RADIATION SAFETY MANUAL

UNIVERSITY OF CALIFORNIA

IRVINE

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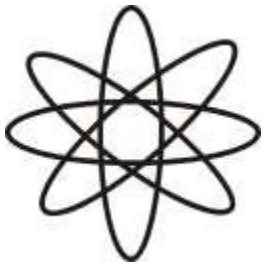
UNIVERSITY OF CALIFORNIA, IRVINE
**** RADIATION SAFETY MANUAL ****



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SECTION 1: TERMS AND DEFINITIONS

TERMS

Reference to the NRC means the United States Nuclear Regulatory Commission.

Reference to the NCRP means the National Council on Radiation Protection and Measurements. This is the United States scientific organization that recommends standards for radiation protection.

Reference to the ICRP means the International Commission on Radiological Protection. This scientific organization provides guidance on the use of radiation sources and their properties.

Reference to the State means the State of California and any of its agencies empowered to establish or enforce regulations regarding radiation and/or radioactive materials.

Reference to the University means the University of California and to the Campus means the Irvine Campus.

The abbreviation 10CFR20: Code of Federal Regulations, Title 10, Chapter 1, Part 20. For example: Paragraph 20.101 may be referred to as 10CFR20.101.

The abbreviation 17CAC30100: California Administrative Code, Title 17, Section 30100. Other sections are referred to in a similar manner.

Controlled Area: Any area to which access is controlled for purposes of radiation safety.

ALARA (As Low As Reasonably Achievable): The policy of maintaining radiation levels and exposures as low as reasonably achievable.

Radiation Use Authorization (RUA): A permit, sometimes incorrectly referred to as a "license", issued to an employee, usually a faculty member who is a principal investigator or a class instructor, by the Radiation Safety Committee, prescribing conditions for the use of radioactive material and/or radiation producing machines on campus.

DEFINITIONS

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

Alpha Particle: A charged particle having a mass and charge equal in magnitude to a helium nucleus (a cluster of two protons and two neutrons) that is emitted from the nucleus of an atom.

Anemia: Deficiency of blood as a whole, or deficiency in hemoglobin or in the number of the red blood cells.

Atom: Smallest unit of an element which is capable of entering into a chemical reaction.

Atomic Mass: The mass of a neutral atom of a nuclide, usually expressed in terms of "atomic mass units". An "atomic mass unit" is one-twelfth the mass of one neutral atom of ^{12}C; equivalent to 1.6604 x 10^{-24} grams. (Symbol: A).

Atomic Number: The number of protons in the nucleus of an atom of a nuclide. The "effective atomic number" is calculated from the composition and atomic numbers of a compound or mixture of atoms with different atomic numbers. An element of this atomic number would interact with photons in the same way as the compound or mixture. (Symbol: Z).

Attenuation: The process by which a beam of radiation is reduced in intensity when passing through some material. It is the combination of absorption and scattering processes and leads to a decrease in flux density of the beam when projected through matter.

Autoradiograph: Record of radiation from radioactive material in an object, made by placing the object in close proximity to a photographic emulsion.

Beam: A unidirectional or approximately unidirectional flow of electromagnetic radiation or particles.

> Useful Beam (Radiology): Radiation that passes through the aperture, cone, or other collimating device of the source housing. Sometimes called the "primary beam".

Becquerel: international unit of activity having the value of one disintegration per second.

Beta Particle: Charged particle emitted from the nucleus of an atom, with a mass and charge equal in magnitude to that of the electron.

Bone Marrow: Soft material which fills the cavity in most bones; it manufactures most of the formed elements of the blood (white and red blood cells).

Bone Seeker: Any compound or ion which preferentially migrates into bone in the body.

Bremsstrahlung: Secondary photon radiation produced by deceleration of charged particles passing through matter.

Carcinogenic: Capable of producing cancer.

Chamber, Ionization: An instrument designed to measure a quantity of ionizing radiation in terms of the electric charge associated with ions produced within a defined volume.

Contamination, Radioactive: Deposition of radioactive material anywhere where it is not desired, particularly where its presence may be harmful. The harm may be in interfering with an experiment or a procedure, or in actually being a source of danger to personnel.

Counter, Geiger-Mueller: Highly sensitive, gas-filled radiation-detecting device. It operates at voltages sufficiently high to produce avalanche ionization.

Counter, Proportional: Gas-filled radiation detection device; the electronic pulse produced is proportional to the number of ions formed in the gas by the primary ionizing particle.

Counter, Scintillation: The combination of phosphor, photomultiplier tube, and associated circuitry for measuring light emissions produced by ionization in the phosphors.

Curie: The special unit of activity. One curie equals 3.700×10^{10} nuclear disintegrations per second. (Abbreviated Ci.) Several fractions of the curie are in common usage.

> Millicurie: One-thousandth of a curie (3.7×10^{7} disintegrations per second). Abbreviated mCi.
>
> Microcurie: One-millionth of a curie (3.7×10^{4} disintegrations per second). Abbreviated μCi.
>
> Picocurie: One-millionth of a microcurie (3.7×10^{-2} disintegrations per second, or 2.22 disintegrations per minute). Abbreviated pCi.

Decay, Radioactive: Disintegration of the nucleus of an unstable nuclide by spontaneous emission of charged particles and/or photons.

Detector, Radiation: Any device for converting radiant energy to a form more suitable for observation. An instrument used to determine the presence, and sometimes the amount, of radiation.

Dose: A general term denoting the quantity of radiation or radiant energy absorbed. For special purposes it must be appropriately qualified. If unqualified, it refers to absorbed dose.

> Absorbed Dose: The energy imparted to matter by ionizing radiation per unit mass of irradiated material. The unit of radiation absorbed dose is the rad. One rad equals 100 ergs or energy per gram of matter.

Cumulative Dose (Radiation): The total dose resulting from repeated exposures to radiation.

Dose Equivalent (DE): A quantity frequently used in radiation protection. It expresses all radiation on a common scale for calculating the effective absorbed dose. It is defined as the product of the absorbed dose in rads and certain modifying factors. (The unit of dose equivalent is the rem.)

Maximum Permissible Dose Equivalent (MPD): The greatest dose equivalent that a person or specified body part shall be allowed to receive in a given period of time.

Dose, Fractionation: A method of administering radiation, in which a single dose of radiation is divided into a number of smaller portions that are then dispensed with a pause of time between each portion..

Dose, Protraction: A method of administering radiation by delivering it continuously over a relatively long period at a reduced dose rate.

Dosimeter: Instrument to detect and measure accumulated radiation dose. See Film Badge and TLD.

Electron: A stable elementary particle having an electric charge equal to +/- 1.60210 x 10^{-19} coulomb and a rest mass equal to 9.1091 x 10^{-31} kg.

> Secondary Electron: An electron ejected from an atom, molecule, or surface as a result of an interaction with a charged particle or photon.
>
> Valence Electron: Electron that is gained, lost, or shared in a chemical reaction.

Electron Volt: A unit of energy equivalent to the energy gained by an electron in passing through a potential difference of one volt. Larger multiple units of the electron volt are frequently used: keV for one thousand (or kilo) electron volts; MeV for one million (or mega) electron volts. (Abbreviated: eV, 1 eV = 1.6 x 10^{-12} erg.)

Exposure: A measure of the ionization produced in air by x or gamma radiation. It is the sum of the electrical charges on all ions of one sign produced in air when all electrons liberated by photons in a volume of air are completely stopped in air, divided by the mass of the air in the volume. The special unit of radiation exposure is the roentgen (R).

> Acute Exposure: Radiation exposure of short duration.
>
> Chronic Exposure: Radiation exposure of long duration by fractionation or protraction. (See Dose, Fractionation and Dose, Protraction.)

Film Badge: A pack of photographic film which measures radiation exposure for personnel monitoring. The badge may contain two or three films of differing sensitivity and filters to shield parts of the film from certain types of radiation.

Fissile: A nuclide capable of undergoing fission by interaction with slow neutrons.

Fission, Nuclear: A nuclear transformation characterized by the splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy in the form of heat and nuclear radiations.

Gamma Ray: Short wavelength electromagnetic radiation (range of energy from 10 keV to 9 MeV) emitted from the nucleus of an atom during radioactive decay.

Gas Amplification: As applied to gas ionization radiation detecting instruments, the ratio of the charge collected to the charge produced by the initial ionizing event.

Geiger Region: In an ionization radiation detector, the operating voltage interval in which the charge collected per ionizing event is essentially independent of the number of primary ions produced in the initial ionizing event.

Geiger Threshold: The lowest voltage applied to a counter tube for which the number of pulses produced in the counter tube is essentially the same, regardless of a limited voltage increase.

Half-Life, Biological: The time required for the body to eliminate one-half of an administered dosage of any substance by regular biological processes of elimination. It is approximately the same for both stable and radioactive isotopes of a particular element.

Half-Life, Effective: Time required for a radioactive element deposited in a human or animal to be diminished by 50 percent as a result of the combined action of radioactive decay and biological elimination.

Effective half-life =

$$\frac{\text{Biological half-life x Radioactive half-life}}{\text{Biological half-life + Radioactive half-life}}$$

Half-Life, Radioactive: Time required for a radioactive substance to lose 50 percent of its radioactivity by decay. Each radionuclide has a unique half-life.

Half Value Layer (Half Thickness) (HVL):
The thickness of a specified substance which, when introduced into the path of given beam of radiation, reduces the exposure rate by one-half.

Interlock: A device, usually electrical and/or mechanical, to prevent activation of a device until a preliminary condition has been met, or to prevent hazardous operations. Its purpose usually is safety.

Ion: Atomic particle, atom, or chemical radical bearing an electrical charge, either negative or positive.

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

> Specific Ionization: Number of ion pairs per unit length of path of ionizing radiation in a medium; e.g., per cm of air, or per micrometer of tissue.
>
> Total Ionization: The total electric charge of one sign on the ions produced by radiation in the process of losing its kinetic energy. For a given gas, the total ionization is closely proportional to the initial ionization and is nearly independent of the nature of the ionizing radiation. It is frequently used as a measure of radiation energy.

Ion Pair: Two particles of opposite charge, usually referring to the electron and positively charged atomic or molecular residue resulting from the interaction of ionizing radiation with the orbital electrons of atoms.

Irradiation: Exposure to radiation.

Isotopes: Nuclides having the same number of protons in their nuclei, and hence the same atomic number, but differing in the number of neutrons, and therefore differing in the mass number. Almost identical chemical properties exist between isotopes of a particular element.

Kerma: The sum of the initial kinetic energies of all charged particles liberated by indirectly ionizing particles in a volume, divided by the mass of matter in that volume.

Linear Energy Transfer (LET): The amount of energy transferred to matter as radiation interacts with it. Often expressed in units of keV per micron of path length.

Monitoring: Periodic or continuous determination of the amount of ionizing radiation or radioactive contamination present in an occupied region.

> Area Monitoring: Routine monitoring of the radiation level or contamination in a particular area, building, room, or piece of equipment. Some laboratories or operations distinguish between routine monitoring and survey activities.
>
> Personnel Monitoring: Monitoring of any part of an individual, his breath or excretions, or any part of his clothing.

Photon: A quantity of electromagnetic energy (E) whose value in joules is the product of its frequency (ν) in hertz and Planck's constant (h). The equation is $E = h\nu$.

Proton: Elementary nuclear particle with a positive electric charge equal numerically to the charge of the electron and a mass of 1.007277 mass units.

Quality Factor (QF): The linear-energy-transfer-dependent factor by which absorbed doses are multiplied to obtain (for radiation protection purposes) a quantity that expresses (on a common scale for all ionizing radiations) the effectiveness of the absorbed dose of radiation.

Rad: The unit of absorbed dose in rads is equal to 0.01 J/kg in any medium. (See Absorbed Dose.)

Radiation or Ionizing Radiation: Gamma rays and x-rays, alpha and beta particles, neutrons, protons, high-speed electrons and other nuclear particles, but not visible light, sound, radio waves, laser radiation, or microwaves.

Radiation-Producing Machine: Any device capable of producing radiation when the associated control devices are operated or electrical circuits are energized.

Radioactive Material: Any material which emits radiation spontaneously.

Rem: A special unit of radiation dose equivalent. The dose equivalent in rems is numerically equal to the absorbed dose in rads multiplied by the quality factor QF.

Roentgen (R): The unit of radiation exposure. One roentgen equals 2.58×10^{-4} coulomb per kilogram or air. (See Exposure.)

Scattering: Change of direction of subatomic particles or photons as a result of a collision or interaction.

Sealed Source: Any radioactive material permanently encapsulated in such a manner that it will not be released under the most severe conditions likely to be encountered in normal use. This encapsulation must meet rigid specifications.

Special Nuclear Material (SNM): Plutonium or Uranium-235, or material enriched in U-233, U-235, or Plutonium.

Source Material: Uranium or Thorium, or any combination thereof, in any physical or chemical form except SNM, and ores which contain less than one-twentieth of one percent (0.05%) of Uranium or Thorium.

TLD (Thermoluminescent Dosimeter): A crystalline material (e.g., lithium fluoride) which is used to measure accumulated radiation dose. When exposed to radiation at ambient temperatures, electrons migrate to crystal lattice defects. When heated, the crystal releases this energy as light which can be detected by a photomultiplier tube and correlated to the amount of radiation dose received.

X-Rays: Penetrating electromagnetic radiation whose wavelengths are shorter than those of visible light and ultraviolet radiation. X-rays are usually produced by bombarding a metallic target with fast electrons in a high vacuum. In nuclear reactions, it is customary to refer to photons originating in the nucleus as gamma rays, and those originating in the extra-nuclear part of the atom as x-rays. These rays are sometimes called roentgen rays after their discoverer, W.C. Roentgen.

SECTION 2: RESPONSIBILITIES

It is the policy of the University to maintain an environment for its students, faculty, staff, and visitors that will neither adversely affect their health and safety nor expose them to avoidable risk of injury, insofar as is reasonably achievable.

The purpose of the Irvine Campus Radiation Safety Manual is to set forth the UC Irvine Chancellor's policy, organization, operating procedures and standards of conduct for the Irvine Campus radiation safety program, and to guide individuals using or having responsibility for the use of radiation in complying with University policy, conditions stipulated in the University's licenses, applicable regulations of governmental agencies, and national radiation protection standards.

The applicable Federal and State statutes and regulations are incorporated by this reference as part of the UC Irvine Radiation Safety Manual.

Each Responsible Principal Investigator (RPI) who is authorized to use radioactive material or a radiation-producing machine will be notified as to where a copy of the Radiation Safety Manual is available.

All persons using radioactive materials or radiation-producing machines are required to be familiar with all of the provisions included in the UC Irvine Radiation Safety Manual.

A. CHANCELLOR

The Chancellor is responsible for implementation of the University's radiation safety policies and for establishing supplementary campus policies and standards. He/she has delegated his/her responsibilities to the campus committees, departments and individuals, as delineated in the following sections of the Manual.

B. CAMPUS RADIATION SAFETY COMMITTEE (RSC)

The Campus RSC reports to the Vice Chancellor for the Division of Finance and Administration and the Vice Chancellor of Research on all matters related to radiation safety and recommends such policies and procedures it deems appropriate to ensure an adequate radiation safety program. It is responsible for reviewing and approving all proposed uses of radiation and radioisotopes, and for advising and guiding the Environmental Health and Safety (EH&S) Office in carrying out the campus radiation safety program.

The Chair of the RSC shall be a member of the Academic senate. The Chair may appoint subcommittees to perform other duties as directed. Technical support members serve

continuously, ex-officio with vote. These include the campus RSO, medical center RSO, the Reactor Facility Supervisor, and a buyer of radioactive Materials.

At least one member of the RSC must approve each "Radiation Use Authorization" (RUA), thus providing assurance that the work proposed has been reviewed in such a manner as to ensure compliance with the related requirements. The RSC has the authority to suspend or revoke an RUA and direct the Radiation Safety Officer (RSO) to impound radioactive materials or stop the use of radiation-producing machines for violations of any of the provisions of the program.

C. INSTITUTIONAL REVIEW BOARD (IRB)

The IRB reports to the Vice Chancellor for Research on all matters regarding the welfare of human research subjects and is responsible for reviewing all applications for human subjects use involving radioactive materials or radiation-producing machines on campus (except diagnostic x-rays at the Student Health Center). The IRB and UC Irvine Medical Center RSC must both approve all uses of human research subjects prior to the administration of any radiation source to the subjects. Either committee has the authority to suspend or revoke their authorization.

D. UC IRVINE MEDICAL CENTER RADIATION/ISOTOPE SAFETY COMMITTEE

The UC Irvine Medical Center in the City of Orange has a separate license issued by the California Department of Public Health. Any use of radioactive materials or radiation-producing devices at UC Irvine Medical Center must be approved by the Medical Center Radiation Safety Committee, which reports as a Medical Staff Committee. An RUA issued by the UC Irvine Medical Center RSC is not valid for use on main campus, and an RUA issued by the campus RSC is not valid for uses at the Medical Center.

Any transfers of radioactive materials or radiation-producing devices between UC Irvine Medical Center and the campus must be approved by both the campus RSO and the Medical Center RSO prior to the transfer.

The UC Irvine Medical Center RSC reviews new and revised protocols and RUAs for medical uses of radioactive materials on campus if new and/or revised patient doses are proposed, only if they are not considered "standard of care".

E. REACTOR OPERATIONS COMMITTEE (ROC)

The ROC reports to the Executive Vice Chancellor and is responsible for review of all matters relating to the use of the UC Irvine Nuclear Reactor Facility in Rowland Hall. All users must comply with the Facility's Standard Operating Procedures Manual, the Facility's Nuclear Reactor License, and all applicable federal regulations and campus policies. The Reactor Supervisor is a member, ex-officio, of the ROC and the RSC.

F. INSTITUTIONAL BIOSAFETY COMMITTEE (IBC)/BIOSAFETY OFFICER

The IBC reports to the Vice Chancellor for Research, and is responsible for review of all work with infectious agents, carcinogens and recombinant DNA, including those labeled with radioactive materials, to assure compliance with applicable codes and standards. The campus Biosafety Officer in the EH&S Office or the Chair of the IBC must be notified to evaluate projects involving radioactive materials with infectious agents, carcinogens, and/or recombinant DNA.

G. INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE (IACUC)

The IACUC is a faculty committee responsible for reviewing all animal use protocols, ensuring compliance with federal regulations, inspecting animal facilities and laboratories, and overseeing training and educational programs. The primary role of IACUC is to ensure the ethical and humane care and use of animals in research, testing and teaching.

H. RADIOACTIVE DRUG RESEARCH COMMITTEE (RDRC)

The RDRC is constituted under the FDA to approve the use of experimental radioactive drugs in humans for specific types of basic research. The committee reports to the FDA on quarterly and annual bases.

I. ENVIRONMENTAL HEALTH AND SAFETY (EH&S) OFFICE

The EH&S Office is responsible for surveillance of all uses of radioactive materials and radiation-producing machines and providing consultation and radiation safety services in conformance with policies and standards set forth in this Manual, government regulations, license conditions, and national radiation protection standards and recommendations.

Director, Environmental Health & Safety

The Executive Director of Environmental Health & Safety is responsible for reviewing campus performance regarding policies and procedures on radiation safety, and assuring that the university administration is adequately informed of its responsibilities on matters related to radiation safety.

Manager, Radiation Safety Division/Radiation Safety Officer

The Manager of the Radiation Safety Division, designated as the campus Radiation Safety Officer (RSO), is responsible for administering the operation of the radiation safety program; for assuring that use of radiation is in conformance with University and campus policies and with applicable governmental regulations; and for referring to the Radiation Safety Committee matters requiring its review and approval.

The RSO is a member, ex-officio, of the Radiation Safety Committee, the UCIMC Radiation Safety Committee, the Radioactive Drug Research Committee, and the Reactor Operations Committee. The RSO has the authority to immediately terminate any operation involving the use of radiation which in his or her judgment presents a significant hazard to the health and safety of UC Irvine students, staff, faculty, visitors, or the general population.

J. DEANS, DEPARTMENT CHAIRS AND ADMINISTRATIVE OFFICERS

Deans, Department Chairs and Administrative Officers are responsible for review and approval of proposed uses of radioisotopes and radiation-producing machines within their jurisdiction. Such approval signifies that the department will provide the resources necessary to control hazards and will assist in the enforcement of pertinent campus and governmental standards and regulations. Each department shall possess radiation survey instruments capable of detecting the types of radiation which are used in that department. These instruments shall be continuously available for routine monitoring and emergency uses, and shall be calibrated/operationally checked on a routine basis.

K. RESPONSIBLE PRINCIPAL INVESTIGATOR (RPI)

The RPI is personally responsible for compliance with campus and governmental regulations as they pertain to his/her authorized use of radioactive materials or radiation-producing machines. Specific responsibilities include, but are not limited to:

1. Ensuring that only work authorized by the approved RUA is carried out.

2. Ensuring that operations involving radioactive materials or radiation-producing machines are performed only by personnel who have been properly instructed and authorized for such work.

3. Ensuring that adequate instruction in proper procedures for control of radiation hazards has been given to all personnel under his/her supervision, and assuring that radiation exposures are reduced to levels as low as reasonably achievable (ALARA).

4. Maintaining records to document:

    a. An inventory containing accurate quantities of all radionuclides in possession.

    b. Monitoring of laboratories and other work places to check for radiation and contamination levels.

    c. Calibration of survey instruments used for monitoring.

    d. Waste disposal of radioactive materials.

e. Any transfers of isotopes between segregated work places.

5. Making records (listed in # 4 above) available for inspection by the EH&S Office and authorized government agencies.

6. Notifying personnel under his/her supervision of radiation dose data as provided by EH&S.

7. Posting any required hazard warning signs, including signs/labels on radioisotope containers, storage locations and use areas.

8. Providing materials and equipment required by the RUA and enforcing the use of these items (including protective clothing, personnel dosimeters, survey instruments, etc.) by personnel involved in work under his/her supervision.

9. Conducting periodic surveys of authorized work places to assure compliance with RUA guidelines and general safety requirements.

10. Notifying the EH&S Office immediately in cases of personnel contamination or excessive radiation exposure, accidents or other unusual events that result in contamination of work areas or releases of radioisotopes or radiation beyond the confines of the authorized work areas.

11. Notify the Radiation Safety Office when taking a sabbatical or other extended leave of absence. Designate a responsible individual to act for the Principal Investigator throughout the duration of the leave.

L. <u>USERS</u>

All radioactive material users are required to comply with the following:

1. Complete Radiation Safety Part I training as soon as possible, and prior to any use of radioactive materials. Complete on-the-job training prior to working with radioactive material unsupervised.

2. Wear protective clothing and impermeable gloves when working with unsealed sources.

3. Use secondary containment that will hold the contents in the event of spills or breakage of containers during storage or transport between laboratory areas and common hallways.

4. Line working surfaces with absorbent paper.

5. Store liquid form of radioactive materials in sealed containers.

6. Properly label all containers, storage, and use areas.

7. Properly shield high-energy beta and gamma emitters.

8. Use remote handling tools, when appropriate, to minimize extremity exposures.

9. Proper use and storage of assigned dosimetry and their timely return.

10. Work with radioactive materials in accordance with radiation safety operating and emergency procedures.

11. Monitor work areas, hands, and clothing whenever there is a possibility of contamination and after each day of use.

12. Clean up spills promptly in accordance with this Manual.

13. Do not eat, drink, smoke, store food, or apply cosmetics in areas where radioactive materials are used.

14. Do not pipette by mouth.

15. Avoid working in a radiologically controlled area if you recently received a nuclear medicine diagnostic or therapeutic procedure.

SECTION 3: LICENSING REQUIREMENTS

A. UNIVERSITY LICENSES

The UC Irvine campus has a broad-scope research and development license issued by the California Department of Public Health (DPH), and a nuclear reactor facility license issued by the United States Nuclear Regulatory Commission (NRC). The campus may have one or more additional specific purpose licenses issued by the NRC or other states for operations outside of the State of California.

Copies of licenses applicable to the Irvine campus are available for review at the Environmental Health and Safety Office (EH&S). The licenses describe the campus possession limits for each radionuclide and the approved locations for use, and provide for internal campus authorization procedures.

Any requests for amendments to the campus licenses must be approved by the Radiation Safety Officer (RSO), subject to Radiation Safety Committee (RSC), Institutional Review Board (IRB), Radioactive Drug Research Committee (RDRC), and/or Reactor Operations Committee (ROC) review, as appropriate.

B. EXEMPTIONS

Any person is exempt from the licensing provisions of this manual to the extent that such person receives, possesses, uses, or transfers:

1. Any unprocessed naturally-occurring radioactive material (NORM) in a concentration which occurs naturally.

2. Any material containing up to 0.25 percent by weight of natural or depleted uranium or natural thorium.

3. Consumer products, provided they have been manufactured and distributed in accordance with applicable federal and state regulations, that are used for the purposes intended by the manufacturer.

C. CAMPUS AUTHORIZATION PROCEDURES

1. Research Authorization Procedures

Each Responsible Principal Investigator (RPI) must apply for a Radiation Use Authorization (RUA) by completing an application form and a Statement of Training and Experience and submitting them to EH&S. The RSO or designee then conducts a detailed health physics evaluation of the proposed project. This

evaluation usually includes an interview with the applicant and a visit to the proposed use locations to evaluate the factors outlined below.

a. Training and experience of all personnel who will be involved in the project.

(1) The RPI must have a college degree or the equivalent in the physical or biological sciences or engineering and at least 20 hours of practical experience in the safe handling of radioactive materials, and a thorough understanding of the characteristics of ionizing radiation, radiation dose quantities and limits, radiation detection instrumentation, and biological hazards of exposure to radiation appropriate to the types and forms of radiation to be used.

(2) All personnel associated with the project must demonstrate their familiarity with campus radiation protection requirements and procedures. This is usually accomplished by taking a radiation safety course.

b. The radionuclides, quantities, and chemical and physical forms of each of the radionuclides to be used.

c. The protocol for experiments, including descriptions of laboratory procedures to be used.

d. The adequacy of all locations for the proposed use with respect to:

(1) Storage facilities and use areas.

(2) Hoods, glove boxes, and other special equipment.

(3) Housing and maintenance of experimental animals, if used.

(4) Impact of radioactive materials use on surrounding areas.

(5) Housekeeping and guidelines for clean areas.

e. A thorough knowledge and understanding of the proper procedures for radioactive materials control and personnel protection measures to be used, including:

(1) Inventory records for receipts, use, transfers, and disposals.

(2) Radioactive waste segregation and disposal procedures.

(3) Monitoring methods, frequency, and records.

(4) Survey instrumentation, calibration procedures, and records.

(5) Access control, posting, and labeling procedures.

(6) Shielding and/or remote handling techniques.

(7) Radioactive contamination control procedures.

(8) Provisions for controlling releases of radioactive materials to the environment.

(9) Personnel dosimetry and bioassay procedures.

(10) Methods of assuring that all external and internal radiation exposures, and all releases of radioactive materials to the environment, are reduced to as low as reasonably achievable (ALARA).

2. Classroom Authorization Procedures

A separate RUA is required for radiation uses in academic courses. These RUAs are usually valid for one academic quarter, but they may be issued for a longer time period to permit storage of radioactive materials between courses. An application for an RUA must be submitted to EH&S for review and approval by the RSC prior to the commencement of the quarter in which radioactive materials will be used.

The following additional information is required to supplement the standard application for an RUA:

a. Course number, names of course instructors and teaching assistants.

b. Training and experience forms for instructors and teaching assistants.

c. Duration of course (i.e., 1 quarter, 1 year).

d. Number of students anticipated (names to be submitted when they are available).

e. Number of laboratory sections, number of students per section, and number of students per teaching assistant (as the hazard potential dictates, the Radiation Safety Committee may require that this ratio be decreased).

f. Number and type of monitoring instruments available in the laboratory for routine use.

g. Description of lab procedures and safety protocols, including:

(1) Health and safety instructions for students.

(2) Radioactive waste disposal procedures for students.

(3) Extent to which students will actually be handling radioisotopes.

3. Radiation Safety Committee Review

The RUA and supporting documents are submitted to the RSC for approval as required. The Hazard Category as determined in Section I of this chapter will determine the level of review required by the RSC. The Hazard Categories and RUA review criteria are:

HAZARD CATEGORY	***MINIMUM DEGREE OF RUA REVIEW BY RSC****	
	ORIGINAL RUA	RENEWALS/AMENDMENTS
I	RSO	RSO[#]
II	RSO + 1 Member	RSO[#]
III	Quorum of Members	RSO + 1 Member
IV	Quorum of Members[$]	Quorum of Members

Notes:

[*] Any member of the RSC may request a higher degree of RSC review for a specific RUA.

[#] Amendments in Hazard Categories I and II may also be approved by an EH&S health physicist, provided that the RUA is for non-human use and the Hazard Category is not increased.

[$] Experiments in Hazard Category IV may require an amendment to the UC Irvine Radioactive Materials License in addition to approval by the RSC.

4. Period of RUA Issuance

All RUAs will be reviewed and renewed every three years.

5. Radiation Protection Surveys

The frequency of routine radiation protection surveys conducted by the Office of Environmental Health and Safety will be determined by the following table:

HAZARD CATEGORY	***RADIATION PROTECTION SURVEY SCHEDULE*** SCHEDULE A	SCHEDULE B
I	Semiannual	Semiannual
II	Quarterly	Semiannual
III	Monthly	Quarterly
IV	Weekly	Monthly

Where, at the discretion of the RSO,

a. In laboratories containing any unsealed sources of radioactive materials:

(1) Schedule A applies for all new RUAs, and for renewal RUAs that involve substantial and routine uses of radionuclides.

(2) Schedule B applies for renewal RUAs that involve only occasional uses or long-term storage of radionuclides.

b. In laboratories containing only sealed sources of radioactive materials, survey frequencies will be established to meet the requirements for performing sealed source leak tests.

c. Survey frequencies may be temporarily increased, as appropriate, for RUAs with a recent history of significant noncompliance with radiation safety requirements.

6. User Surveys

Routine user surveys are required in research and teaching laboratories to detect excessive radiation and/or contamination levels in order to alert laboratory personnel to potential hazards.

All laboratories are required to have access to radiation detection equipment capable of assessing ambient radiation levels and/or radioactive contamination levels of the radioisotopes to be used, as appropriate.

User surveys are required according to the minimum frequencies specified in the following table (facility designations are defined in table I of this chapter):

TYPE OF FACILITY	***MINIMUM USER SURVEY SCHEDULE*** GENERAL USE	STORAGE ONLY
Nominal Activity	Not Required	Not Required
Low Activity	Monthly	Quarterly
Medium Activity	Weekly*	Monthly
High Activity	Daily*	Weekly*

*Most likely performed by EH&S under an agreement.

Periods of non-usage must be noted in the user survey records whenever the "storage only" frequencies are used.

Laboratories that have RAM in deep storage are exempt from all survey requirements. Deep storage is defined as RAM that is not intended for use in the immediate future and is stored for an extended period of time for future work. The RAM must be double contained and labeled as "Deep Storage."

7. Notification of Authorizations

A copy of the approved RUA is distributed to the RPI. No work may be conducted until the approval process has been completed.

8. Amendment of Authorizations

Any changes to, or modifications of, an existing RUA must be reviewed and approved as an amendment to the RUA prior to their implementation. Amendment requests must be submitted in writing.

a. Requests for minor amendments which do not add new radionuclides or cause an increase in the Hazard Category may be granted temporary telephone approval in order to provide for the continuity of research and/or teaching programs, followed up by the issuance of an e-mail or written amendment.

b. Requests for significant amendments may require approval by the RSC, depending upon its nature and complexity, in accordance with the procedures in this Manual.

c. After review and approval, an amended RUA will be issued.

D. PROCEDURES FOR RENEWAL OF AUTHORIZATIONS

1. General Procedures

a. A renewal for an RUA will usually be approved, provided that:

(1) All radiation safety requirements have been satisfactorily complied with in past operations.

(2) The RUA is amended to incorporate any changes in personnel, locations, procedures, radioisotopes, chemical and physical forms, acquisition limits, and precautions required.

b. Renewal procedures will be initiated by the Environmental Health and Safety Office prior to the expiration date of the RUA.

c. If RSC approval is granted, a notification is sent to the RPI. If RSC approval is not granted, the RUA is terminated according to procedures in Section E below.

2. Health Physics Reviews

As part of the renewal process, an EH&S health physicist reviews the total uses of radiation for each RPI. This review includes:

a. The results of all recent radiation protection surveys.

b. The occurrence of any major incidents, such as radioactive spills or excessive exposures.

c. A personal interview with the RPI, or designated representative, which will cover:

(1) The scope of the current authorized uses of radiation and radioactive materials, and prospective future uses.

(2) The use of radioisotopes in human or laboratory animal research, or in clinical studies.

(3) The authorized personnel working in the program.

(4) The training and experience of all radiation workers, including completion of EH&S trainings and on-the-job training in the specific radiation safety and laboratory procedures to be used in the research.

(5) The personnel monitoring and bioassay monitoring program and results.

(6) The radiation monitoring instrumentation used in the research group.

(7) All radiation and contamination control methods utilized to keep exposures and releases ALARA.

(8) The disposal of all radioactive waste.

d. An evaluation of the separation of radioisotope and non-radioisotope work areas.

e. An inspection of the work areas and work practices under the supervision of the RPI, which will include:

(1) The access control, posting, and labeling of all rooms, interior zones, and storage enclosures containing a source of radiation.

(2) The radiation and contamination control procedures, equipment and facilities in use, and radioactive waste disposal techniques.

(3) The records of radioisotope acquisitions, transfers, and disposals.

(4) The records of radiation protection monitoring conducted by the research group.

The health physicist prepares a report of the findings and any corrective actions to be implemented by the RPI. The report is reviewed by the RSO prior to distribution. It is placed in the RUA file of the RPI and is reviewed by the RSC during the renewal process.

E. TERMINATION PROCEDURES FOR AUTHORIZATIONS

1. In the event that any RPI (or a person working under the supervision of the RPI) is found to be willfully and/or negligently violating any of the federal, state, University, or campus regulations governing the use of radioactive materials and/or radiation producing machines, any or all RUAs under that RPI may be suspended or

revoked by the RSO, with the concurrence of the RSC, and any radioactive materials in his/her possession may be impounded.

2. An RUA will ordinarily be terminated by EH&S upon:

   a. Notification that a project has been completed and that no sources of radiation are to be retained by the authorized users, or

   b. Expiration, if no request for renewal is pending.

3. Upon termination of the RUA, an accounting of all radioisotopes or radiation producing machines acquired thereunder must be reported to the RSO. All remaining radioactive materials must be transferred to another active RUA that is authorized for the radionuclides and their quantities, or to EH&S for disposal.

4. EH&S shall be notified of the termination of projects using radioisotopes in sufficient time to permit scheduling of the final monitoring of radiation use areas, accounting of radioisotope inventory, and satisfaction of requirements for personnel monitoring.

F. SHIELDING AND EXPOSURE CONTROL REQUIREMENTS

1. Requirements for shielding and/or remote handling devices will depend upon the external radiation levels of the specific radioisotopes and the amounts to be handled. Specific requirements will be established by the RSO or RSC.

2. In Restricted Areas:

   a. Experimental setups and storage operations should be designed so that the dose rates in laboratories measured at 30 centimeters from any unshielded source or shielded enclosure are very low. Suggested design guidelines are maximum dose rates of:

      (1) 0.2 millirem per hour deep dose equivalent rate.

      (2) 0.5 millirem per hour lens dose equivalent rate.

      (3) 2.0 millirems per hour shallow dose equivalent rate.

   b. Whenever dose rates in controlled areas are expected to be significantly above the design guidelines on a routine basis, remote area monitors, with alarms, will be installed to measure gamma and/or neutron dose rates, as appropriate.

3. In Unrestricted Areas

. Deep, lens, and shallow dose equivalent rates at 5 centimeters from the boundaries of any adjacent restricted area should be below 2 millirems in any one hour. In addition, the total effective dose equivalent (TEDE) to any member of the public should be below 100 millirems in any year.

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G. FACILITY AND CONTAINMENT REQUIREMENTS

Requirements for facilities and specific containment equipment for work with unsealed radionuclides will depend upon the specific radionuclides and amounts to be handled, as well as the procedures to be utilized.

The minimum specific facility and containment specifications are listed in Table 1.

H. DESIGN FEATURES OF RADIOISOTOPE LABORATORIES

The following guidelines establish general design features for radioisotope laboratories:

1. Nominal Activity Laboratories

Nominal activity laboratories are campus laboratories that usually contain only very small quantities of radioactive materials. Examples of these are counting rooms, and some cold rooms and tissue culture labs.

2. Low Activity Laboratories

Low activity laboratories are normal campus laboratories with impervious bench tops and floors which meet standard chemical laboratory requirements concerning items such as dilution ventilation, fume hood design, earthquake safety, emergency showers, emergency exits, fire extinguishers, and security.

3. Medium Activity Laboratories

In addition to the design features usually found in normal campus laboratories, the RSC may require medium activity laboratories to have some or all of the following:

a. Clothing change areas with lockers.

b. Restricted access to, and use of, the area. All work must involve radioactive materials - no desk space, clean areas, or other "dual" use of the area will be permitted.

c. HEPA filters and/or other suitable filters or traps in the exhaust ventilation with progressive stages of lower negative pressure from the exterior to non-radioisotope areas to radioisotope work areas.

d. Impervious floors with one piece construction and coved corners to facilitate decontamination.

e. Radioisotope fume hoods and glove boxes of appropriate design and construction.

f. Continuous external radiation and/or exhaust duct monitoring systems with alarms.

g. Where appropriate, continuous general room air monitoring systems with alarms.

h. Automatic fire suppression equipment.

i. Additional administrative controls, as approved by the RSC, such as protective clothing (e.g., shoe covers, one piece coveralls, etc.), more frequent monitoring, air sampling, and exit or portal contamination monitors.

4. High Activity Laboratories

High activity laboratories are those using extremely high levels of radioactivity and may require some or all of the following additional design features:

a. Clothing change areas with lockers and showers.

b. Remote handling equipment such as caves or shielded hot cells with manipulators or robot arms.

c. High level, shielded, waste collection facilities.

d. Glove boxes with additional HEPA filters and/or other suitable filters or traps in series with the filtration in the general exhaust ventilation.

e. Sophisticated access control provisions, including security systems with alarms.

f. Continuous sewer effluent monitoring systems with alarms.

g. Additional radiation safety features and administrative controls, as may be required by the RSC.

I. PROCEDURES FOR DETERMINATION OF HAZARD CATEGORIES

The individual Procedure Hazard Guide Value (HGV) must be determined for each radionuclide, form, and operation for all gases, and for all liquids and solids if the quantities to be used are equal to or greater than the quantities listed in Table 2. This table lists quantities of commonly used radionuclides as liquids or solids which are in Hazard Category II (e.g., the Procedure HGVs are equal to 100). Lower quantities are in Hazard Category I.

Table 3 lists the minimum quantities of commonly used radionuclides which must be used in low activity laboratories (e.g. the Procedure HGVs are equal to 1). Lower quantities may be used in nominal activity laboratories.

1. Calculation of Procedure HGV

HGVs are calculated using the criteria of the HGV Worksheet with:

a. Use Factors (U), Special Hazard Factors (S) and Containment Factors (C) prescribed by Tables 4 and 5.

b. Toxicity Factors (T) equal to the Annual Limits of Intake (ALI), in µCi, for inhalation (for potential airborne hazards) or oral ingestion (for no potential airborne hazards), rounded to one significant figure with the first digit either 1, 2 or 5.

The Procedure HGV, rounded to one significant figure, is calculated by the following equation:

$$HGV = \frac{Q \times U \times S \times C}{T}$$

where Q is the quantity (µCi) in use for a specific procedure.

2. Hazard Categories

The Hazard Category for the RUA will be based on the highest individual procedure HGV calculated on the HGV Worksheet, as described by the following criteria:

HAZARD CATEGORY	MAXIMUM INDIVIDUAL PROCEDURE HGV
I	0 to <100
II	100 to <10,000
III	10,000 to <1,000,000
IV	1,000,000 or more

The RSO may assign a higher hazard category to any RUA if the RPI has a history of noncompliance with radiation safety requirements and procedures.

TABLE 1: FACILITY AND CONTAINMENT SPECIFICATIONS

TYPE OF LABORATORY	PROCEDURE HAZARD GUIDE VALUE (HGV)	CONTAINMENT REQUIREMENTS FOR POTENTIAL AIRBORNE HAZARDS	CONTAINMENT REQUIREMENTS FOR NO POTENTIAL AIRBORNE HAZARDS
Nominal Activity[1]	0 to <1	Open Bench	Open Bench
Low Activity[1,2]	1 to <100	Open Bench	Open Bench
	100 to <10,000	Fume Hood	Open Bench
Medium Activity[3]	10,000 to <1,000,000	Fume Hood	Fume Hood
	1,000,000 to <100,000,000	Glove Box	Fume Hood
High Activity[4]	100,000,000 or more	Glove Box	Glove Box

Notes:

[1] Exemptions from specific requirements may be approved by the RSO, as necessary and appropriate, when the HGV is <100.

[2] With appropriate dilution ventilation and proper airflow across the face of fume hoods.

[3] With HEPA or other suitable filter or trap, and continuous duct air monitor, with alarm, in exhaust.

[4] With two HEPA and/or other suitable filters or traps, in series, and continuous duct air monitor, with alarm, in exhaust; continuous general room air monitor, with alarm, in work area; and continuous effluent monitor, with alarm, in sewer line.

TABLE 2:
MINIMUM QUANTITIES OF RADIOACTIVE MATERIALS REQUIRING HAZARD CATEGORY OF II AND CALCULATION OF HAZARD GUIDE VALUES IN ORDER TO DETERMINE CONTAINMENT CRITERIA FOR RADIONUCLIDES AS LIQUIDS OR SOLIDS
(e.g., THE PROCEDURE HGV IS 100)

		QUANTITY OF RADIOACTIVE MATERIAL	
		USED FOR LABELING	PURCHASED
NUCLIDES	CHEMICAL FORMS	OR IN ASSAYS	PER ORDER
H-3	Borohydrides	5 mCi	50 mCi
	Nucleotides, water	50 mCi	500 mCi
	All other forms normally used	500 mCi	5 Ci
C-14	Nucleotides	2 mCi	20 mCi
	All other forms normally used	20 mCi	200 mCi
F-18	All forms normally used	500 mCi	5 Ci
Na-22	All forms normally used	2 mCi	20 mCi
P-32	All forms normally used	5 mCi	50 mCi
P-33	All forms normally used	50 mCi	500 mCi
S-35	All forms normally used	100 mCi	1 Ci
Ca-45	All forms normally used	20 mCi	200 mCi
Cr-51	All forms normally used	200 mCi	2 Ci
Mn-54	All forms normally used	20 mCi	200 mCi
Fe-59	All forms normally used	5 mCi	50 mCi
Rb-86	All forms normally used	5 mCi	50 mCi
I-125	Sodium iodide, nucleotides	50 μCi	500 μCi
	All other forms normally used	500 μCi	5 mCi
I-131	Sodium iodide	20 μCi	200 μCi
	All other forms normally used	200 μCi	2 mCi

TABLE 3: MINIMUM QUANTITIES OF RADIOACTIVE MATERIALS REQUIRING WORK IN LOW ACTIVITY LABORATORIES FOR RADIONUCLIDES AS LIQUIDS OR SOLIDS
(e.g., THE PROCEDURE HGV IS 1)

NUCLIDES	CHEMICAL FORMS	QUANTITIES OF RADIOACTIVE MATERIALS USED FOR LABELING OR IN ASSAYS	QUANTITIES OF RADIOACTIVE MATERIALS PURCHASED PER ORDER
H-3	Borohydrides	50 μCi	500 μCi
	Nucleotides, water	500 μCi	5 mCi
	All other forms normally used	5 mCi	50 mCi
C-14	Nucleotides	20 μCi	200 μCi
	All other forms normally used	200 μCi	2 mCi
F-18	All forms normally used	5 mCi	50 mCi
Na-22	All forms normally used	20 μCi	200 μCi
P-32	All forms normally used	50 μCi	500 μCi
P-33	All forms normally used	500 μCi	5 mCi
S-35	All forms normally used	1 mCi	10 mCi
Ca-45	All forms normally used	200 μCi	2 mCi
Cr-51	All forms normally used	2 mCi	20 mCi
Mn-54	All forms normally used	200 μCi	2 μCi
Fe-59	All forms normally used	50 μCi	500 μCi
Rb-86	All forms normally used	50 μCi	500 μCi
I-125	Sodium iodide, nucleotides	500 nCi	5 μCi
	All other forms normally used	5 μCi	50 μCi
I-131	Sodium iodide	200 nCi	2 μCi
	All other forms normally used	2 μCi	20 μCi

TABLE 4: MODIFYING FACTORS FOR OPERATIONS WITH UNSEALED RADIOACTIVE MATERIALS

MODIFYING CONDITIONS	MULTIPLICATION FACTORS
Use Factors	
Gaseous operations, and complex dry operations (e.g., grinding, machining)	100
Simple dry operations (e.g., manipulation of powders), and complex wet operations (e.g., distillation, injection into humans or animals, evaporation)	10
Normal wet operations (e.g., gel separations, thin layer chromatography, centrifuging, routine chemical preparations)	1
Simple wet operations (e.g., dilution of stock solutions, adding aliquots to media, labeling or incubating when the labeled compounds and media are all nonvolatile and non-reactive)	0.1
Storage of unsealed radioactive materials	0.01
Special Hazard Factors	
Reactive compounds capable of generating radioactive gaseous emissions (e.g., H-3 sodium borohydride)	100
Nucleic acid precursors, nucleotides, and nucleosides (labeled with H-3, C-14 or I-125), and skin permeable or volatile compounds (e.g., H-3 water, I-125 sodium iodide)	10
General organic and soluble inorganic compounds	1
Insoluble inorganic compounds (e.g., microspheres)	0.1
Uncompressed tritium or noble gas	0.01
Containment Factors	
Work on open bench or in the field	10
Work in standard or radioisotope fume hood	1
Work in glove box or equivalent enclosed system with suitable filters or traps in exhaust ventilation	0.1

TABLE 5: MODIFYING FACTORS FOR OPERATIONS WITH SEALED (ENCAPSULATED) RADIOACTIVE MATERIALS

MODIFYING CONDITIONS	MULTIPLICATION FACTORS
Use Factors	
Experimental procedures with sealed sources	0.1
Storage of sealed sources in unshielded area	0.01
Operation of Irradiator with internal chamber, and storage of sealed sources in shielded area	0.001
Special Hazard Factors	
Alpha emitters, neutron sources, and gamma or x-ray emitters with maximum photon energy of 0.5 MeV or more	10
Gamma or x-ray emitters with maximum photon energy of less than 0.5 Mev, with no alpha or neutron emissions	1
Beta emitters with no alpha, neutron, gamma or x-ray emissions	0.1
Containment Factors	
Single encapsulation with Mylar® or plastic covering	0.1
Single encapsulation in strong metal container, or double encapsulation in strong metal containers, with one or both containers not welded closed under an inert gas atmosphere	0.01
Double encapsulation in strong metal containers, with both containers welded closed under an inert gas atmosphere	0.001

SECTION 4: ACQUISITION, TRANSFERS AND DISPOSAL

A. ACQUISITION PROCEDURES

Acquisition of all radioisotopes from off-campus, whether by purchase, gift, or loan, must be arranged through the UC Irvine Purchasing Department via a Purchase Requisition Form. Acquisition procedures from other researchers on campus are described in Section B (Transfer Requirements).

Submission of Requisitions

Specific information to be provided includes:

a. Name of radioisotope in standard nomenclature (e.g., H-3, C-14, I-125)

b. Quantity of isotope, in units of radioactivity (e.g., millicurie, microcurie, Becquerel)

c. Chemical and physical form

d. RUA number and name of R.P.I.

Approval of Requisition

On receipt of a requisition for radioisotopes, the Radiation Safety Division will review it and verify that:

a. The R.P.I. has a valid RUA

b. The materials requisitioned are authorized by the RUA

c. The amount of radioactivity is within the limits prescribed by the RUA.

Receiving and Distribution

All radioisotope shipments must be delivered by the supplier to the EH&S Services Facility or to authorized labs on campus where very short half-life isotopes (F-18) are used. These authorized labs are trained to receive RAM and document all required surveys in accordance with pertinent regulations. Radiation safety personnel will sign for the packages and inspect them with respect to the following:

a. Visual inspection of package integrity.

b. Assessment of removable contamination levels of radioisotope on shipping containers. (Permissible levels are 2,200 dpm per 100 cm^2 for beta/gamma emitters, and 220 dpm per 100 cm^2 for alpha emitters).

c. Adequacy of shielding for control of external radiation hazards.

If the radioisotope shipment passes inspection, it is logged into the EH&S inventory records and delivered to an authorized user.

If the shipment does not pass inspection, the user will be contacted and either the user or EH&S may require that the shipment be replaced by the vendor, depending upon the severity of the situation.

Approval must be obtained in advance from the EH&S Office for special handling of shipments that have very short half-lives.

B. TRANSFER REQUIREMENTS

1. Transfers of Radioactive Materials Off-Campus

a. All transfers of radioactive materials off-campus must have specific prior approval by the Campus RSO and the receiving institution's RSO.

b. All shipments must be routed through EH&S to assure compliance with governmental regulations. EH&S will arrange for all packaging and shipping.

2. Transfer of Radioactive Materials between Locations on Campus

a. No radioactive materials may be transferred from one person or laboratory to another unless the recipient has a valid RUA for the radioisotopes and quantities to be transferred.

b. A "Radioactive Material Transfer" form must be completed and sent to EH&S.

C. DISPOSAL REQUIREMENTS

All radioactive waste must be transferred to EH&S for disposal. No radioactive materials are permitted to be discharged into the campus plumbing system or into the air without specific prior approval by the Campus RSO to assure compliance with Federal, State and local restrictions.

Waste containing radioactive materials must be segregated into one of the following categories: 1. Solid; 2. Liquid; 3. Animal; 4. Full Liquid Scintillation Counting (LSC) Vials; 5. Small Volume Liquid Containers; 6. Unusual Forms or Conditions

1. Solid Radioactive Waste

   a. All solid radioactive waste must be placed into plastic-lined boxes authorized and distributed by the EH&S Office. The following information must be recorded onto the container before it will be accepted for disposal by EH&S:

      1) Radioisotope(s) contained (e.g., P-32)
      2) Amount of each radioisotope in millicuries or microcuries
      3) Date
      4) Responsible Principal Investigator's name
      5) Other hazards

   b. To protect personnel from injury, all hypodermic needles must be placed into a puncture-proof container (e.g., plastic snap top or aluminum can) before being placed into the solid waste box for disposal.

   c. No liquids, animal tissue, or active pathological agents are permitted in the solid radioactive waste containers.

2. Liquid Radioactive Waste

   a. All liquid radioactive waste shall be collected in EH&S-approved Nalgene® jugs with tight screw caps. All liquids must be maintained at a pH between 6 and 11 to reduce corrosion of steel drums used for shipment to disposal sites. Aqueous and water soluble materials most be placed in separate containers from non-aqueous materials due to varying disposal site requirements.

   b. All liquid waste containers shall be placed into secondary containers (e.g., plastic dish pans) of sufficient size to contain a spill in case of breakage or leakage. Primary waste containers must not be filled to capacity (space must be allowed for expansion, since waste is transported outdoors).

   c. Each container of liquid radioactive waste must be labeled with a special radioactive caution label (available from EH&S) stating:

      1) Radioisotope(s) (e.g., P-32)
      2) Amount of each radioisotope in millicuries or microcuries
      3) Date
      4) Responsible Principal Investigator's name
      5) Chemical composition

6) Other hazardous agents

d. Because of stringent local restrictions, no liquid radioactive materials are permitted to be discharged into the campus plumbing system.

e. No solid materials or active pathological agents are permitted in liquid waste containers.

f. Short-lived radioisotopes (i.e., half-lives less than or equal to 120 days) should be separated from longer-lived materials.

3. Animal Waste

a. All radioactively-contaminated animal carcasses, tissues, and excreta must be placed into sealed double plastic bags and labeled with the following information.

1) Radioisotope(s) (e.g., H-3)
2) Amount of each radioisotope in millicuries or microcuries)
3) Date
4) Responsible Principal Investigator's name
5) Other hazardous agents (e.g., carcinogenic chemicals)

b. Carcasses containing 0.05 μCi/gram or less of C-14 or H-3 are to be kept separate from all others and be so labeled. All animal waste must be stored frozen, either in the lab or in a specially designated departmental freezer.

d. No animal weighing 10 lbs. or more may have radioisotopes administered without special approval from EH&S. Contact EH&S prior to the administration of any radioactive material to such an animal.

4. Full Liquid Scintillation Counting (LSC) Vials

Full LSC vials must be packaged separately from all other wastes, in EH&S-approved containers and identified as "full LSC vials" with the following additional information:

1) Radioisotope(s) (e.g., H-3)
2) Amount of each radioisotope in millicuries or microcuries)
3) Date
4) Responsible Principal Investigator's name

No other material of any kind is to be included in the containers with LSC vials. Vials containing H-3 and/or C-14 must be segregated from all other radioisotopes in a separate box labeled as H-3/C-14 only.

5. Other Small Liquid Sample Containers (e.g., centrifuge tubes, gamma counter vials)

   Securely-contained small volumes of liquid must be packaged separately from all other types of waste in EH&S-approved containers, identified as "full vials and/or tubes (not LSC)" with the same additional information as required above (i.e., radioisotope(s), amount(s), date, and R.P.I.'s name).

6. Unusual Waste Disposal Forms or Conditions

   In cases where radioactive material cannot be disposed of as outlined above, the EH&S Office should be consulted before the waste is generated. Special procedures may be required by the RSO and/or the RSC.

Waste disposal manifests and associated documentation shall be retained for the life of the RAM license and decay-in-storage records shall be retained for three years following disposal.

SECTION 5: DOSIMETRY

A. ALARA POLICY

The campus has an aggressive policy to prevent unnecessary radiation exposures to personnel and to the environment and to reduce all exposures to as low as reasonably achievable (ALARA), in accordance with the recommendations of the National Council on Radiation Protection and Measurements (NCRP), and all federal and state regulatory requirements.

B. SUPPLEMENTARY DEFINITIONS

1. General Dosimetry

Administrative Guidelines are dose equivalent recommendations which have been adopted by the UC Irvine Radiation Safety Committee for all campus personnel. These guidelines should not be exceeded in routine operations unless justified by the need to conduct specific research experiments and/or treat patients in clinical medicine or medical research.

A **Declared Pregnant Woman** is a woman who, in accordance with federal and state regulations, voluntarily informs the UC Irvine Radiation Safety Officer, in writing, of her pregnancy and the estimated date of conception.

Regulatory Advisories are recommendations of federal and state regulatory agencies.

Regulatory Limits are legal dose equivalent limits in effect that have been adopted by the U.S. Nuclear Regulatory Commission (NRC) and/or the California Department of Public Health (DPH).

2. Combined External and Internal Exposure

Total Effective Dose Equivalent (TEDE) is the sum of the Deep Dose Equivalent from external exposure and the Committed Effective Dose Equivalent from internal exposure.

- **Deep Dose Equivalent (DDE)** is the dose from external exposure due to penetrating gamma, x-ray, and/or neutron radiation (measured by, for example, the heavily shielded area of a TLD body dosimeter).

- **Committed Effective Dose Equivalent (CEDE)** is the weighted sum of the doses from internal exposures to all organs and tissues of the body

over the 50 years after intake from radioactive materials taken into the body (measured by, for example, thyroid counting or urine radiochemistry).

Total Organ Dose Equivalent (TODE) is the sum of the Deep Dose Equivalent to an organ or tissue from external exposure and the Committed Dose Equivalent to that organ or tissue from internal exposure.

- **Deep Dose Equivalent (DDE)** is the dose from external exposure due to penetrating gamma, x-ray and/or neutron radiation to a specific organ or tissue. The DDE, as measured by a body dosimeter, is used to calculate the TODE to an organ or tissue.

- **Committed Dose Equivalent (CDE)** is the dose from internal exposure to a specific organ or tissue of the body over the 50 years after intake from radioactive materials taken into the body. The thyroid gland is the organ or tissue with the highest probability of receiving significant exposures at UC Irvine, due to individuals conducting iodinations with I-125.

Dose Equivalent to the Embryo/Fetus is the total dose equivalent to the embryo/fetus during the entire 9 month gestation period. It is the sum of:

- The Deep Dose Equivalent **to the Declared Pregnant Woman** during pregnancy.

- The dose equivalent to the embryo/fetus from **radionuclides in the embryo/fetus** during pregnancy. It is the actual dose received, not a committed dose to be received over a period of up to 50 years.

- The dose equivalent to the embryo/fetus from **radionuclides in the Declared Pregnant Woman** during pregnancy.

3. <u>External Exposure Only</u>

Lens Dose Equivalent (LDE) for the lens of the eye (measured by, for example, the slightly shielded area of a TLD body dosimeter).

Shallow Dose Equivalent (SDE) for the **Skin** (measured by, for example, the open window area of a TLD body dosimeter) and/or the **Extremities** (measured by, for example, a TLD ring dosimeter).

4. Internal Exposure Only

Annual Limits of Intake (ALI) are quantities of radioactive materials taken into the body by inhalation or oral ingestion resulting in:

- An annual Total Effective Dose Equivalent of 5 rems, called a **stochastic ALI (SALI)**.

- An annual Total Organ Dose Equivalent of 50 rems, called a **nonstochastic ALI (NALI)**.

Derived Air Concentrations (DAC), calculated for each radionuclide, are the airborne concentrations that will lead to an Annual Limit of Intake by inhalation by assuming that a worker breathes air containing those radionuclides at a standard rate over a working year.

5. Biological Effects of Radiation

Stochastic Effects are those where the probability of an adverse health effect occurring, but not its severity, is a function of increasing dose. Examples of stochastic effects are cancer and genetic damage. The limits for TEDE and for the dose to the embryo/fetus are based on stochastic effects.

Nonstochastic Effects are those where the severity of an adverse health effect is a function of increasing dose. Examples of nonstochastic effects are cataract formation and skin erythema. The limits for TODE, LDE and SDE are based on nonstochastic effects.

C. DOSE EQUIVALENT LIMITS AND GUIDELINES

Specific U.S. Nuclear Regulatory Commission (NRC) and California Department of Public Health (DPH) Regulatory Limits and UC Irvine Campus Administrative Guidelines for campus personnel who are exposed to ionizing radiation from radioisotopes and/or radiation-producing machines are:

1. Dose Limits and Guidelines for Adults:

Category of Dose Equivalent	NRC & DPH Regulatory Limits (rems/year)	Campus Administrative Guidelines (rems/year)
Total Effective (TEDE)	5	0.5
Total Organ (TODE)	50	5
Lens (LDE)	15	1.5
Shallow (SDE)		
To the Skin	50	5
To the Extremities	50	5

2. Dose Limits and Guidelines for Minors Under Age 18:

Category of Dose Equivalent	NRC & DPH Regulatory Limits (rems/year)	Campus Administrative Guidelines (rems/year)
Total Effective (TEDE)	0.5	0.1
Total Organ (TODE)	5	1
Lens (LDE)	1.5	0.3
Shallow (SDE)		
To the Skin	5	1
To the Extremities	5	1

3. Dose Limits and Advisories: Embryo/Fetus of a Declared Pregnant Woman:

Category of Dose Equivalent	NRC & DPH Regulatory Limits (rems during pregnancy)	Campus Administrative Guidelines and NRC & DPH Regulatory Advisories (rems/month during pregnancy)
Dose Equivalent to the Embryo/Fetus	0.5	0.05

4. Dose Limits for Members of the General Public:

Category of Dose Equivalent	NRC & DPH Regulatory Limits (rems/year)	Campus Administrative Guidelines and NRC & DPH Regulatory Limits (rems in any one hour)
Total Effective (TEDE)	0.1	--
Deep (DDE), Lens (LDE) or Shallow (SDE)	--	0.002

The TODE applies to all organs and tissues of the body and is usually recorded for the maximally exposed organ (usually the thyroid gland from intake of radioiodine).

TEDE and TODE for the embryo/fetus include external DDE, doses from external exposure of the fetus from radioactive materials in the mother's body and internal exposure of the fetus from radioactive materials which cross the placental barrier.

The campus administrative guidelines are not intended to be absolute limits, but are established in order to provide guidelines for keeping exposures ALARA.

D. EXTERNAL RADIATION DOSIMETRY

1. Federal and State Regulatory Requirements

Federal and State regulations require personnel monitoring for any person who is occupationally exposed to external radiation sources under such conditions that they are likely to receive doses exceeding ten percent of any of the applicable regulatory limits from those sources.

2. UC Irvine Campus Dosimetry Criteria

a. There are few, if any, individuals at UC Irvine who are required to wear dosimeters under the provisions of NRC and/or DPH regulations. However, for campus administrative purposes,

(1) Radiation dosimeters will normally be issued to individuals who have a reasonable likelihood of actually receiving measurable exposures during the monitoring period.

(2) Separate campus procedures will be established for assigning dosimeters to declared pregnant women and to minors under age 18.

(3) Most individuals who do not routinely receive significant exposures will wear a single dosimeter, either a whole body or ring dosimeter, placed at the location likely to receive the highest dose or highest fraction of the applicable dose limit, as appropriate. Declared Pregnant Women working with penetrating radiation capable of delivering a deep dose equivalent, however, will always wear a whole body dosimeter in addition to any other dosimeters.

b. In determining if dosimeters are needed, consideration will be given to:

(1) The amount and type of shielding, and the likelihood of use in an unshielded manner for a significant period of time.

(2) The potential for serious exposure in the event of an accidental failure of any safety device or a violation of an established procedure.

(3) Historical dosimetry data, which may be an important source of information for determining which category should be used for any individual radiation worker, is based on exposures of individuals doing similar experiments in laboratories in separate departments and schools across the campus.

3. Types of Dosimeters for Routine Monitoring

There are two types of dosimeters which can be assigned to individuals for routine monitoring of radiation doses. They are:

a. Thermoluminescent (TLD) body dosimeters, which are used to monitor deep, lens, and shallow dose equivalents to the body, lens of the eye, and skin of the individual. They may be used for monitoring periods of one to four months.

b. Thermoluminescent (TLD) ring dosimeters, which are used to monitor shallow dose equivalents to the extremities (usually the fingers/hands). They may be used for monitoring periods of one to four months.

4. Issuing of Dosimeters

Dosimeters are issued by EH&S. The appropriate types of devices will be assigned according to the exposure conditions likely to be encountered, including the adequacy of shielding for experimental procedures and storage, and the duration of the exposures.

a. Dosimeters will not detect exposures to weak beta emitters such as H-3, C-14, P-33, S-35 and Ca-45.

b. The dosimeter must be returned to EH&S to be **immediately processed** by the dosimetry vendor whenever serious (high-level) radiation exposure is suspected.

5. Exchange of Dosimeters

a. Dosimeters must be exchanged by Responsible Principal Investigators and outdated dosimeters must be returned to EH&S at required frequencies. A good way of insuring prompt exchange of dosimeters is to designate a dosimetry coordinator for each department or research group.

b. Dosimeters must be cancelled and returned to the Radiation Safety Division as soon as a person terminates status as an employee or student, or otherwise leaves the laboratory and stops working with radioisotopes and/or radiation-producing machines.

6. Proper Use of Dosimeters

Dosimetry results are legally presumptive evidence of personnel exposures. Therefore, it is imperative that dosimeters be used only as prescribed.

a. Dosimeters must be worn at all times by each individual as assigned while working with radioisotopes or radiation-producing machines at UC Irvine. Any individual who is exposed to sources of radiation off-campus **must not** wear his/her UC Irvine dosimetry to measure these exposures.

b. Dosimeters must only be worn by the individual whose name appears on the label.

c. Dosimeters must be stored away from all radiation sources when not being worn.

d. Dosimeters must be protected against contamination or excessive heat or moisture.

e. TLD ring dosimeters must be worn underneath gloves that will protect them from contamination. The ring should be worn so that the dosimeter chip (under identification label) will face the source of radiation. For the majority of workers handling radioactive materials in a lab, the chip should be on the palm side of the finger.

f. EH&S must be notified immediately in cases of suspected unusual exposure, contamination, improper storage, loss, misuse or damage of dosimeters.

g. Any lost or damaged dosimeters must be replaced for the remainder of the designated use period.

E. INTERNAL RADIATION DOSIMETRY

1. Federal and State Regulatory Requirements

Federal and State regulations require individual monitoring for any person who has the potential for occupational intake of radioactive materials under such conditions that they are likely to receive internal doses exceeding ten percent of any of the applicable regulatory limits.

2. UC Irvine Campus Dosimetry Criteria

There are few, if any, individuals at UC Irvine who are required to have bioassays under the provisions of NRC and/or DPH regulations. However, for campus administrative purposes,

a. . Whenever a new or renewal RUA is approved by the Radiation Safety Committee, an analysis is made whether or not any individuals are likely to exceed 10% of the internal dose limits and therefore required to be monitored

b. Campus administrative procedures may establish lower quantities of radioisotope utilization for bioassays to be required or recommended.

3. Bioassay Procedures

a. . Form “Med/Lg Lab Cklist (9/17)” titled “Requirements for a Bioassay Program” provided by the California Department of Public Health Radiologic Health Branch will be utilized to develop a bioassay program and associated procedures if required.

4. Control of Intakes and Airborne Contamination

a. Annual Limits of Intake have been established for each radionuclide.

(1) Various factors are considered in their development, such as physical and biological half-life of the material, energy and types of radiation emitted, transportability of the material into and from the lungs and other body compartments, and metabolism in the G.I. tract.

(2) Radionuclide intakes may be compared to tabulated ALI values in order to assist in the calculation of the CEDE (using the SALI) and the CDE (using the NALI).

b. Derived Air Concentrations for occupational and educational exposures have been calculated for purposes of establishing airborne concentration values for posting of airborne radioactivity areas and for requiring the use of respiratory protection.

c. Lower effluent concentration limits for air and water in the environment, and for the release of liquids to the sanitary sewer system, have been established by the federal and state regulatory agencies to determine levels which meet the dose limits for members of the public.

F. PRENATAL RADIATION EXPOSURE POLICY

1. Exposure of Pregnant Women

a. Federal and state regulatory agencies have established the category of Declared Pregnant Woman in order to address two competing objectives of national policy. These objectives are:

(1) The desire to establish a legal mechanism to offer special protection to the developing embryo/fetus by limiting external and internal doses to levels lower than those established for the mother.

(2) Decisions of the U.S. Supreme Court which prohibit the establishment of mandatory legal dose limits for women that are lower than the legal dose limits for men.

b. Therefore, each woman must choose to become a Declared Pregnant Woman if she wants to have voluntary lower legal dose limits for the exposure of her developing embryo/fetus.

c. UC Irvine procedures establish administrative criteria for external and internal dosimetry for declared pregnant women which are often lower

(e.g., for penetrating gamma radiation emitters and most internal exposures) than those established for adults who are not Declared Pregnant Women.

d. Radiation emitted by external radionuclides that are pure beta emitters (e.g., which do not emit gamma rays) will not penetrate into the uterus. Therefore, external exposures of the embryo/fetus from P-32 and other beta emitters should not be of concern to prospective mothers.

2. Specific Information for Prospective Mothers

It is UC Irvine's campus policy to inform female radiation workers (employees and students) of:

a. The enhanced risks to the developing embryo/fetus from exposures to ionizing radiation.

b. The options available to prospective mothers to maintain such exposures as low as reasonably achievable below the *in utero* legal limit of 500 millirems (for Declared Pregnant Women) during pregnancy for external and internal exposures.

c. That all such workers are strongly encouraged to contact the EH&S Office if they have any questions regarding radiation exposures during pregnancy.

3. Special Precautions for Prospective Mothers

Precautions required or recommended for prospective mothers (i.e., those who are pregnant or who are actively trying to become pregnant) who choose to continue working with or around radioactive materials and/or radiation-producing equipment, include:

a. The prospective mother should avoid situations where her abdomen may be exposed to penetrating radiation (gamma, x-ray, neutron) levels greater than 2 millirems per hour or 10 millirems per week.

b. Protective aprons may be worn, if appropriate for the energy and type of radiation encountered. Thin lead aprons may be used for x-rays, but they are not recommended for use with gamma emitters (such as Cr-51) or high-energy beta emitters (such as P-32).

c. The EH&S Office may issue a radiation dosimeter to a Declared Pregnant Woman to be used as a "fetal monitor" to assess penetrating radiation exposures (from external sources) to the prospective mother's abdomen whenever it is likely to receive a deep dose equivalent of more than

50 millirems in a year and the woman's usual dosimeter is likely to measure doses that are less than the doses to the abdomen.

d. If the deep dose equivalent to the embryo/fetus of a Declared Pregnant Woman equals or exceeds 50 millirems per month for more than two consecutive months of a pregnancy, the prospective mother's work will usually be reviewed to determine if restrictions are necessary to reduce further exposures during the remainder of the pregnancy.

e. If the dose equivalent to the embryo/fetus of a Declared Pregnant Woman exceeds 500 millirems during her pregnancy, the woman will normally be required to avoid all further occupational and educational radiation exposure until after the birth of her baby.

f. The prospective mother should avoid working with volatile or reactive radiochemicals which could result in the inhalation, ingestion, or absorption of radioactive materials through her skin.

(1) While pregnant, she should not perform either iodinations using radioiodine or labeling procedures using tritiated water or tritiated borohydride.

(2) Nursing mothers should also avoid such procedures.

g. In any case of suspected accidental exposure to radiation sources or uptake of radioactive materials, the prospective mother should contact the EH&S Office immediately, or call campus police after hours, or on weekends or holidays.

G. ALARA REVIEW OF SIGNIFICANT EXPOSURES

1. Routine ALARA Exposure Investigations

a. A routine ALARA exposure investigation will be performed by an EH&S health physicist, with review by the RSO, to determine the conditions of exposure and to suggest preventative measures to maintain future exposures ALARA, whenever:

(1) Any single dosimeter reading or bioassay measurement is:

(a) For adults -- 5 percent or more of any applicable annual regulatory limit.

(b) For minors under age 18 -- 10 percent or more of any applicable annual regulatory limit.

(c) For the embryo/fetus of a declared pregnant woman -- 10 percent or more of the regulatory limit for the embryo/fetus during pregnancy.

(2) Any accumulated annual combined external and internal dose reaches:

(a) For adults -- 10 percent or more of any applicable annual regulatory limit during the year.

(b) For minors under age 18 -- 20 percent or more of any applicable annual regulatory limit during the year.

(c) For the embryo/fetus of a declared pregnant woman -- 20 percent or more of the regulatory limit for the embryo/fetus during pregnancy.

b. A lower exposure may be investigated for any reason.

c. The Radiation Safety Committee (RSC) may authorize higher investigation levels for individuals or groups of individuals, as appropriate.

2. Special ALARA Exposure Investigations

A special ALARA exposure investigation will be performed by the RSO, with review by the RSC, whenever any accumulated annual combined external and internal dose reaches:

(1) For adults -- 30 percent or more of any applicable annual regulatory limit during the year.

(2) For minors under age 18 -- 50 percent or more of any applicable annual regulatory limit during the year.

(3) For the embryo/fetus of a declared pregnant woman -- 50 percent or more of the regulatory limit for the embryo/fetus during pregnancy.

H. INVESTIGATION OF OVER-EXPOSURES

1. The Environmental Health & Safety Office is responsible for notification of the NRC and/or the DPH, as appropriate, in cases of known or suspected exposure above the regulatory dose equivalent limits.

2. Medical evaluation and/or treatment by a qualified physician for any overexposed personnel may be required by the RSO, the RSC, or the appropriate regulatory agency.

3. Whenever the annual regulatory dose limits have been reached or exceeded, personnel will usually be required to avoid work with radioisotopes and/or radiation-producing machines for the remainder of the year.

I. DOSIMETRY RECORDS

1. UC Irvine Individual Monitoring Records

All records of individual monitoring results are kept at the Environmental Health & Safety Office.

a. Copies of external dosimetry reports are sent to each Responsible Principal Investigator for his/her group.

b. In cases of exposures which require notification of the DPH, a report will be provided to the individual involved.

c. Copies of internal dosimetry reports are sent to each individual for his/her personal records.

d. When required by law, copies of an individual's external and internal radiation exposures will be provided to them following the end of each calendar year.

e. At the written request of any individual, a report of his/her dose history will be provided.

2. Dosimetry Records From Other Employers/Institutions

The law requires that dosimetry records of non-UC Irvine radiation exposures from concurrent and former employers and other institutions attended be obtained by EH&S for the current calendar year.

a. Written permission is required of each individual for whom such records will be obtained.

b. All occupational and educational exposures for the individual in a year, including non-UC Irvine exposures, must be added together by category to determine if the annual limits have been exceeded.

SECTION 6: RADIATION HANDLING PROCEDURES

Every person who uses radioactive materials or radiation-producing equipment is responsible for handling them in such a manner as to ensure that radiation exposures are ALARA. The Radiation Safety Factsheet (which can be found on the EH&S website at http://www.ehs.uci.edu/radsafe.html), contains information regarding recommended laboratory procedures and requirements to accomplish this. The RUA will usually prescribe additional specific safety precaution and conditions. The following is an excerpt from the State Health Department Broad Scope License requirements.

BASIC RADIATION SAFETY PRINCIPLES AND WORK RULES

Radiation sources can be divided into two groups when discussing physical principles for preventing or minimizing exposure to ionizing radiation. These groups contain those sources which are external to the body and those sources which are internally deposited within the body.

A. CONTROL OF EXTERNAL EXPOSURE

External radiation exposure from a given radioactive source is controlled by the distance from the source, the exposure time, and shielding.

Increasing the distance from the source is frequently the most effective and economical means to reduce radiation exposure from gamma rays and other highly penetrating forms of radiation. The radiation field varies inversely with the square of the distance. For this reason, tongs or other long-handled tools should always be used for manipulating radionuclide preparations emitting significant levels of radiation. Radioactive materials should never be picked up with the fingers. Low-level sources can be handled with short forceps, which provide a large reduction in exposure when compared with direct skin contact.

Decreasing the time of exposure decreases the radiation dose proportionately. It is important to include “dry runs” with non-radioactive material for critical steps in pre-planning of all work which may involve substantial radiation exposure.

An estimate of radiation dose is a fundamental aspect in pre-planning for work with radioactive material.

Shielding the source of radiation will be necessary when the maximum distance and minimum time do not insure a significantly low exposure to operating personnel. Shielding for gamma radiation is accomplished by interposing materials, preferably of high atomic number and high density, between the source of radiation and the area to be shielded.

Beta rays produce a penetrating x-ray called Bremsstrahlung. The intensity of Bremsstrahlung varies directly with the square of the energy of the beta radiation and the average atomic number of the shielding material. Low atomic number materials such as Lucite®, Plexiglas® or glass should, therefore, be used for shielding of beta radiation whenever possible.

External radiation from low-energy beta rays is rather simply controlled. A few millimeters of solid material is often sufficient to totally absorb most commonly encountered beta radiations. High energy beta radiation should be shielded first with Lucite® or Plexiglas® and then with an OUTER layer of high Z material such as lead if Bremsstrahlung is significant. When working with energetic beta emitters, care must be taken to avoid exposing hands above opened containers where the dose rate can be on the order of rads per minute or above for commonly-used quantities of beta emitters such as P-32. Where radioactive material emits both beta and gamma radiations, shielding considerations will be controlled by the gamma radiation.

B. CONTROL OF INTERNAL EXPOSURE

Distance, time, and shielding are obviously not available for protection when the source of radiation is internally incorporated into the body. Incorporation of radioactive material into the body is most easily controlled by preventing exposure to unsealed sources of radioactive material. Large quantities of unsealed radioactive material must be used inside properly designed exhaust-ventilated enclosures.

A second reason for preventing radioactive contamination is to assure reliable experimental results, avoiding contamination of radiation measuring instruments and cross-contamination of experiments. If this technical contamination is controlled, internal exposure of laboratory personnel will usually not be a serious problem.

C. WORK RULES

The following rules of good radiation protection practice should be scrupulously observed by all radiation workers to prevent unnecessary radiation exposure and to minimize contamination.

1. Do wear buttoned-up lab coats and impermeable gloves when working with radioactive materials.

2. Do work with potentially volatile radioactive material (such as radioiodines or sulfur-35) in an exhaust-ventilated enclosure.

3. Do store and transport containers of radioactive liquids in secondary containers that will hold the contents of the primary container in the event of breakage.

4. Do line trays and working surfaces with absorbent paper. Absorbent paper with an impermeable/plastic base is commercially available.

5. Do keep radioactive liquids in sealed containers.

6. Do clearly label all containers of radioactive material and post all radiation and storage areas with the standard radiation warning symbol. Labels on containers should bear the legend, "Caution – Radioactive Material," an indication of the radionuclide and activity of radioactive material, and the date of the assay. Placards for posting of radiation and storage areas should bear the legend, "Caution—Radiation Area" or "Caution—Radioactive Material".

7. Do conduct work with radioactive material in accordance with written radiation safety and standard operating procedures (SOPs).

8. Do carry out new procedures in a "dry run" with inactive/harmless materials before using radioactive material.

9. Do monitor around work areas after each procedure where there is any possibility of contamination, and otherwise on a regular periodic basis (every 30 days at UC Irvine). Keep records of such surveys.

NOTE: If a source is found to have greater than 0.005 μCi of removable contamination, the EH&S Office must be notified immediately and the source must not be used.

11. Do clean up radioactive spills promptly.

12. Do not eat, drink, store consumables, or apply cosmetics in areas where unsealed radioactive materials are used.

13. Never pipette by mouth.

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SECTION 7: EMERGENCY PROCEDURES

A. PERSONNEL CONTAMINATION OR IRRADIATION INCIDENTS

1. Administer first aid, if necessary. In cases of serious or life threatening injuries (e.g., severe bleeding, broken bones, heart attack, etc.), call x911, Then call EH&S at 949-824-6200.

2. In any case of personnel contamination or accidental irradiation, notify the EH&S office immediately at 949-824-6200. If no answer, call the campus police at x911. They can contact EH&S staff outside of work hours.

3. In cases of minor contamination where no serious injury is involved, the first step should be to remove any contaminated clothing and wash contaminated skin areas with cold water and non-abrasive soap. Repeat this washing several times, then monitor areas with a thin-window Geiger counter (if the isotope is not H-3). Prevent contamination of radiation dosimeters. Keep all contaminated clothing and cleaning material for future analysis.

4. If the skin areas remain contaminated, do not attempt any drastic measures of decontamination which may encourage skin abrasion and absorption of materials into the skin.

B. LABORATORY CONTAMINATION INCIDENTS

1. Isolate the contaminated area to prevent further spread of contamination. Prevent people from becoming contaminated by avoiding contact with contaminated surfaces or walking through the area.

2. For those radioisotopes that can be detected with a Geiger counter which has a thin-window probe (generally, everything except H-3), check the radiation level over the contaminated area. If the level is greater than 5 mR/hr at 30 centimeters from any surface, the lab should be evacuated and EH&S notified immediately (949-824-6200; if no answer, call campus police at x911). Do not allow evacuated people to completely leave the scene. They may be needed for information or to be checked for contamination.

3. If the radiation level is less than 5 mR/hr, you may attempt to contain the spill area by first damming the area with absorbent material (diatomaceous earth, sand,

paper towels, etc.), or notify EH&S for assistance in the decontamination effort. Do not step in the spill or contaminate anyone in the process!

4. Before attempting any decontamination, wear protective clothing: lab coat, gloves, impervious shoe covers (if available), and respiratory protection, if potential airborne hazards exist.

5. Contaminated absorbent materials should be disposed of in a plastic-lined radioactive waste box. After loose contaminated materials have been disposed of, then decontamination of surfaces may begin by washing the areas with a minimum volume of soapy water. Use paper towels and dispose of wet towels in the plastic-lined box. To avoid contaminating the wash water, never place a contaminated towel into it. Always take a new towel, use it, and dispose of it in the radioactive waste box.

6. Check the areas for residual contamination levels by monitoring them with filter paper swipes counted in an LSC, and record the results. If areas are still contaminated, repeat decontamination procedures. Consult the UC Irvine Radiation Safety Handbook for additional suggestions.

   After decontamination has been completed, dispose of all materials that may have been contaminated (absorbents, gloves, shoe covers, etc.) in radioactive waste box.