" run. For example, before implanting radioactive sources into a patient under medical treatment, rehearsals under the guidance and control of a

mentor allow the medical resident or fellow to become familiar with the procedure before employing the radioactive implant sources. Similar rehearsals help the novice in undertaking certain radiochemical procedures, such as iodinations with I-125 or preparing an I-131 dose for thyroid treatment. Limiting the time that “stock” solutions of radioactive material are removed from storage also reduces exposure time.

Procedures also should be planned with the idea of maintaining as much distance as possible between the source and the worker. The exposure rate from a radiation source drops off by the inverse of the distance squared. If a problem arises during a procedure, don't stand next to the source and discuss your options with others present. Move away from the source or return it to storage, if possible.

The third exposure control is based on radiation shields, automatic interlock devices, and in-place radiation monitoring instruments. Except temporary or portable shields, this type of control is usually built into the particular facility. At UCLA, radioisotope facilities requiring control devices and shielding must be evaluated and approved by the Radiation Safety Division before construction and operation.

Shields should be located close to the source to minimize the extent and cost of shielding material. While the required thickness of lead, iron, or concrete is independent of the source-to-shield distance, one can save significantly on the lateral and vertical extent, and therefore the total quantity, of material if the shield is close to the source.

Alphas and low-energy betas do not produce an external exposure problem. However, the alpha and low-energy beta emitting isotopes are potential problems if they can be taken into the body.

TABLE 7.4
RECOMMENDED SHIELDING FOR RADIONUCLIDES

	<u>Permanent</u>	<u>Temporary</u>	Additional Clothing
Alpha	Unnecessary	Unnecessary	Unnecessary
Beta	Aluminum, plastics	Aluminum, plastics, wood	Leather, rubber, plastic, cloth
Gamma, X-rays	Lead, iron, lead glass, heavy aggregate concrete, ordinary concrete, water	Lead, iron, lead glass, concrete blocks, water	Lead fabrics (not for “hard” gamma)

G. FUME HOODS

The purpose of a laboratory fume hood is to minimize or eliminate worker exposure to hazardous contaminants, including radioactive material, and to provide dilution and dispersal of the contaminants. The principal contaminant control factor in the use of hoods is the flow of air across the hood face and into the exhaust system.

1. Fume hood face velocities must be maintained at 100 ft/min, and the hood must be kept clear and operated with the sash in the designated position (as marked by labels affixed to the edge of the hood opening).

Chemical fume hoods are tested on at least an annual basis to determine that the air velocity is at least 100 ft/min. Such tests are done regularly by the Office of Environment, Health & Safety (EH&S). However, if a malfunction is suspected, EH&S should be contacted immediately. The hood will be checked promptly and arrangements made for repair, if necessary.

2. The use of I-125 or I-131 may require special precautions because some procedures involving use of these isotopes result in unwanted quantities of carrier-free iodine. **Minihoods**, which are sometimes used with I-125 and I-131 under specific circumstances, must be carefully maintained and surveyed to assure proper performance. A small fan that pulls air through access ports and exhausts through an activated charcoal filter into the regular fume hood exhaust provides airflow.
 - a. The minihoods must be used inside a functioning fume hood that is certified with the minihood installed and functioning. The minihoods must not be moved from one hood to another without the approval of the Radiation Safety Division.
 - b. If a minihood is taken out of service, whether temporarily to free the main hood for another experiment or permanently, it must be monitored and decontaminated, if necessary. If removal is permanent, the charcoal filter must be removed and disposed as radioactive waste.

If removal is temporary, the entire hood may be sealed in a large heavy plastic bag that should not be reopened unless in a fume hood due to possible resuspension of radioiodine from the filters.
 - c. The blower motor on the minihood should be left in continuous operation following an experiment to ensure that the amount and direction of airflow through the contaminated filters is maintained.
 - d. The charcoal filters used in minihoods should be changed periodically. Change is recommended under any of the following conditions:
 - i. If the exposure rate from the filter is 0.6 mR/hr or above at the nearest accessible external point.
 - ii. If either the prefilter or the charcoal filter show a loading from dust or debris that could reduce airflow.
 - iii. At least annually. It is difficult to assess the continued efficiency of the charcoal over the various uses and atmospheric conditions. The filter should be changed before it is no longer functioning properly.
 - e. If there is any question about adequate airflow, contact the Office of Environment, Health & Safety for assistance or any required tests.
 - f. The armholes should be checked for contamination after each procedure to prevent the spread of contamination.
 - g. Suitable entries should be made in the AU's logbook on periodic checks and repairs to provide guidance toward effective use, maintenance, and control of the minihood.
3. Laminar Flow Hoods using recirculating air are unsuitable for work with radioactive isotopes except procedures in which only a few microcuries are used. Determination of the need for a hood is based on the quantity of the volatile isotope used per procedure.

Chapter 8: Personnel Radiation Monitoring

A. INTRODUCTION

Personnel monitoring or dosimetry includes the measurement and interpretation of worker exposure to radiation sources both external to the body (e.g., sealed sources and X-ray machines) and radioisotopes that may be deposited in the body by inhalation or ingestion.

It is the responsibility of the Radiation Safety Division to provide external and internal monitoring for those who meet the requirements listed in this chapter.

B. EXTERNAL DOSIMETRY PROGRAM

The purpose of the external dosimetry program is to provide occupational workers with an estimate of their radiation dose. In order to provide an accurate exposure record, the following guidelines should be followed:

- The dosimeter must be worn only during periods of occupational exposure and should not be worn away from the work place.
- Do not wear your dosimeter when you receive personal medical, dental, or nuclear medicine examinations.
- Wear only your assigned dosimeter; do not wear any other occupationally-exposed individual's dosimeter.
- Do not tamper with or unnecessarily expose a dosimeter to radiation, heat, or moisture.
- Do not store your radiation badge near a radiation source. For example, do not leave it attached to a lead apron that will be stored in the X-ray examination room.
- Do not send your dosimeter through the clothes washer or dryer.
- Exchange your dosimeter at the predetermined time.
- Wear your whole-body badge on the front of your body, between the neck and waist, preferably at the collar. If a lead apron is worn, wear the badge outside the apron. The badge must be facing outwards – towards the source of exposure.
- Wear ring badges with the label side facing the source of exposure. Ring badges should be worn underneath gloves.

Area monitoring dosimeters are used to evaluate exposure from X-ray, gamma ray, and neutron activity in a specific work area. Personnel dosimeters shall not be used as area monitors. Please contact the Radiation Safety Division for information regarding area monitors.

1. External Dosimetry Requirements

External dosimetry requirements can be found in the California Code of Regulations (CCR), Title 17.

TABLE 8.1
ADULT EXTERNAL OCCUPATIONAL DOSE LIMITS

DOSE TERM	DOSE LIMIT
Total Effective Dose Equivalent (TEDE) (whole-body ^a dose from both external and internal sources)	5 rem (5,000 mrem)/yr
Lens Dose Equivalent (LDE) (dose to the lens of the eye)	15 rem (15,000 mrem)/yr
Shallow Dose Equivalent (SDE) (Skin and Extremity dose)	50 rem (50,000 mrem)/yr
Total Organ Dose Equivalent (TODE)	50 rem (50,000 mrem)/yr

(The organ receiving the highest dose from both external and internal sources)	
Declared Pregnant Woman	0.5 rem (500 mrem) for entire term

^a Whole-body means, for purposes of external exposure, head, trunk, arms above the elbow, or legs above the knee.

State regulations require that personnel dosimeters be worn under the following working conditions:

- Adults who are likely to receive in one year (from sources external to the body), a dose in excess of 10% of any occupational dose limit.
- Minors (<18 years of age) are allowed to receive 10% of the annual occupational dose limits (TEDE = 500 mrem) and must be provided dosimeters if they are likely to receive in one year (from sources external to the body), 10% of their allowable limit (TEDE = 50 mrem).
- Declared pregnant women likely to receive in one year (from sources external to the body), 10% of the allowable limit to the embryo/fetus (50 mrem).
- Individuals who enter a high or very high radiation area.
- All individuals who operate mobile X-ray equipment.

In addition to the above dosimetry requirements, the Radiation Safety Division has implemented policies that assist with determining whether or not personnel are eligible to receive dosimetry.

It is the responsibility of the authorized user (AU) to inform the Radiation Safety Division of dosimetry needs. All personnel who wear dosimetry must be trained. See Chapter 12 for specific training requirements. Contact the Radiation Safety Division with any questions regarding external dosimetry.

2. Dual Badge Program

As part of the external dosimetry program, the Radiation Safety Division offers dual badges to individuals who work in unusually high radiation exposure areas of the UCLA campus, such as Interventional Radiology and the Cardiac Catheterization Laboratory.

Two whole-body badges are issued to each individual. The “IN” designated badge is “red” and must be worn under the apron at the waist level. The “OUT” designated badge is “blue” and must be worn outside of the lead apron at the collar level. A dose-weighted calculation (Niklason Formula) is applied, and an effective dose equivalent (EDE) is determined. It is imperative that participants in this program properly wear their “IN/OUT” badges so the effective dose equivalent calculation can be performed. Questions regarding eligibility to participate in this program should be directed to the Radiation Safety Division.

3. Declared Pregnant Woman Program

A “Declared Pregnant Woman” is a woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception. After she declares her pregnancy, the Radiation Safety Division may issue a monthly whole-body badge that is to be worn at the waist level, underneath a lead apron, if applicable. The occupational dose limit for the embryo/fetus of a declared pregnant woman is 0.5 rem for the entire term of pregnancy.

Please contact the Radiation Safety Division with any questions regarding the declared pregnant woman program or to obtain the U.S. Nuclear Regulatory Commission’s Regulatory Guide entitled “Instruction Concerning Prenatal Radiation Exposure.” Also, see Appendix 2 for more information.

4. Dosimetry Exchange

Film badges are routinely exchanged on a monthly basis. Whole-body thermoluminescent dosimeter (TLD) badges are routinely exchanged on a quarterly basis and extremity TLDs are routinely exchanged on either a monthly or quarterly basis, depending on the user’s need.

5. Evaluation of Exposure History Reports

Radiation Safety Division staff evaluate monthly and quarterly exposure history reports to determine exposure trends, accuracy of doses, and to identify doses to individuals that exceed any of the occupational dose limits. Personnel exposure histories are a legal record of the individual's occupational exposure at UCLA. It is important that there are no gaps in monitoring service and that all badges are turned in on a timely basis.

Exposure history records are maintained by the RSD. Exposure reports are normally distributed to individuals through a department representative; however, the RSD will provide these records upon request.

6. Late or Lost Dosimeters

External dosimeters are considered late if they are not returned to the Radiation Safety Division by the due date, which is the fifth working day of the month following the wear period. A notice listing the late dosimeters will be sent to a department representative. If dosimeters are not turned in by the due date, a late fee may be assessed. If you have lost your dosimeter, please contact the Radiation Safety Division.

For questions regarding late or lost dosimeters, contact the Radiation Safety Division.

7. External Dose-Equivalent Estimation for Lost Badges

A lost (non-returned) dosimeter causes a permanent gap in the individual's exposure history record. With the concurrence of the California Department of Health Services, the Radiation Safety Division and the affected individual will work together to assign a realistic dose for the delinquent period of time.

8. Record Keeping Requirements for Exposure History Reports

Permanent records are maintained in the form of hard copies and microfiche for all individuals assigned personnel dosimetry.

9. ALARA Limits

All laboratories using any form of ionizing radiation at UCLA (e.g., radioisotopes, X-ray generating machines, and cyclotrons) are expected to follow the radiation safety principle of ALARA, an acronym for **As Low As Reasonably Achievable**. This principle implies the search for a balance between maximizing the benefit and reasonably minimizing risks associated with ionizing radiation. The Radiation Safety Division uses ALARA dose limits to keep exposures well below the regulatory limits.

The UCLA Radiation Safety Committee has approved the following campus-wide ALARA limits:

TABLE 8.2
ALARA LIMITS TABLE

Dosimetry Type	ALARA I Limit	ALARA II Limit	ALARA III Limit
Film-Whole-body (monthly)	100 mrem	300 mrem	500 mrem
TLD-Whole-body (quarterly)	300 mrem	900 mrem	1,500 mrem
TLD-Extremity (monthly)	100 mrem	1,000 mrem	5,000 mrem
TLD-Extremity (quarterly)	300 mrem	3,000 mrem	15,000 mrem
Declared pregnant woman (monthly)	20 mrem	40 mrem	50 mrem

The Radiation Safety Division is notified when individuals exceed the ALARA I limit. These notifications are reviewed and kept on file for future analysis.

Individuals who exceed the ALARA II limits on either a monthly or quarterly basis receive a “Report of Unusual Radiation Exposure” (RURE) from the Radiation Safety Division. The purpose of this report is to notify the individual that their dose has exceeded the ALARA II limit but has not yet exceeded the regulatory occupational dose limits.

Radiation Safety Division staff will follow up on a case-by-case basis with the individual/authorized user to determine the adequacy of worker training and if safe operating procedures, administrative controls, or engineered safeguards are being followed. This type of quality assurance provides useful information to the authorized user and the Radiation Safety Division as they evaluate the effectiveness of their prospective training programs in reducing exposures to ALARA limits.

Individuals who exceed the ALARA III limit of 500 mrem/month are on track to exceed the annual whole-body occupational dose limit. These individuals will receive a RURE from the Radiation Safety Division. The Radiation Safety Division staff will review the adequacy of worker training and if safe operating procedures, administrative controls, or engineered safeguards are being followed. Additionally, the Radiation Safety Division staff will work with the individual/authorized user to determine what changes, if any, can be made to reduce the worker’s overall exposure.

10. Department of Health Services Notification

Pursuant to the California Code of Regulations, UCLA is required to notify the Department of Health Services (DHS) in cases where an individual has received a dose in excess of any of the occupational dose limits.

**TABLE 8.3
Notification of Incidents Requirements**

Dose Term	Immediate Notification	Twenty-four Hour Notification
Total Effective Dose Equivalent (TEDE)	≥ 25 rem	>5 rem <25 rem
Lens Dose Equivalent (LDE)	≥ 75 rem	>15 rem <75 rem
Shallow Dose Equivalent (SDE)	≥ 250 rad	> 50 rem < 250 rad
Individual Intake	5 times the annual limit for intake	Excess of one occupational annual limit

In addition to the notification of incidents, DHS requires that a written report be submitted by the licensee/registrant within thirty days after learning of an overexposure. The report must include estimates of each individual’s dose, concentration of radioisotope involved (as applicable), the circumstances under which the exposure occurred, and the corrective action taken or planned to ensure against a recurrence.

C. PERSONNEL MONITORING FOR INTERNAL RADIATION EXPOSURE

The term "bioassay" refers to the assessment of radioisotope intake and deposition in the worker's body. The type and quantity of radioisotope is determined by *in vivo* or *in vitro* measurement of radioisotopes excreted or removed from the body.

Radiation Safety Division staff perform thyroid and urine bioassays and total body counting. The need for monitoring individual workers is determined by the radioactive material and amount of activity handled, survey measurements, and the effectiveness of safeguards.

1. Internal Dosimetry Requirements

The purposes of bioassay measurements are to confirm the adequacy of radiological controls and to determine compliance with the occupational dose limits. Internal dosimetry requirements can be found in the California Code of Regulations (CCR), Title 17.

**TABLE 8.4
Adult Internal Occupational Dose Limits**

DOSE TERM	DOSE LIMIT
Committed Dose Equivalent (CDE) (Dose received by <u>an internal organ</u> from material deposited inside the body)	50 rem (50,000 mrem)/year
Committed Effective Dose Equivalent (CEDE) (Dose received by <u>the whole-body</u> from material deposited inside the body)	5 rem (5,000 mrem)/year

2. Internal Dosimetry Triggers

The Radiation Safety Division has implemented policies that assist with determining whether or not radioactive material users should receive a thyroid or urine bioassay. Table 8.5 should be used as guidance when determining bioassay needs:

**TABLE 8.5
Standard Trigger Thresholds for Bioassay**

Radionuclide	Trigger	Requirement
Beta emitters (other than ³ H)	≥20 mCi per experiment or shipment	Urine bioassay
³ H	≥40 mCi per experiment or shipment	Urine bioassay
¹²⁵ I/ ¹³¹ I (unbound)	≥1 mCi/experiment or shipment	Thyroid bioassay

3. Thyroid Bioassay

For non-human research operations, the use of unbound I-125 or I-131 sources in an open room or on a laboratory bench is prohibited. All procedures with a potential for producing airborne activity, including the opening of sealed bottles or storage containers holding more than 0.1 mCi of I-125 or I-131, should be done in an approved fume hood having a face velocity of at least 100 linear ft/min. The use of either an approved fume hood or a special iodination hood (minihood) is required as a condition of any isotope authorization.

A thyroid bioassay is required when any individual handles ≥1 mCi of unbound radioactive iodine. Thyroid bioassays are **not** required when an individual handles radioimmunoassay kits (RIA) (which are usually = 100 µCi), I-125 seeds used in radiation oncology, or I-131 capsules used in nuclear medicine patients.

a. I-125 Bioassay Frequency

For individuals who meet the above criteria for handling I-125, routine bioassays are conducted each calendar quarter, preferably within 48 to 72 hours of use. Handling includes the opening of a supply container as well as the removal of a working quantity. This applies to both the quantity handled in one procedure or the total activity handled by the worker over the three month period of time.

b. I-131 Bioassay Frequency

For individuals who meet the above criteria for handling I-131, thyroid bioassays should be performed within a week, preferably within 48 to 72 hours of use. This requirement is included as a condition of isotope authorization as necessary. Handling includes the opening of a supply container as well as the removal of a working quantity. This applies to both the quantity handled in one procedure or the total activity handled by the worker over a five-day period of time.

c. Investigation Level

Follow-up bioassays will be conducted when the thyroid burden exceeds 120 nCi of I-125 or 40 nCi of I-131. If the original measurement is confirmed, the following steps may be invoked:

- i. The bioassay procedure will be repeated on a weekly basis until the thyroid measurement shows a reduction to 120 nCi or 40 nCi, as applicable.
- ii. The Iodine work area and the handling procedure will be evaluated by the Radiation Safety Division and the authorized user will be required to identify necessary corrective actions.

d. Intervention Level

If the thyroid bioassay measurement exceeds 500 nCi for I-125 or 140 nCi for I-131, the Radiation Safety Division will initiate the following procedure:

- i. Work with radioactive Iodine will be interrupted and the worker may be referred to appropriate medical consultation.
- ii. Steps in the Investigation Level section may be followed, as necessary.

4. Urine Bioassay

Urine bioassay measurements are conducted for the assessment of type and amount of radioisotope deposited in the body of radiation workers. Urinalysis is commonly used for workers who handle beta-emitting isotopes, such as H-3, C-14, P-32, S-35, Ca-45, or Cl-36, in activities in excess of the standard trigger thresholds.

A urine bioassay is required when an individual handles 40 mCi of tritium or 20 mCi of a beta emitter other than tritium.

a. Tritium

Authorized personnel who have handled 40 mCi are required to submit a urine sample. Handling includes the opening of a supply container as well as the removal of a working quantity. This applies to both the quantity handled in one procedure or the total activity handled by the worker within a five-day period. The sample must be collected within 24 to 48 hours after handling the specified activity.

b. Beta Emitters other than Tritium

Authorized personnel who have handled 20 mCi are required to submit a urine sample. Handling includes the opening of a supply container as well as the removal of a working quantity. This applies to both the quantity handled in one procedure or the total activity handled by the worker within a five-day period. The sample must be collected within 24 to 48 hours after handling the specified activity.

c. Investigation Level

Positive urine bioassay results with a measured activity or an intake of 1% or greater of the applicable annual limit on intake (ALI) fall under this action level (1% of the ALI leads to 50 mrem of CEDE). When urine bioassay measurements indicate an intake equal to, or in excess of, the investigation level, the following steps will be taken:

- i. Follow-up bioassay measurements will be conducted.
- ii. If necessary, temporarily limit the worker's potential for receiving additional internal exposure.

5. Total Body Counting

Total body counting can be performed on workers who handle significant quantities of gamma emitters. Most of these workers are involved with the cyclotrons, nuclear medicine clinics, or certain types of research. For those workers involved with very short-lived positron emitters, the

internal exposure from inhalation is usually not very large compared to the external exposure. Individuals working with 25 mCi or more of Cr-51 during a quarter and individuals involved with research that utilizes other unsealed gamma emitters may be required to participate in this program.

D. ADDITIONAL INFORMATION

Individuals who do not meet the above triggers for external or internal monitoring may request to participate in either program, if they so desire, by contacting the Radiation Safety Division.

Chapter 9: Radiation Surveillance

A. INTRODUCTION

The authorized user (AU) for radioisotope authorizations and radiation machine registrations is responsible for assuring radiation safety by providing, maintaining, and using appropriate survey instrumentation, equipment, facilities, and procedures. Laboratory activities must be conducted so as to prevent unnecessary radiation exposure, and must conform to UCLA's radioactive material license, applicable regulations and accepted good practice. Radiation surveys reflect requirements of UCLA's broad scope radioactive material license as well as applicable state and federal regulations. They serve to evaluate the quality of radiation protection practices used on campus.

The Radiation Safety Division conducts periodic audits of laboratory areas. These performance-based inspections identify radiation safety deficiencies and provide the AU with important information regarding the overall radiation safety conditions within a laboratory. These surveys complement those performed by the AU to achieve the desired goals of safe, legal, and cost-effective radiation use.

B. OPERATIONAL STANDARDS

Contamination must be controlled to avoid inadvertent exposure to radiation workers, non-radiation workers, and members of the public. Through careful management of radiation and radioactive material, exposure to laboratory personnel and members of the public can be maintained as low as reasonably achievable. Radiation exposure levels above the regulatory limits indicated below must be reduced through means such as decontamination, shielding, or modification of work procedures.

1. *Dose Rate Limits:* The annual regulatory limit to any member of the public is 1 mSv (100 mrem). Dose rates to any accessible unrestricted area must not exceed 2 mRem in any one hour. Laboratories authorized for radioactive material or radiation use are restricted areas; as such, personnel within these areas are subject to a broader set of dose rate limitations. Restricted areas (an area controlled for radiological protection) must be under the direct or positive control of the authorized user so as to restrict personnel access.
2. *Radioactive Contamination Limits:* The action levels for removable contamination are shown in Table 9.1. Removable contamination is that which can be transferred by swiping a 100 cm² surface with absorbent material using moderate pressure. The swipe sample must be counted in an appropriate instrument (i.e. liquid scintillation, gas flow proportional, thin-window GM) that has been calibrated using appropriate radioactive reference standards. The output of any radiation counter must be corrected for counting efficiency and geometry in order to record results in disintegrations per minute (activity), rather than counts per minute (instrument response).

Radioactive material contamination fixed to a surface is not readily available for intake by ingestion or inhalation and will not cause cross-contamination. It is monitored with a detector appropriate to the radiation emission rate. Typically, a thin-window GM instrument should be used for energetic betas or a NaI(Tl) detector for I-125 (low-energy) photons.

3. *Airborne Radioactive Material:* The identification and control of airborne radioactive material are important radiation safety considerations. However, standard practice at UCLA is to avoid designating any area as "Airborne Radioactivity Area" by controlling or eliminating the condition. Authorized users are encouraged to apply engineered safeguards (chemical fume hoods and special iodination cabinets) in place of administrative procedures and personal respiratory protection equipment for routine work.

The routine bioassays described in Chapter 8 serve as a reliable test for the actual intake of airborne radioactivity.

C. CAUTION SIGNS AND LABELS

A visible warning sign may be required to alert individuals to radiological conditions. Each sign must bear the standard magenta, purple, or black three-bladed caution symbol on a yellow background and appropriate warning message and be posted in a conspicuous location.

The warning on the sign indicates the potential degree of exposure due to radioisotopes or machines:

1. A "CAUTION RADIATION AREA" sign is required for areas accessible to personnel in which the dose to an individual could exceed 5 millirems in one hour at 30 cm from a radiation source or from any surface that radiation penetrates.
2. A "CAUTION HIGH RADIATION AREA" sign is required for areas accessible to personnel in which the dose to an individual could exceed 100 millirems in one hour at 30 cm from a radiation source or from any surface that radiation penetrates. High radiation areas may require physical controls, barriers, radiation monitors, and special administrative procedures.

It is essential that the Radiation Safety Division be consulted before a high radiation area is built and made operational.
3. A "CAUTION X-RAY" warning should be used for any X-ray machine installation.
4. A "CAUTION RADIOACTIVE MATERIAL" sign is required for areas or rooms in which radioactive material is used or stored.
5. A "CAUTION RADIOACTIVE MATERIAL" label is required on any container that is used to transport or store any quantity of radioactive material. When containers are used for storage, the labels should state the type and quantity of radioactive material in the container and the date of measurement. Radioactive material labels on non-contaminated, empty containers must be removed or thoroughly defaced.
6. A "CAUTION AIRBORNE RADIOACTIVITY AREA" sign is required if airborne radioactive material concentrations exceed applicable regulatory limits. Airborne radioactivity is usually the result of inadequate techniques, or facilities, or equipment malfunction. The AU or Department should alert the Radiation Safety Division when the presence of significant airborne radioactivity is suspected so that a corrective action may be devised.

D. Responsibilities of the Authorized User

Radiation Protection Survey

The authorized user (AU) is required to perform periodic monitoring of laboratory areas. Surveys and monitoring should be done during and after radioactive material handling and experimental procedures that involve radioactive material. The intent of these surveys is to assure the timely detection of radioactive contamination and guide the necessary decontamination before radioactive material is spread throughout the laboratory and beyond. The AU must assure that survey instruments to be used are calibrated and appropriate to the radioisotope involved.

1. *Frequency:* The AU, or qualified designee, must perform monthly radiation surveys of all laboratory areas. The Radiation Safety Division may increase the required survey frequency for a project, as necessary. Routine laboratory surveys, as well as follow-up actions, must be documented and kept as a permanent laboratory record.
2. *Survey Records:* Survey records must be developed and maintained by the AU, or qualified designee. Each survey record must include:
 - a. The authorization number and laboratory location by building and room
 - b. The signature of the surveyor and the date
 - c. A sketch of the laboratory showing locations surveyed
 - d. Identification of survey instrument(s) used for survey
 - e. Results of survey swipe counting, including gross and background counts
 - f. Results of survey instrument measurements, including gross and background measurements
 - g. Actions taken to correct off-standard conditions and final results

If radioactive material has not been used in a laboratory since that laboratory was last surveyed, the routine radiation survey need not be performed. However, a confirmatory statement of this condition must be documented in the survey record.

3. *Survey Guidelines:* Laboratory personnel should survey themselves and laboratory clothing before work breaks and at the end of the day. Work surfaces, equipment, floors, light switches, telephones,

refrigerators, freezers, door and drawer handles should also be surveyed routinely. Effective monitoring includes measurements of radioactive contamination by both direct instrument measurement for fixed contamination and counting of swipe samples for removable contamination.

The following guides concern survey techniques for commonly-used isotopes:

- a. As direct radiation measurements may be inadequate for low-energy beta emitters (H-3, C-14, S-35, Ca-45), swipe samples should be used for analysis. Swipe samples are obtained by swiping a 100 cm² surface with absorbent material using moderate pressure. Each swipe should cover approximately 100 cm² of an area such as a bench top, hood lip, or the floor in front of a work area. Larger areas may be swiped when a location is being screened and no removable activity is expected.

After collection, the surveyor should place the swipe samples in individual liquid scintillation counting vials, add scintillation fluid, and count using the appropriate liquid scintillation counter window settings. Background data must be obtained for each batch of swipes by counting an unused sample swipe in a liquid scintillation vial. Frequent instrument checks using reference radioactive standards are recommended.
 - b. Direct measurement of high-energy beta emitters (P-32, Sr-90) and photon emitters (Fe-59, Cr-51, I-125 etc.) should be performed with appropriately sensitive instruments. Specific guidance is available from the Radiation Safety Division.
 - c. A Geiger Mueller (GM) instrument, even with a thin-window "pancake" detector, is inefficient for low-energy photons. Instruments with a special low-energy photon response, such as a thin NaI(Tl) scintillation detector, are preferred for the detection of such photons.
 - d. Surveys with hand-held instruments may be ineffective when background radiation levels in the laboratory are more than a few times the normal background (a "high" background area). A high background may mask the radioactive emissions from contamination and therefore reduce the overall instrument effectiveness. In an iodination hood, for example, the nearby background may be too high to detect slight contamination. In such cases, swipe samples are essential, because they can be counted with an instrument located in a low background laboratory.
 - e. If the observed contamination level (usually converted to disintegrations per minute per 100 cm²) exceeds the values shown in Table 9-1, the area should be marked and decontaminated. Follow-up samples should be taken after an area is cleaned to document the corrective action. If contamination persists, a change in laboratory procedure should be made.
 - f. All radioactive material packages or containers brought into the authorized user work area should be surveyed for removable contamination prior to use. This procedure is applicable to material acquired through normal purchasing, that received from another investigator outside UCLA, or that received from an investigator at UCLA. The transfers of isotopes or labeled compounds can be made within the limits specified in the recipient's authorization and must be documented. Before initiating such a transfer, the AU must ascertain that the recipient is authorized to receive the material.
4. *Correction of Survey Deficiencies:* Upon review of the Radiation Safety Division survey by a health physicist, the authorized user will be notified of significant continuing problems and recommended corrective actions. If subsequent surveys show that survey deficiencies have not been sufficiently addressed, a formal notice or memorandum will be sent to the AU. If the problem remains unresolved, the Radiation Safety Officer may defer to the Radiation Safety Committee for action. This may lead to a temporary suspension of isotope receipts, suspension of the authorization, or closure of the laboratory.

Clearance of Equipment or Laboratory Furniture

Equipment and laboratory furniture that has been used or stored in a laboratory or work area possessing uncontained sources of radioactive material may not be transferred to general or non-radioactive material use without the express approval of the Radiation Safety Officer or designee.

Special precautions must be taken for such equipment as liquid scintillation counters or gas chromatographs, which have small radioactive sources installed. The Radiation Safety Division must be contacted to assure proper disposal or transfer of the installed radioactive material, in particular when such material is sent outside the University.

Clearance of Laboratory Facilities

Authorized radioactive material users may not remodel a laboratory, relocate to a different laboratory, or abandon the radiation use area without express written approval of the Radiation Safety Division. Abandoning a radiation use area without this approval is not only a violation of California law, but will subject the AU, department chair, or division head, as signatory of the original application, to payment of costly clean-up fees.

AUs wishing to remodel an existing radiation use area, relocate from one laboratory to another, or discontinue use of radioactive material in a laboratory must advise the Radiation Safety Division of the planned remodel, relocation, or termination of use to avoid the clean-up fees.

Depending on the anticipated change in plans by the AU, the Radiation Safety Division will direct the user to do one or more of the following:

1. Return all remaining radioisotopes to the Radiation Safety Division for disposal.
2. Assure that all personnel working on the project have completed their required bioassay measurements and returned personnel dosimetry to the Radiation Safety Division.
3. Perform a final radiation survey of laboratory areas to assure that decontamination and source removal is complete.
4. Report findings to the Radiation Safety Division.

When the Radiation Safety Division staff has verified adequacy of the close-out, a written release will be issued to the AU.

Volume contamination can result from neutron activation or from the penetration of radioactive contamination into cracks or interior surfaces within the matrix of an item. Clearance of volume-contaminated material will be performed in accordance with ANSI/HPS N13.12-1999. This standard provides primary radiation dose criterion and derived screening levels for volume contamination for groups of radionuclides.

E. Radiation Surveillance by the Radiation Safety Division

The Radiation Safety Division conducts annual inspections of all radioactive material use areas. However, based on considerations such as the safety index, the quantity and type of radioisotopes in use, recent laboratory radiation safety performance, and worker exposure status as reflected by the personnel radioactive badge or bioassay results, radioactive material use areas may be audited more frequently.

Although RSD inspections will evaluate the general radiation safety performance of a laboratory, special attention will be paid to the following areas:

1. Authorized personnel working with radioactive material
2. Authorized rooms used for working with radioactive material
3. Security of radioactive material
4. Proper labeling of work areas, equipment, and isotope storage areas
5. Evidence of food or drink in laboratory areas
6. Isotope inventory and survey records
7. Survey instrument calibration and availability
8. Fume hood and iodination hood certification
9. Waste segregation and management
10. Radiation and radioactive material control
11. Proper utilization of dosimetry, if issued.
12. Use of appropriate radiation safety apparel and shielding.
13. Personnel training records

14. Posting of “Notice to Employees”

TABLE 9.1
LIMITS FOR REMOVABLE SURFACE RADIOACTIVITY

V.	Type of Surface	Type of Emitter (in units of disintegrations per minute per 100cm ²)		
		α^a	$\beta/\chi/\gamma$	$\beta/\chi/\gamma^b$
1	Non-radioactive Material Use Area	22	220	2,200
2	Radioactive Material Use Area	220	2,200	22,000
3	Personal Clothing (in public areas)	22	220	2,200
4	Personal Clothing (in restricted areas)	220	2,200	2,200
5	Skin	220	220	2,200

- a. Values are for transuranic isotopes (not in common use at the University). Values for uranium isotopes and decay products may be fifty times tabular value; values for natural thorium may be five times tabular value.
- b. Values pertain to H-3, C-14, S-35 and Tc-99m and certain other isotopes identified in NRC-R.G., 1981.

Chapter 10: Radioactive Waste

A. INTRODUCTION

This chapter provides users of radioactive material with instructions for storing radioactive waste in the laboratory and preparing radioactive waste for pickup and disposal. Not all radioactive wastes generated at UCLA are described within this chapter. If you have any questions regarding any procedure in this chapter or need additional information, please contact the Waste Management Section of the Radiation Safety Division.

B. RESPONSIBILITIES

1. Prior to procurement, authorized users (AUs) must ensure that a method for disposal of radioactive material presently exists or can be worked out to the satisfaction of the Radiation Safety Division (RSD).
2. Each laboratory must maintain accurate records of the types, quantities, and chemical forms of radioisotopes that comprise the radioactive waste delivered to the RSD. This information is needed to complete the UCLA Radioactive Waste Tag. All activity amounts recorded must be based on either calculations or measurements.

C. RADIOACTIVE WASTE STORAGE IN THE LABORATORY

1. It is the AU's responsibility to secure proper storage for radioactive wastes.
2. Radioactive waste containers shall be stored as close to the work area as feasible to minimize the possibility of spillage during the transfer of waste to the container.
3. Radioactive waste containers should be kept closed at all times when not in use. Liquid waste must be kept in secondary containment at all times, including transport to the radioactive waste pickup location.
4. Each radioactive waste container in the laboratory shall be labeled with a "Caution Radioactive Material" sticker on the lid and side of the container.
5. Do NOT place any radioactive waste in regular trash receptacles. Provide distinctly different containers for radioactive waste to avoid disposal in the regular trash.
6. Do NOT combine different radioisotopes in the same waste container unless you have prior authorization from the RSD to do so. Use a separate container for each isotope and waste stream.
7. Radioactive waste containers shall NOT be stored or left unattended in hallways, stairwells, or other uncontrolled areas.
8. Radioactive waste should not be stored in the laboratory for extended periods of time. The waste should be delivered to the designated pickup location in a timely manner. This minimizes radiation exposure in the laboratory and reduces the possibility of the radioactive waste being disposed of in the regular trash.

D. DISPOSAL OF RADIOACTIVE MATERIAL PACKING MATERIAL / EMPTY BOXES

1. External packaging (e.g. cardboard boxes) shall be monitored for contamination before disposal into the regular trash. NO package with detectable radioactive contamination may be disposed of in the regular trash.
2. All radioactive material stickers, labels, and symbols MUST be defaced prior to disposal in the regular trash.

E. PRUDENT LABORATORY PRACTICES

1. When handling or transferring radioactive waste, the individual shall wear appropriate laboratory attire including lab coat, disposable gloves, and protective eyewear. Closed-toed shoes are recommended.
2. Radioactive wastes containing carcinogens, biohazards, or hazardous material must be handled separately and packaged in such a way that they present minimal hazards to people who handle wastes. Contact the RSD for specific requirements.

F. RADIOACTIVE WASTE PACKAGING

1. Under NO circumstances shall radioactive waste be released into the sewage disposal system.
2. Package the waste properly. Please refer to laboratory radioactive waste procedures for instructions.
3. Take necessary precautions to prevent external contamination of the outer waste bag.
4. All radioactive waste packages must contain a properly completed three-part UCLA Radioactive Waste Tag. Refer to the radioactive waste procedures for instructions on how to properly fill out the waste tags for each waste stream.
5. All radioactive waste tags must accurately reflect the radioactive content. Terms such as “less than” or “trace” are unacceptable.
6. Call the RSD to request waste management information, waste tags, containers, etc.

G. RADIOACTIVE WASTE TRANSPORTATION

1. All liquid radioactive waste must be transported within secondary containers to prevent leakage and spills.
2. The AU is responsible for ensuring that no member of the public receives a dose greater than 2 mrem in 1 hour. Adequate shielding of the radioactive waste is required. Please contact the RSD for assistance with shielding radioactive waste containers for transportation to the pickup location.
3. Take radioactive waste to the nearest pickup location within your building complex.
4. Properly packaged waste will contain all radioactive material. Therefore, the use of gloves during transport is not recommended. However, gloves should be taken along for use in the unlikely event of a spill.
5. Please use freight elevators if possible; do not use patient elevators.

H. NONCOMPLIANCE

Failure to adhere to all of the radioactive waste disposal procedures and requirements outlined in this chapter may result in the following:

1. Rejection of radioactive waste at the pickup location and return of radioactive waste to the laboratory for proper re-packaging.

2. Issuance of a “warning” to the laboratory for non-compliance with UCLA Radioactive Waste Policies, followed by escalating enforcement which may include review by the Radiation Safety Committee and/or loss of the Radioactive Material Use Authorization.

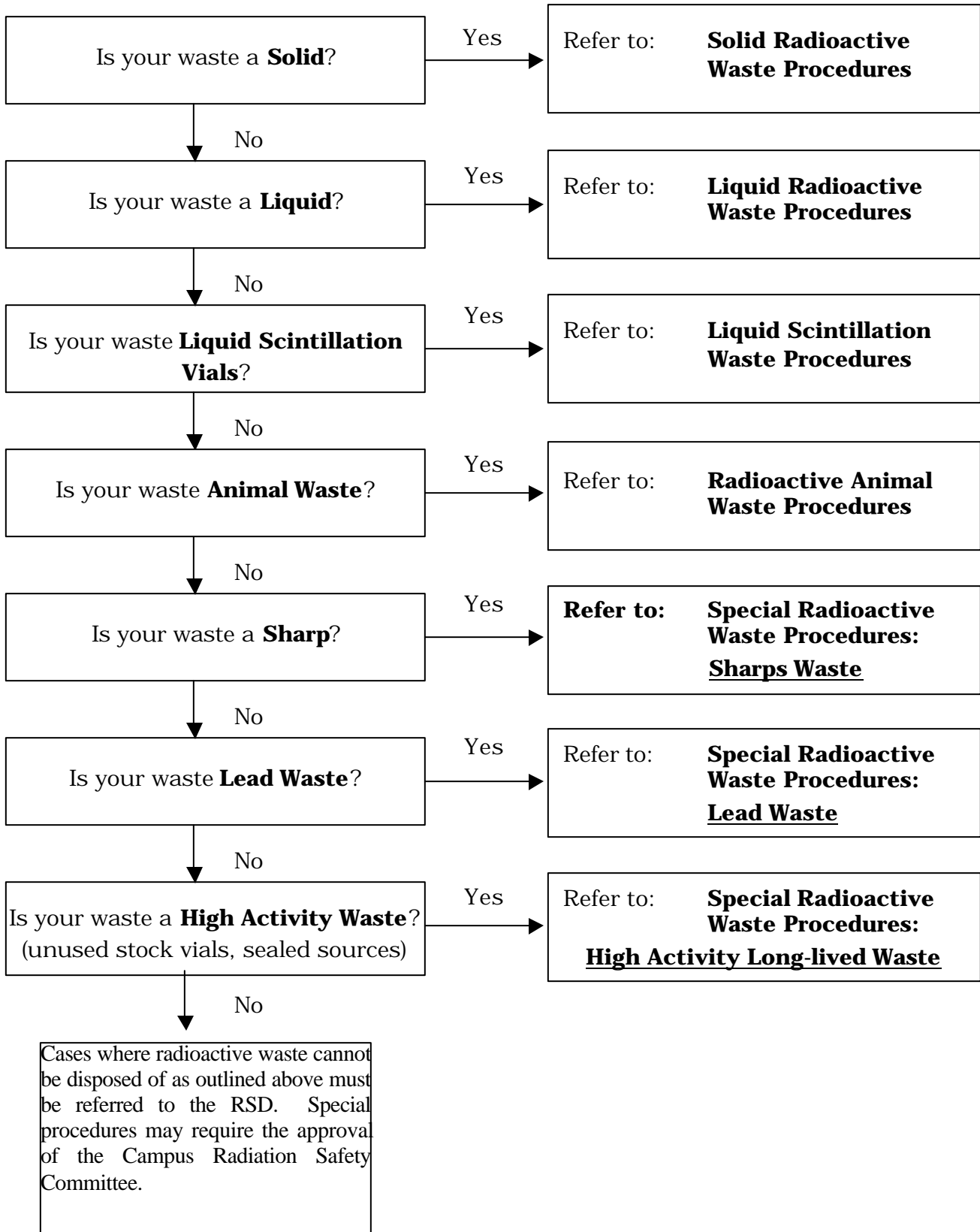
I. RADIOACTIVE WASTE MINIMIZATION GUIDELINES

Whenever possible, the following guidelines should be used to minimize the production of and disposal costs associated with radioactive waste:

1. Use biodegradable liquid scintillation fluids.
2. Segregate liquid scintillation fluids and animal carcasses with concentrations of H-3 / C-14 less than 0.05 μCi / gram.
3. Use smaller liquid scintillation vials instead of larger vials.
4. Use radioisotopes with half-lives less than 90 days.
5. Segregate radioisotopes, if possible.
6. For dry waste, ensure that only contaminated material is disposed of as radioactive waste. Use an appropriate radiation detection instrument (GM Survey Meter) to meticulously scan the waste (one inch per second and one-half inch above the surface) to determine whether or not the material is contaminated before placing it in the radioactive waste container. If the radioactivity measurement of an item or area cannot be distinguished from background, deface all radioactive symbols and place in the regular trash.
7. H-3 (Tritium) CANNOT be detected with a GM Survey Meter. Tritium experiments should include waste minimization considerations. Procedures should be established to limit glove changes and other undesirable waste generation. Equipment contamination levels should be verified by swipe survey prior to disposal. If you have questions regarding possible H-3 contaminated items, contact the RSD.
8. If radioactive contamination is present on a small area of bench-top liner / absorbent paper, the contaminated area may be cut away from the uncontaminated portion for disposal as radioactive waste. The remainder of the bench-top liner should be re-surveyed and, if no contamination is present, it may be disposed of as regular trash. Be sure to remove or deface any radioactive labels before disposing of anything in the regular trash.
9. Segregate organic, toxic, or corrosive liquid wastes from aqueous, non-toxic, non-corrosive solutions.
10. Ensure proper segregation of radioactive and chemical waste. Do not mix chemicals and radioactive material unnecessarily, thereby creating mixed wastes.
11. Aqueous solutions with pH between 2 to 5 or 9 to 12.5 should be neutralized prior to placement in approved radioactive liquid waste containers. This process must be part of your written experimental protocol and receive approval from the RSD.
12. Do NOT perform any treatments without permission from RSD waste management personnel. Researchers may inquire about bench-top treatment of mixed waste from the Waste Management Section of the Radiation Safety Division.
13. Substitute non-radioactive tracers for radioactive tracers.

The flowchart on the following page is for waste classification.

MASTER FLOWCHART - WASTE CLASSIFICATION



Chapter 11: Environmental Monitoring

A. INTRODUCTION

The broad objectives of environmental radiation monitoring are to assess actual or potential exposure to radioactive material or radiation present in the environment, to explore the feasibility of remediation, and to facilitate good public relations. The University relies on administrative controls and tracking quantities and types of radioisotopes to minimize environmental impacts.

B. CONTROL AND MONITORING OF RADIOACTIVE DISCHARGES FROM POTENTIAL RELEASE LOCATIONS

There are three potential effluent pathways at UCLA:

1. **Waste Handling Facility.** Dry, liquid, and mixed waste is prepared for disposal in the Environmental Services Facility. Periodic swipe and air monitoring samples of the area will be performed.
2. **Cyclotron Laboratories.** Cyclotrons are dedicated to the production of C-11, N-13, O-15 and F-18 for use in various chemical forms in positron emission tomography (PET) for research and medical clinical applications. Effluents are continuously monitored, and historical measurements indicate that airborne concentrations are less than 1% of regulatory limits.
3. **Fume Hoods and Minihoods.** Fume hoods and minihoods are located in most laboratories on campus. Iodination cabinets or minihoods may be installed inside fume hoods or other types of enclosures for the control of airborne radioactive material. When the airborne concentration of any isotope or combination of isotopes is likely to approach or exceed the established limit for work areas, a fume hood will be stipulated in the authorization. When iodination processes are planned, a minihood may be required. A fume hood is required when subdividing stock vials of I-131. During periodic laboratory inspections, Radiation Safety Division personnel verify fume hood certification and perform surface contamination surveys.

Chapter 12: Training

A. INTRODUCTION

The management of an organization that uses radioactive material must assure that its radiation workers are trained in radiation protection as well as in their job proficiencies. The use of radioactive material may result in radiation exposure to faculty, students, and staff employees. In addition, persons visiting the University may potentially be exposed to radiation fields above background. Proper training equips workers with the knowledge and skills necessary to maintain radiation exposure as low as reasonably achievable (ALARA) for themselves and visitors under their supervision. Also, radiation safety training informs individuals of the associated risks involved with exposure to ionizing radiation.

The Radiation Safety Division (RSD) cannot identify and track the training levels of each individual without the direct support of the Authorized Users (AU) and group supervisors. Ultimately the responsibility for meeting initial and continuing training requirements falls upon the AU. This chapter outlines the training guidelines and procedures for radioactive material users. It is intended to meet the requirements of the State of California and to assist in maintaining personnel exposure as low as reasonably achievable through proper training. Chapter 6 provides the training requirements for the operation of radiation-producing machines.

B. PERSONNEL REQUIRING TRAINING

In order to maintain compliance with State of California regulations, training events must be documented with the RSD. Documented initial training is required for all individuals prior to working with or in close proximity to radioactive material. Initial training conducted by the Radiation Safety Division includes a handout containing relevant safety and compliance information followed by a training session to introduce basic radiation safety principles, techniques, and requirements. The initial training sessions provided by the RSD may be customized to meet the needs of a specific group or project such as iodination cabinet users or laboratories which use sealed sources. At the conclusion of the formal training session, a quiz is administered to document the success of the training. Only those who successfully pass this quiz will be permitted to work with radioactive material. Initial training must be supplemented by training specific to the laboratory and/or project. This ongoing training is to be arranged and supervised by the AU.

Persons who do not work directly with ionizing radiation but work in areas where it is used, are designated as peripheral workers. These workers are not required to go through the formal Radiation Safety Division training. They may be trained directly in the laboratory, as needed, under the guidance of the AU. Nevertheless, training of peripheral workers **must be documented** by the AU.

Non-occupationally exposed workers are those who perform occasional or short-term tasks in areas where radioactive materials are authorized for use. These workers are not expected to receive additional radiation exposure beyond that received by the general public. Individuals such as the housekeeping staff who service radioactive material use laboratories will be trained by the Radiation Safety Division as appropriate.

Visitors are individuals who do not work in radioactive material use laboratories but may enter these rooms for short periods of time. Visitors do not require documented formal training as long as they are under the supervision of a trained individual. A visitor's radiation exposure may not exceed the limits allowed to a member of the general public (10CFR20).

C. GENERAL CRITERIA FOR TRAINING

Not every radiation worker requires training in all topics listed below. For example, workers who occasionally handle small amounts of tritium or C-14 would require training in only a few selected topics. However, a worker who handles therapeutic doses of I-131 would require training in more areas.

Include the following topics in your training program, as appropriate:

- Radioactivity and radioactive decay
- Nuclear characteristics of ionizing radiation
- Man-made sources of ionizing radiation

- Acute effects of exposure
- Risks associated with occupational exposure
- Exposure to the embryo/fetus
- Dose-equivalent limits
- Mode of exposure – internal, external
- Dose-equivalent determinations
- Fundamental protective measures – time, distance, shielding
- Basic radiation survey instrumentation – calibration and limitations
- Radiation monitoring programs and procedures
- Contamination control
- Handling and delivery of radioactive waste material
- Personnel decontamination
- Emergency procedures
- Safety warning signs and warning alarms
- Responsibilities of employees and of the organization
- Interaction with Radiation Safety Division staff
- Maintaining exposure as low as reasonably achievable (ALARA)

D. CONTINUING EDUCATION

Training is required for all principal radiation workers including authorized users. One continuing training credit must be obtained each calendar year. Continuing training credits (CTC) may be obtained in several ways:

1. **New Radiation Worker Quiz (NRWQ) training sessions.** Persons wishing refresher training may attend one of the monthly NRWQ training sessions. They will not be required to retake the examination.
2. **Seminars offered by the Radiation Safety Division.** Routine Radiation Safety Division seminars are offered periodically. Flyers are sent to the AU and are available upon request.
3. **Videos from the Radiation Safety Division.** A list of videos is available from the RSD. Each video presentation provides one (1) CTC.
4. **In-house seminars.** An authorized user or delegate may give an in-house seminar on radiation safety issues.
5. **Special seminars.** Special seminars offered by RSD personnel are available upon request, subject to staff availability.
6. **Course work and/or professional education.** Persons who teach radiation courses or who take course work or professional education that includes radiation issues can apply the training/education to the annual CTC requirement.
7. **State Certification.** Physicians and technologists who are certified with the Department of Health Services to work with ionizing radiation (X-ray machines or radioactive material) will not be required to obtain continuing education credits through the RSD since they must obtain State-approved CTCs in order to maintain their certification.

Personnel training will be evaluated during routine laboratory inspections by the inclusion of performance-based questions. This element of the inspection will be used to determine if training levels are sufficient to maintain compliance. If compliance issues are found during routine inspections, the RSD may require additional training sessions.

APPENDIX 1: TERMINOLOGY AND SPECIAL ABBREVIATIONS

The following list identifies the various organizations, guides, and standards referred to and abbreviated in the Manual. This list also includes terms that are commonly used in the radiation protection profession.

A

Activity The quantity of a radionuclide expressed as the number of radioactive decay events occurring per unit time (Example: disintegrations per second).

ALARA "As Low As Reasonably Achievable," means making every reasonable effort to maintain exposures to radiation as far below the dose limits as is practical consistent with the purpose for which the activity is undertaken, taking into account the economic and social factors

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

Alpha A particle emitted from the nucleus of an atom during radioactive decay, identical in mass and electrostatic charge to the helium nucleus, two protons and two neutrons, represented as α .

ANSI American National Standards Institute

Authorized User (AU) The lead investigator identified on all radiation use and radiation-producing machine use authorizations (RUAs), sometimes referred to as the Principal Investigator (PI).

B

Bq Becquerel, the international unit of activity having the value of one disintegration per second, represented as Bq.

Beta A particle emitted from the nucleus of an atom during radioactive decay, identical in mass and electrostatic charge to an electron, represented as β .

Bioassay The assessment of radioisotope intake in the body by *in vivo* or *in vitro* measurement.

Bremsstrahlung Photons emitted when charged particles decelerate or change direction through electrostatic interaction with matter.

C

17 CCR Title 17 of the California Code of Regulation on Health, administered by the Department of Health Services.

10 CFR Title 10 of the Code of Federal Regulations. Title 10 is divided into many regulations by the United States Nuclear Regulatory Commission.

40 CFR Title 40 of the Code of Federal Regulations by the United States Environmental Protection Agency.

49 CFR Title 49 of the Code of Federal Regulations by the United States Department of Transportation.

Contamination (Radioactive Contamination) Finely divided particles of radioactive material in an undesired location.

APPENDIX 1: TERMINOLOGY AND SPECIAL ABBREVIATIONS

Controlled Area An area, outside of a *restricted* area but within the site boundary, access to which can be limited by the authorized user or Licensee for any reason.

Curie (Ci) A unit of activity having the value 3.7×10^{10} disintegrations per second.

D

Decay Radioactive decay or the *disintegration* of the nucleus of an unstable atom by spontaneous emission of energy in the form of high speed particles or electromagnetic waves.

DHS California Department of Health Services, the University's licensing and regulatory agency.

Disintegration A spontaneous nuclear transformation (See Decay).

DOE United States Department of Energy

Dose Absorbed dose or energy imparted to matter per unit mass of the irradiated matter. Expressed in units of Rads or Grays.

Dose Equivalent (DE) Absorbed dose multiplied by certain modifying factors. The principle factor is the *quality factor (QF)*, which corrects absorbed dose for relative biological damage for various types of radiation. Expressed in units of Rems or Seiverts.

Quality factors for:

Beta, gamma, and x-rays	=	1
Alpha	=	20

(1) Rad = (1) Rem for beta, gamma and x-ray.

a. Deep dose equivalent- applies to the external whole body exposure in terms of dose equivalent at a tissue depth of 1 cm (1000 mg/cm²).

b. Shallow Dose Equivalent applies to the skin at a max. tissue depth of 0.007 cm (7 mg/cm²).

c. Effective Dose Equivalent is the sum of the product of the dose equivalents each weighted by a factor for the tissue organ in question.

E

EH&S Environment, Health and Safety.

EPA Environmental Protection Agency

Exposure A special radiation quantity of ionization in air from x-rays or gamma rays. Units are expressed in Roentgen (R). Also a conversational term meaning simply exposure to radiation or radioactive material.

External exposure Radiation exposure from a source outside the body.

G

APPENDIX 1: TERMINOLOGY AND SPECIAL ABBREVIATIONS

NIST National Institute of Standards and Technology

NCRP Nation Council of Radiation Protection and Measurement

NRC Nuclear Regulatory Commission

NVLAP National Voluntary Laboratory Accreditation Program, a program for assuring that accredited personnel dosimetry systems will meet specific standards when reporting personnel radiation exposures.

P

Positron Emission Tomography (PET) A technique for measuring the concentrations of positron-emitting radioisotopes within the tissue of living subjects. These measurements are made outside of the living subjects.

Q

Quality Factor (QF) A linear energy transfer dependent factor by which absorbed dose is multiplied to obtain a dose quantity, dose equivalent, to indicate the biological effectiveness of absorbed dose.

R

Radiation The emission and propagation of energy through space.

Radiation Area An area defined by 10CFR20 as an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 Rem (5 mRem) in (1) hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

Radiation Safety Committee UCLA committee that develops campus policies concerning radiation safety and has an overview function of the Radiation Safety Division.

Radiation Safety Division (RSD) A division of the Office of Environment, Health & Safety which deals with radiation safety as a regulatory and service organization.

Restricted Area An area, access to which is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials.

RSO Radiation Safety Officer, the manager of the Radiation Safety Division and the radioactive materials license.

Radiation-producing Machine Any high voltage machine capable of producing penetration radiation, usually X-rays, but may be any nuclear reaction, e.g. neutrons, protons.

RUA Radiation Use Authorization, a document issued by the Radiation Safety Division that defines the limitations of the authorized user (AU) regarding the use of radioactive materials and radiation-producing machines. These limitations include authorized isotopes, acquisition limits, dosimetry requirements, chemical form restrictions, and special conditions.

APPENDIX 2: PRENATAL RADIATION EXPOSURE

A. INTRODUCTION

Employers of radiation workers are expected to provide instructions on risks from exposure to radioactive materials and radiation from machines. Of special interest is the potential exposure of women workers of childbearing age and risks to the unborn child. This appendix presents basic information and guidance for women of childbearing age. Additional information will be provided during regular training seminars and in informative handouts prepared by the Radiation Safety Division. Supervisors and coworkers should be aware of the special risks and limits on the occupational exposure of radiation workers of childbearing age.

Children are more sensitive to radiation than adults. The unborn are generally more sensitive than children, especially during the initial two to three months after conception. Therefore, the acceptable dose limits are lower than those for adult workers.

B. RADIATION EXPOSURE LIMITS

A radiation worker probably will be exposed to more radiation than the public. The amount of radiation an individual receives is called the "dose" and is measured in rem^a. The radiation exposure limit for all occupationally-exposed workers is 5000 mrem (50 mSv) per year. For individuals under eighteen years of age, the limit is 500 mrem per year; members of the public are permitted to be exposed to only 100 mrem (1 mSv) or 1/50th of the occupational limits.

When a woman is pregnant and is exposed to radiation, exposure of her abdomen to sufficiently penetrating radiation (high-energy gamma rays or X-rays) from either external or internal radiation sources also would involve exposure of her unborn baby. A woman may not be aware that she is pregnant during the early stages of her pregnancy.

Revised 10 CFR Part 20, "Standards for Protection Against Radiation", requires that the dose to an embryo/fetus during the ~~entire~~ pregnancy from occupational exposure of a ~~declared~~^b pregnant woman does not exceed 500 mrem (5 mSv). 10 CFR Part 20 also requires the licensee to make efforts to avoid substantial variation above a uniform monthly exposure to a declared pregnant woman that would satisfy the 500 mrem (5 mSv) limit. The dose to the embryo/fetus is to be the sum of:

1. The deep-dose equivalent to the declared pregnant woman, and
2. The dose to the embryo/fetus from radionuclides in the embryo/fetus and radionuclides in the declared pregnant woman.

The deep-dose equivalent that shall be assigned is a representative dose to the

^a See Appendix 1. Developing practice encourages the unit sievert, (Sv) in place of rem, where 1 Sv = 100 rem.

^b A declared pregnant woman is a female radiation worker that voluntarily informs her employer in writing of her pregnancy and estimated date of conception.

APPENDIX 2: PRENATAL RADIATION EXPOSURE

embryo/fetus (i.e., in the mother's lower torso region).

The internal dose to the embryo/fetus shall include the contribution from any radionuclides in the declared pregnant woman from occupational intakes occurring prior to and after conception.

If the dose to the embryo/fetus has exceeded 450 mrem (4.5 mSv) by the time the woman declares the pregnancy to the licensee, the licensee shall be deemed to be in compliance with existing regulations if the additional dose to the embryo/fetus does not exceed (0.5 mSv) 50 mrem during the remainder of the pregnancy.

C. WORKER RESPONSIBILITY

Each person must decide whether the risks to the worker or to a known or potential unborn child are acceptable. The following facts may aid the decision making:

1. The first three months of pregnancy are the most important. The decision should be made early.
2. Due to body shielding, the actual dose received by an unborn child will be less than that to the woman in most work situations. At UCLA, most occupational exposures are well below the limits recommended above for prenatal exposure.
3. The dose to the unborn child can be reduced by decreasing the amount of time spent in a radiation work area and by increasing the distance from the sources of radiation or shielding the sources from the abdominal area.
4. When occupational exposure to the mother is below the five rem-per-year limit, the risk to an unborn child is small in relation to other day-to-day risks to the unborn. Experts disagree on the exact amount.
5. There is no need to be concerned about sterility, that is, loss of the ability to bear children. The radiation dose required to produce sterility is more than 100 times greater than the basic dose limits for adult workers (five rem per year).

D. RIGHTS AS A WORKER

The worker should compare the benefits of employment against the possible risks involving occupational radiation exposure to a known or potential unborn child. The Pregnancy Discrimination Act, an amendment of Title VII of the Civil Rights Act of 1964, states that “. . . women affected by pregnancy, childbirth, or related medical conditions, shall be treated the same for all employment-related purposes, including receipt of benefits under fringe benefit programs, as other persons not so affected but similar in their ability or inability to work . . .” The

Equal Employment Opportunity Commission, a Federal agency, is responsible for examining cases for compliance with this act.

E. WHY THE UNBORN ARE MORE SENSITIVE

The unborn baby (conceptus) is more sensitive to radiation than the adult because of its rapid rate of development. At certain times during development, those cells forming a specific organ or body function are dividing very rapidly and therefore are most likely to be damaged. In addition, the unborn's organs and systems for fighting infections and harmful substances are not yet developed. However, there is no scientific evidence that birth defects are induced below the limits recommended above.

Four to six percent of live births show some birth defect, though it is usually not possible to say what caused a particular birth defect. However, of 100 children born with birth defects, two or three can be attributed to drugs and chemicals. Defects in the genetic material of the parents are thought to cause another 25 out of 100 birth defects. About one out of three naturally aborted fetuses shows abnormal genetic material. There are other factors in the mother's life that are thought to cause another six out of 100 birth defects, e.g., exposure to naturally-occurring radiation.

F. PRENATAL RADIATION RISKS COMPARED TO OTHER RISKS

Some common activities once considered safe have now been shown to be harmful during pregnancy. Alcoholic beverages are said to be the most common chemical causing infant malformation and mental retardation. The "fetal alcohol syndrome" was reported to begin in the children of women who drank two to four drinks a day during their pregnancies. This syndrome consists of growth problems, brain dysfunction, and abnormal facial features.

Babies born to women who smoked cigarettes while they were pregnant weighed less than average babies. This contributes to a higher risk of early death. In addition, higher numbers of natural abortions were seen with these mothers. Lower school performance and physical well being were seen in their children when tested at age seven. Aspirin, antihistamines, cold remedies, barbiturates, and amphetamines are a few common drugs suspected of having harmful effects on the developing baby. The Food and Drug Administration has warned pregnant women to avoid or reduce their intake of caffeine (found in coffee, tea, and cola drinks) because of animal studies showing related birth defects.

Very large doses of radiation (greater than one hundred rem) to unborn babies can cause growth retardation, severe birth defects, and even death. The specific organ most seriously affected by radiation depends on the stage of growth at the time of the exposure. For growth defects, the period of greatest sensitivity is between weeks eight and twelve of a woman's pregnancy. During a large part of this time, a woman may not be aware that she is pregnant.

APPENDIX 2: PRENATAL RADIATION EXPOSURE

National Academy of Sciences studies addressed the effects of radiation on the growing baby. Small head size was seen in studies of Japanese children who were in the womb when their mothers received doses of atomic bomb radiation over a very short period (greater than ten rads at Hiroshima and greater than 150 rads at Nagasaki). At higher doses, greater than twenty-five rads, mental retardation was associated with the small head size, but only if the dose was received after the eighth week.

G. INHALATION AND INGESTION OF RADIOACTIVE MATERIAL

Potentially pregnant women should take special care when working with radioactive material that can be inadvertently taken into the body. Radioactive material may enter the body and cross the placenta into the baby's body. Those working with such material should consult with their supervisor or the Radiation Safety Division on the following questions.

1. Will the radioactive material be retained in my body?
2. Will the radioactive material cross from my body to my baby's body?
3. How can I avoid breathing or swallowing this radioactive material?
4. How can I get rid of this radioactive material if I get it into my body?

Radioiodine is used for diagnostic and therapeutic procedures and for research. Radioiodine, as a gas, easily mixes with the air and enters the body. It has been found in many workers. Radioiodine easily crosses into the unborn baby and may affect its developing thyroid gland, which starts to function around the tenth week of pregnancy. By the time of birth, the amount of radioiodine in each ounce of the baby's thyroid could be higher than that in the mother's thyroid. In addition, the baby's thyroid is more sensitive than the adult thyroid. While the ingestion of agents such as potassium iodide pills will "block" the thyroid against the uptake of radioactive iodine, the timing of the ingestion of these pills is important to ensure its effectiveness. The routine prophylactic use of blocking agents is not recommended. Upon serious exposure by inhalation or skin contamination, the worker should consult an appropriate medical person and the Radiation Safety Division.

APPENDIX 3: EMERGENCY RESPONSE

A. INTRODUCTION

When responding to radiological emergencies, there are a few basic steps that should be followed to prevent both the spread of contamination and further radiation exposure. This appendix provides guidance on those situations.

B. SPILLS

The most common emergency is spillage of a radioactive solution or the dispersion of radioactive material in the laboratory. Spills are divided into two categories, minor and major. A minor spill is a localized spill inside a laboratory that can be cleaned up by trained laboratory personnel. Major spills are defined as those requiring outside assistance for cleanup or those involving areas outside the authorized radioactive material use laboratory. The Radiation Safety Division should be notified immediately for spills in public areas (any area not authorized for radioactive material use). The Radiation Safety Division will aid in evaluation and provide guidance on decontamination.

General guidelines for immediate and follow-up actions are provided below:

MINOR SPILLS

1. Notify persons in the area that a spill has occurred.
2. Determine whether anyone is injured. The treatment of life-threatening injuries takes precedence over contamination concerns. Call campus 911* for medical emergencies.
3. To avoid the spread of contamination to nearby areas, prevent uninjured persons from leaving the spill area until personal contamination checks have been conducted.
4. Prevent unauthorized persons from entering the spill area.
5. Cover the spill with absorbent paper to prevent the spread of contamination.
6. Use disposable gloves and, if necessary, remote handling tongs to clean up contamination. Change gloves frequently. Carefully insert contaminated items such as gloves and absorbent paper into a plastic bag and dispose as radioactive waste.
7. Survey the area with a low-range survey meter appropriate to the radioisotope involved. Check hands, clothing, and the area around the spill for contamination. Note that tritium (H-3) cannot be detected using portable instrumentation (a liquid scintillation counter must be used).

* Dialing **9-1-1** using an on-campus phone line will connect the caller to the UCLA Police Department (UCPD). Please ask to speak with a Radiation Safety Division representative. This will prompt the UCPD to contact the on-call health physicist.

APPENDIX 3: EMERGENCY RESPONSE

8. Document the incident in the laboratory survey record. Documented information should include the date and time the incident occurred, the isotope(s) and quantities involved, affected personnel, actions taken, and survey results.

MAJOR SPILLS

1. Notify all persons not involved in the spill to vacate the room or area.
2. Determine whether anyone is injured. The treatment of injuries takes precedence over contamination concerns. Call campus 911* for medical emergencies.
3. Cover the spill with absorbent pads, but do not attempt to clean it up.
4. The spill should be shielded only if it can be done without further spread of contamination or without significantly increasing personnel radiation exposure.
5. Isolate the spill area. If possible close and lock the room. For spills outside of the authorized use area, use physical boundaries to isolate the spill. Verify contamination boundaries by scanning with the appropriate radiation detection instrument. Note that tritium (H-3) cannot be detected using portable instrumentation (a liquid scintillation counter must be used).
6. Call the Radiation Safety Division at **5-5396** during working hours. Call campus 911* during off-work hours.

C. INHALATION OR INGESTION

1. Determine the radioisotope involved, the chemical form, and if possible, the amount ingested.
2. Call the Radiation Safety Division at **5-5396** during working hours. Call campus 911* during off-work hours.

D. EXTERNAL CONTAMINATION

1. Remove contaminated clothing.

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2. Rinse contaminated skin with tepid water, and mild soap. Give special attention to areas between fingers and around fingernails. Repeat as necessary. Stop decontamination effort if the skin begins to redden or become irritated.

SPECIAL CASE: Eye contamination should be washed with copious amounts of warm water only.

3. A safety shower (or other shower if safety shower is not available) should be used for extensive personnel contamination.
4. Call the Radiation Safety Division at **5-5396** during working hours. Call 911* during off-work hours.
5. Do not leave the immediate area until instructed to do so by Radiation Safety Division personnel.

* Dialing **9-1-1** using an on-campus phone line will connect the caller to the UCLA Police Department (UCPD). Please ask to speak with a Radiation Safety Division representative. This will prompt the UCPD to contact the on-call health physicist.