Baylor University

Environmental Health and Safety

Radioactive Materials Safety Manual

Working Safely With Radioactivity

- **Understand the nature of the hazard and get practical training**
- **Plan ahead to minimize time spent handling radioactivity**
- **Distance yourself appropriately from sources of radiation**
- **Use appropriate shielding for the radiation**
- **Contain radioactive materials in defined work areas**
- **Wear appropriate protective clothing and dosimeters**
- **Monitor the work area frequently for contamination control**
- **Follow the local rules and safe ways of working**
- **Minimize accumulation of waste and dispose of it by appropriate routes**
- **After completion of work, monitor yourself, wash and monitor again**

Introduction

TEXAS RADIOACTIVE MATERIAL LICENSE
AND RADIATION CONTROL REGULATIONS

The Texas Regulations for the Control of Radiation (TRCR) were adopted by the Texas Board of Health in accordance with the Texas Radiation Control Act, Health and Safety Code, Chapter 401. They apply to all ionizing radiation, whether emitted from radio nuclides or devices. Licensing of all radioactive material including naturally occurring, such as radium, and accelerator-produced radionuclides is required. Registration of all equipment designed to produce x-rays or other ionizing radiation is required.

Radioactive materials are used in the Department of Chemistry at Baylor University under the authority of the Texas department of Health, Bureau of Radiation Control which delegates specific licensing authority to a technically qualified radiation Safety Officer. This authority includes approval of applications for use, issuance of notices of violations of state regulations or license provisions, and modification, suspension or revocation of approvals for health and safety considerations.

Analytical X-ray equipment and radiation producing equipment are used at Baylor University under the authority of the Texas Department of Health, Bureau of Radiation Control Regulations and require approval of the Radiation Safety Officer.

RADIATION SAFETY OFFICER

1. The Director of Instrumentation also has the duties of Chemistry Department Radiation Safety Officer (RSO) and in this capacity is under the direction of the Baylor University Safety Officer and the Chemistry Department Chairperson. The Departmental RSO is responsible for the annual radiation safety training required by the Texas Department of Health, Bureau of Radiation Control, for all individuals actively involved in research where (1) radioisotopes are used and/or (2) radiation emitting– or x-ray equipment is in use. The Departmental RSO, with the Baylor University Safety Officer, will also conduct an annual safety inspection of all Departmental laboratories involved in these activities.

2. The Departmental RSO shall develop a radioactive isotope and radiation safety program as required by the Texas Department of Health and the Nuclear Regulatory Commission.

3. The Departmental RSO shall develop a radiation monitoring program and provide for the monitoring of dose limits for those individuals involved in radiation research, those individuals where accidental radiation exposure is possible and individual members of the public as required by the Texas Department of Health.

4. The Departmental RSO shall be informed of the intent to order radioactive materials and shall receive all incoming radioactive materials. The RSO shall maintain records of these materials and their disposition.

5. The Departmental RSO shall conduct surveys for contamination (wipe surveys) monthly where radioactive materials are used and stored and shall cause remedial action if removable contamination exceeds 1000 per minute per 100 square centimeters. Records of surveys shall be maintained for inspection. It is the responsibility of faculty to inform the Departmental RSO of impending research utilizing radioactive materials.

6. The Departmental RSO shall maintain records of all radiation emitting machines and x-ray machines as required by the Texas Department of Health.

7. The Departmental RSO will do his utmost to insure that the Chemistry Department is in compliance with all national, state and local regulations for laboratory radiation safety.

INTENT TO PURCHASE AND USE RADIOACTIVE MATERIALS

All users of radioactive materials must inform the Radiation safety Officer of the intent to purchase and/or use radioactive materials or radiation sources. The responsible user must be a member of the Chemistry Department faculty.

At all times, the faculty member is responsible for ensuring that the radioactive material or other radiation source is used in compliance with the State of Texas Regulations on the safe handling of radioactive materials. The faculty member must provide a safe workplace for all workers, necessary instrumentation and adequate isotope storage. The faculty member must also ensure that all other users under his/her direction have been approved by the departmental RSO and are aware of safety and regulatory requirements, and that experimental procedures are in accordance with safety approval requirements.

Users are responsible for knowing the characteristics and potential hazards of the isotopes that they are working with, for ensuring that experimental procedures, applicable regulations and safety procedures are followed, for using required radiation safety instrumentation and dosimeters, and for ensuring that all work is conducted with a regard for the safety of themselves and others.

RADIATION DOSE STANDARDS

Permissible occupational radiation dose levels are set by the Texas Regulations for the Control of Radiation (TRCR). The user shall use, to the extent practical, procedures and controls based upon sound radiation protection principles to achieve occupational doses and public doses that are as low as reasonably achievable. (ALARA). The TRCR limits are listed in the table below.

DOSE CATEGORY

Occupational Dose Limits for Adults

(1) An annual limit which is the more limiting of:

(a) The total effective dose equivalent being equal to 5 rems (0.05 sievert); or

(b) The sum of the deep dose equivalent and the committed dose equivalent t any individual organ or tissue other than the lens of the eye being equal to 50 rems (0.5 sievert).

(2) The annual limits to the lens of the eye, to the skin, and to the extremities which are:

(a) An eye dose equivalent of 15 rems (0.15 sievert), and,

(b) A shallow dose equivalent of 50 millirems (0.5 sievert) to the skin or to any extremity.

It should be noted these dose limits are in addition to the background radiation dose or any medical radiation dose received by the worker. The average annual background radiation in the U.S. due to natural sources is approximately 300 millirems per year.

Occupational Dose Limits for Minors

Radiation doses for persons under the age of 18 are to be limited to 10 percent of the limits for adult workers listed above.

Embryo / Fetus Dose

The dose limit to the embryo / fetus of a declared pregnant woman is 0.5 rem. Efforts must also be made to avoid a dose substantially higher than 0.05 rem (0.5 millisievert) in any one month. A declared pregnant woman means a woman who has voluntarily informed the RSO, in writing, of her pregnancy and the estimated date of conception.

The dose to an embryo/fetus shall be taken as the sum of:

(a) The deep dose equivalent to the declared pregnant woman, and

(b) The dose to the embryo/fetus from radio nuclides in the embryo/fetus and radionuclides in the declared pregnant woman.

Dose Limits for Individual Members of the Public

Each user shall conduct operations so that:

(a) the total effective dose equivalent to individual members of the public shall not exceed 0.1 rem (1 millisievert) in a year;

(b) the total effective dose equivalent to individual members of the public from infrequent exposure to radiation from diagnostic machine does not exceed 0.5 rem (5 millisieverts) and

(c) the dose in any unrestricted area from external sources does not exceed 0.002 rem (0.02) millisievert) in any one hour

ALARA Guideline

In practice, radiation doses should be **A**s **L**ow **A**s **R**easonably **A**chievable**. ALARA** is a guideline meant to strike a balance between the cost of radiation protection and the health benefit derived from that protection.

It is the responsibility of everyone to operate within the ALARA guidelines. This is achievable by outlining safety procedures for radiation environments and by monitoring the workplace environment to control contamination and minimize doses.

RADIOACTIVE MATERIAL USE AND PROCEDURES

Applications for possession and use

Requests to acquire and procure radioactive materials are prepared on the form "Application for Possession and Use of Radioactive Material or Equipment Producing Ionizing Radiation", available from the Chemistry Department RSO.

You should submit an experiment protocol or describe in your application those experimental procedures or actions that may affect or cause the inadvertent release or ingestion/inhalation of radioactive material. You should also name any hazardous chemicals and compounds that will be used. Material Safety Data Sheets can and should be provided as guides for their safe use.
Purchase orders for radioactive materials will not be processed without approval of the Chemistry department RSO.

Receipt, Shipment and Delivery of Radioactive Materials.

Upon receipt of a package of radioactive material, the Departmental RSO shall monitor the external surface of the package for radioactive contamination caused by leakage of the radioactive content, except:

(a) Packages which contain no more than the exempt quantities (see Appendix X)

(b) Packages which contain no more than 10 millicuries of radioactive material consisting solely of tritium, carbon-14, sulfur-35, or iodine-125.

(c) Packages which contain only radioactive material such as gases, or are of special form, or contain only radioactive material other than liquid form and do not exceed type A quantity.

(d) Packages containing only radionuclides with half-lives of less than 30 days and a total quantity of no more than 100 millicuries.

The monitoring shall be performed as soon as practical after receipt, but not later than three hours if received during normal working hours or eighteen hours if received after normal working hours.

If removable radioactive contamination in excess of 0.01 microcuries per 100 cm^2 is found on the surface of the package, the licensee shall immediately notify the NRC, Regulatory Operations Regional Office.

Certain quantities of radioactive material are exempt from DOT regulations when classified according to concentration as Low Specific Activity. (See Appendix)

Opening, Wipe Testing and Monitoring Requirements

Radioactive package check-in will be done by the departmental RSO as follows:

(a) Examine address label to verify that the package belongs to Baylor University Chemistry Department.

(b) Wipe surfaces of package covering at least 100 cm^2. All packages marked with a white I, yellow II, or yellow III labels will be wiped.

(c) Count the wipe in a liquid scintillation counter or gamma counter for 1 minute. If removable contamination is found in excess of 0.00001 uCi (22 dpm/cm2) contact the manufacturer.

(d) Deface all radioactive labels on packing materials prior to disposal.

Personnel Monitoring

All persons listed on an application for use of radioactive materials or radiation machines are required to be on the Chemistry Department's dosimetry program. External dosimeters are used to detect and measure radiation exposure to the whole body, skin and extremities.

External Dosimetry

The film badge is Baylor University's basic dosimeter and it's use is required for all authorized users of radioactive materials and radiation machines. Exemption may be given in special cases where a film badge would not provide any useful exposure information, such as persons using only H-3, S-35, C-14, or certain sources installed permanently in equipment or small sealed sources.

Use of a finger dosimeter will usually be required for operations involving the regular handling of millicuries or greater quantities of gamma emitters or high energy beta emitters, e.g., P-32, Sr-90.

Bioassay Program

Persons working with 1 millicuries or more of volatile or dispersible radio iodine or 10 millicuries or more of non-volatile radioiodine must make arrangements after the use to schedule a thyroid check.

POLICIES AND PROCEDURES FOR RADIOISOTOPE USE IN THE LABORATORY

Posting and Marking of Laboratories, Areas and Equipment

Each laboratory or area where radioactive materials are used or stored must be posted at the entrance with a **CAUTION RADIOACTIVE MATERIALS** sign. The name and home phone number of the responsible user must also be posted. Entry and warning signs are to be posted and removed only by the departmental RSO.

Refrigerators, freezers , other in lab storage areas, and containers in which radioactive materials are stored must have a visible label with the radiation caution symbol and the words **CAUTION RADIOACTIVE MATERIALS**. The label should also state the kind and quantity of material in the container. Radioactive material labels should be removed from containers if they are not empty and contaminated.

Areas in the laboratory where radiation levels might expose a person to 5 millirem in any one hour or 100 millirem in 5 consecutive days must be posted with the sign CAUTION **RADIATION AREA**. Equipment doors and covers need not be posted if radiation levels are high only when the doors are open.

Laboratory equipment (flasks, beakers, centrifuges, etc.) containing radioactive materials need not be marked so long as the user is present and the material is in a designated and marked radioactive material work area. Unattended and contaminated equipment and tools must be marked with warning tape or labels.

The departmental RSO may post areas and equipment to indicate significant levels of contamination found during surveys. These signs are to be removed only when the article or area has been satisfactorily decontaminated.

Protective Clothing and laboratory Safety Precautions

A lab coat or plastic apron should always be worn whenever any unsealed sources of radioactive material are handled, even in tracer amounts. Film badges and ring dosimeters should always be worn.

Pipetting radioactive solutions by mouth is extremely dangerous and must not be done under any circumstances. Use a safety pipette or other suitable means.

Do not eat, store food, or apply cosmetics in any laboratory where unsealed radioactive materials are used or stored.

To avoid spills, use metal or plastic outer trays or beakers to carry liquid radioactive materials from one lab to another.

Do not work with unsealed radioactive materials if you have open cuts, sores, etc., on exposed skin areas, even if bandaged.

After handling radioactive materials, be sure to wash hands thoroughly.

Survey of Work Areas

Users of radioactive materials are required to survey their work areas (hoods, bench tops, sinks, floors, etc.) after each experiment and at any time there is a reason to suspect a spill or contamination incident.

The departmental RSO will survey all laboratories using unsealed radioactive materials on a regular basis. Required surveys by **laboratory personnel** are:

Routine Survey.

> Performed by the user after each experiment and at any time there is reason to suspect a spill or contamination incident. These surveys do not have to be documented.

Internal Survey

> Performed weekly by laboratory personnel in laboratories where shipments of at least 10 mCi (or 1 mCi NaI) are used, or in laboratories where two consecutive surveys have found high level contamination. These surveys must be documented in the laboratory. In the case of high level contamination, internal surveys will be required until the laboratory has had four consecutive surveys by the departmental RSO with no high level contamination found.

RSO survey

> Performed and documented monthly or bi-monthly by the departmental RSO in areas where unsealed radioactive materials are used or stored.

Radioactive Nucleic Acids and Derivatives

Experiments involving the use of radioactive nucleic acid and radioactive nucleic acid derivatives present a special hazard in that some of these compounds may become incorporated in the genetic material of the body cells. The following procedures should be followed by personnel using such material.

Special care should be used during all experiments, which involve the use of radioactive nucleic acids, radioactive nucleic acid derivatives, or substances in which these compounds have been incorporated.

The experiment should be done only in a designated area within the laboratory. This area should be physically separated from other work areas if at all possible. The bench top should always be covered with absorbent paper.

Rubber or plastic gloves and lab coats should be worn at all times during the handling of the radioactive materials.

Shielding of Sources and Materials

When not in use, radioactive sources and stock solutions in the laboratory shall be stored or shielded so that radiation levels in occupied areas will not expose persons unnecessarily.

Appropriate shielding should be used when handling millicuries and greater quantities of radioactive materials. H-3 (tritium), C-14, S-35 and similar low energy beta emitters are not usually external radiation hazards and do not require shielding. Gamma emitters and high-energy beta emitters (e.g., P-32, Ru-106, and Sr-90) may present a significant external radiation hazard. The energetic beta emitters should be shielded first with Lucite and then with lead, if necessary, to minimize the generation of penetrating bremsstrahlung radiation.

Aerosols, dusts and gases

Procedures involving aerosols, dusts, volatile or respirable material must be conducted in hoods or suitable closed systems approved by the departmental RSO. Where practical, suitable traps should be used to minimize environmental releases.

RADIOACTIVE WASTE

Hazard Reduction

Radioactive waste containing chemical, biological, or infectious material must be treated to reduce the potential hazard from non-radiological materials to the maximum extent practical. The goal is twofold: to minimize the hazards for those persons who handle the waste at each step of the disposal process and to minimize the potential impact on the environment during the lifetime of the disposal facility. The following steps should be taken:

(a) Adjust the pH of all aqueous radioactive waste as close to neutral as possible. For aqueous waste containing I^{125} or I^{131}, the pH should be between 7 and 9. If necessary, solutions should be buffered to maintain this pH.

(b) Autoclave or chemically treat pathogenic and infectious material. Do not autoclave if radioactive contamination will be spread as a result. **Red or orange biohazard bags shall not be used for radioactive waste.**

(c) If possible, treat carcinogens, teratogens and other highly toxic materials to reduce their impact on the environment.

(d) **Package syringe needles and other sharp objects so as to prevent injury to those handling the waste.**

Record keeping

All material designated as radioactive waste must be identified. **Unidentified material can not be picked up.** “Identification” means stating the isotope, the activity, principal investigator’s name, laboratory room number, and the date labeled as waste.

Segregation of Radioactive Waste

(a) Liquid scintillation vials which contain H^3 and C^{14} shall be segregated from other vials. This is cost effective because H^3 and C^{14} vial waste has been deregulated and can be disposed as chemical rather than radioactive waste.

(b) 0.05 microcurie (1.85 kilobecquerels), or less of H^3, C^{14} or I^{125} per gram of medium used for liquid scintillation counting or in vitro laboratory testing may be discarded without regard to it's radioactivity.

2. **Dry solid waste** shall be segregated by identity according to the combinations listed below:

(a) P^{32} and I^{131}

(b) Na^{24}, P^{33}, Ca^{45}, Sc^{46}, Cr^{51}, Fe^{59}, Co^{57}, Zn^{65}, Ga^{67}, Se^{75}, Br^{82}, Rb^{86}, Sr^{85}, Nb^{95}, MTc^{99}, In^{111}, I^{125} and Ce^{141}.

(c) H^3 and C^{14}

(d) Any other radionuclides which have half-lives greater than 300 days.

(e) Dry waste must not contain any bulk liquids.

RADIOACTIVE LIQUIDS MUST BE SEGREGATED BY RADIOISOTOPE; I.E., ONE RADIO NUCLIDE PER CONTAINER

(f) Radioactive acids will not be accepted for disposal as either radioactive or as chemical waste unless neutralized. Avoid acid washing glassware. Commercially available materials are available for cleaning glassware and are much safer to use than dichromate solutions.

(g) Uranyl acetate is considered a radioactive substance for disposal purposes. It must be collected and disposed of as a radioactive waste. Each container must be labeled with the amount of uranyl acetate, in grams. Do not mix uranyl acetate solutions with other non-radioactive waste.

(h) Liquid scintillation vials , H^3 and C^{14}, shall be separated from other radioactive material for disposal. Liquid scintillation vials are not to be emptied unless the investigator plans to reuse the vials. In this situation, the liquid scintillation cocktail must be poured into clearly labeled bulk containers. In addition to the record keeping requirements as listed above, users must also indicate that it is bulked scintillation cocktail. **LIQUID SCINTILLATION COCKTAIL SHALL NOT BE MIXED WITH AQUEOUS WASTE.**

(i) Vials containing radioactive materials other than H^3 and C^{14} must be disposed of as radioactive waste.

RADIATION PRODUCING MACHINES

General Safety Provisions

A radiation-producing machine is any device capable of producing ionizing radiation when the associated control devices are operated, except devices that produce radiation by the use of radioactive material.

An enclosed system is a radiation producing machine which satisfies the requirements that all areas with exposure rates greater than 0.25 mR/hr are enclosed with an interlocked barrier. All others are considered open systems.

X-ray diffraction units, particle accelerators, electron microscopes and high voltage rectifiers operating above 10 kV all fall into the category of radiation producing machines.

RADIATION SAFETY REQUIREMENTS FOR ANALYTICAL X-RAY EQUIPMENT

Texas Regulations for the Control of Radiation

Scope and Purpose

This part provides special requirements for analytical x-ray equipment. The requirements of this part are in addition to, and not in substitution for applicable requirements in other parts of these regulations.

Analytical x-ray equipment means x-ray equipment used for x-ray diffraction, fluorescence analysis, or spectroscopy.

Analytical x-ray system means a group of local and remote components utilizing x-rays to determine the elemental composition or to examine the micro structure of materials. Local components include those that are struck by x-rays such as radiation source housings, port and shutter assemblies, collimators, sample holders, cameras, goniometers, detectors, and shielding. Remote components include power supplies, transformers, amplifiers, readout devices, and control panels.

Fail-safe characteristics mean a design feature which causes beam port shutters to close, or otherwise prevents emergence of the primary beam, upon the failure of a safety or warning device.

Normal operating procedures mean operating procedures for conditions suitable for analytical purposes with shielding and barriers in place. These do not include maintenance but do include routine alignment procedures. Routine and emergency radiation safety considerations are part of these procedures.

Open-beam configuration means an analytical x-ray system in which an individual could accidentally place some part of his body in the primary beam path during normal operation.

Primary beam means ionizing radiation which passes through an aperture of the source housing by a direct path from the x-ray tube located in the radiation source housing.

Equipment Requirements

(a) Safety Device

A device which prevents the entry of any portion of an individual's body into the primary x-ray beam path or which causes the beam to be shut off upon entry into its path shall be provided on all open-beam configurations. A registrant may apply to the Agency for an exemption from the requirement of a safety device. Such application shall include:

(1) A description of the various safety devices that have been evaluated.

(2) The reason each of these devices cannot be used, and

(3) A description of the alternative methods that will be employed to minimize the possibility of an accidental exposure, including procedures to assure that operators and others in the area will be informed of the absence of safety devices.

(b) Warning Devices

Open-beam configurations shall be provided with a readily discernible indication of:

(1) X-ray tube status (ON-OFF) located near the radiation source housing, if the primary beam is controlled in this manner; and/or

(2) Shutter status (OPEN-CLOSED) located near each port on the radiation source housing, if the primary beam is controlled in this manner.

Warning devices shall be labeled so that their purpose is easily identified. On equipment installed after the effective date of these regulations, warning devices shall have fail-safe characteristics.

(c) Ports Unused ports on radiation machine source housings shall be secured in the closed position in a manner which will prevent casual opening.

(d) Labeling

All analytical x-ray equipment shall be labeled with a readily discernible sign or signs bearing the radiation symbol and the words:

(1) "CAUTION - HIGH INTENSITY X-RAY BEAM", or words having a similar intent, on the x-ray source housing; and

(2) "CAUTION RADIATION - THIS EQUIPMENT PRODUCES RADIATION WHEN ENERGIZED", or words having a similar intent, near any switch that energizes an x-ray tube.

(3) Shutters

On open-beam configurations installed after the effective date of these regulations, each port on the radiation source housing shall be equipped with a shutter that cannot be opened unless a collimator or a coupling has been connected to the port.

(f) Warning Lights

An easily visible warning light labeled with the words "X-RAY ON", or words having a similar intent, shall be located near any switch that energizes an x-ray tube and shall be illuminated only when the tube is energized.

On equipment installed after the effective date of these regulations, warning lights shall have fail-safe characteristics.

Area Requirements

(a) Radiation Levels (paragraph 34.4(a))

The local components of an analytical x-ray system shall be located and arranged and shall include sufficient shielding or access control such that no radiation levels exist in any area surrounding the local component group which could result in a dose to an individual present therein in excess of the these limits given in 21.105 [21.310] of these regulations. These levels shall be met at any specified tube rating.

(b) Surveys

Radiation surveys, as required by 21.201 [21.501], of all analytical x-ray systems sufficient to show compliance with paragraph 34.4(a) shall be performed:

(1) Upon installation of the equipment;

(2) Following any change in the initial arrangement, number, or type of local components in the system;

(3) Following any maintenance requiring the disassembly or removal of a local component in the system;

(4) During the performance of maintenance and alignment procedures if the procedures require the presence of a primary x-ray beam when any local component in the system is disassembled or removed;

(5) Any time a visual inspection of the local components in the system reveals an abnormal condition; and

(6) Whenever personnel monitoring devices show a significant increase over the previous monitoring period or the readings are approaching the Radiation Protection Guides (radiation dose limits).

Radiation survey measurements shall not be required if a registrant can demonstrate compliance to the satisfaction of the Agency with in some other manner.

(c) Posting

Each area or room containing analytical x-ray equipment shall be conspicuously posted with a sign or signs bearing the radiation symbol and the words "CAUTION - X-RAY EQUIPMENT", or words having a similar intent.

Operating Requirements

(a) Procedures

Normal operating procedures shall be written and available to all analytical x-ray equipment workers. No person shall be permitted to operate analytical x-ray equipment in any manner other than that specified in the procedures unless such person has obtained written approval of the radiation safety officer.

(b) Bypassing

No person shall bypass a safety device unless such person has obtained the approval of the radiation safety officer. When a safety device has been bypassed, a readily discernible sign bearing the words "SAFETY DEVICE NOT WORKING", or words having a similar intent, shall be placed on the radiation source housing.

Personnel Requirements

(a) Instruction

No person shall be permitted to operate or maintain analytical x-ray equipment unless such person has received instruction in and demonstrated competence as to:

(1) Identification of radiation hazards associated with the use of the equipment;

(2) Significance of the various radiation warning and safety devices incorporated into the equipment, or the reasons they have not been installed on certain pieces of equipment and the extra precautions required in such cases;

(3) Proper operating procedures for the equipment;

(4) Symptoms of an acute localized exposure; and

(5) Proper procedures for reporting an actual or suspected exposure.

(b) Personnel Monitoring

Finger dosimetric devices shall be provided to and shall be used by:

(1) Analytical x-ray equipment workers using systems having an open-beam configuration and not equipped with a safety device; and

(2) Personnel maintaining analytical x-ray equipment if the maintenance procedures require the presence of a primary x-ray beam when any local component in the analytical x-ray system is disassembled or removed.

APPENDIX A

EMERGENCY PROCEDURES

ALL ACCIDENTS INVOLVING RADIOACTIVE MATERIAL MUST BE REPORTED IMMEDIATELY TO THE CHEMISTRY DEPARTMENT RADIATION SAFETY OFFICER AND THE UNIVERSITY HEALTH AND SAFETY OFFICER

Radiation Spills, general procedures

Spills of radioactive materials, no matter how minor, must be cleaned up immediately.

It is the responsibility of the person causing a spill to clean it up.

The Departmental RSO will provide guidance, but the actual decontamination procedure should be carried out by the persons involved in the incident.

Decontamination efforts should always be conducted in a manner which minimizes the dose to workers, both from external exposure and from contamination and intake.

- Limit access to the area.
- Have the ventilation system (air conditioner) turned off.
- Prevent spread of liquid or powdered contaminates.

For most spills, ordinary detergents and water applied with disposable cleaning materials will be adequate. Commercially available decontamination solutions are usually strong detergents to which complexing agents or surfactants have been added. They may need to be diluted before use.

Use the following guidelines in decontamination efforts:

(a) If there is personal decontamination take care of this first then decontaminate the work area. Flush the skin with soap and water. **Do not abrade the skin.** Remove any contaminated clothing and store in a plastic bag.

(b) Notify individuals in the immediate work area of the spill so they can avoid contamination.

(c) Call the departmental RSO for assistance if you have doubts about how to proceed.

(d) Use appropriate protective clothing: gloves, lab coat, protective goggles, shoe covers, a face mask if conditions are dusty.

(e) Use dosimeters if radionuclides other than H^3, C^{14} or other very low energy beta emitters are involved. Protect them from contamination. Wear ring dosimeters under protective gloves.

(f) Use disposable materials for cleaning: paper towels, Kimwipes, plastic bags.

(g) Dampen dry spills with water (e.g., by application of a dampened paper towel, being careful not to spread contamination). Absorb wet spills immediately with paper towels or Kimwipes.

(h) Work from the least contaminated area at the perimeter of the spill to the most contaminated area. Do not increase the contaminated area any more than necessary.

(i) Place contaminated items in approved radioactive waste containers.

(j) Use time, distance and shielding strategies to minimize dose. Use long-handled tools for spills of energetic beta or gamma emitters. Avoid hand contact.

(k) For tritium (H^3) spills, monitor your progress by wiping the area with filter paper. Put the filter paper into a scintillation vial, add counting media and count in a liquid scintillation counter. H3 is **NOT** detectable with a survey meter.

(l) If you have a survey meter, use it to check your progress, surveying slowly enough to detect small differences in count rates. If you do not have a survey meter, wipe test the area as described in k above. **Use caution not to contaminate the survey meter.**

(m) The limits for removable contamination are very conservative. Any activity which you detect with ordinary survey meters will probably exceed allowable limits. If the activity is not removable (as determined by wipe testing the area), call the Departmental RSO for advice on how to proceed.

(n) Do not use equipment which was contaminated or which was used in the decontamination effort until it has been checked.

(o) Complete the incident report and return it to the departmental RSO.

Any incident involving a possible overexposure from radioisotopes, x-rays or any device labeled as a radiation hazard must be reported immediately to the University Radiation Safety Officer. The individual with which the overexposure is suspected should report as soon as possible with their radiation badge. The badge will be returned to the supplier for an emergency reading. The individual will be notified as soon as a badge reading is obtained.

Classification of Radio nuclides According to Relative Hazard Potential

Class I (Very High Toxicity)

Sr^{90}, Y^{90}, Pb^{210}, Bi210, Po^{210}, At^{211}, Ra^{226}, Ac^{227}, Th^{228}, Th^{229}, Th^{230}, Th^{231}, U^{233}, Pu238, Pu^{239}, Am^{241}, Cm^{242}, Cf^{252}, other transuranic isotopes.

Class II (High Toxicity)

Ca^{45}, Ca^{47}, Fe^{59}, Co^{60}, Sr^{85}, Sr^{89}, Y^{91}, Ru^{106}, Rh^{106}, Cd^{109}, Cd^{115}, I^{125}, I^{131}, Ba^{140}, La^{140}, Ce^{144}, Pr^{144}, Sm^{151}, Eu^{152}, Eu^{154}, Tm^{170}, Hg^{203}, Bi^{2o7}, Th^{232}, natural thorium, natural uranium.

Class III (Moderate Toxicity)

Na^{22}, Na^{24}, P^{32}, P^{33}, S^{35}, Cl^{36}, K^{42}, Sc^{46}, Sc^{47}, Sc^{48}, V^{48}, Cr^{51}, Mn^{54}, Mn^{56}, Fe^{55}, Co^{57}, Co^{58}, Ni^{59}, Ni^{63}, Cu^{64}, Cu^{67}, Zn^{65}, Ga^{67}, Ga^{68}, Ga^{72}, As^{74}, As^{76}, Br^{82}, Kr^{85}, Rb^{84}, Rb^{85}, Y^{90}, Zr^{95}, Nb^{95}, Mo^{99}, Tc^{99}, Rh^{105}, $Pd^{103,}$ $Rh^{103,}$ $Ag^{105,}$ Ag^{111}, Sn^{113}, Te^{127}, Te^{129}, $I^{132,}$ $Xe^{133,}$ $Cs1^{37,}$ $Ba^{137,}$ $La^{140,}$ $Pr1^{43,}$ $Pm1^{47,}$ Ho^{166}, Lu^{177}, Ta^{182}, W^{181}, Re^{183}, Ir^{190}, Ir^{192}, Pt^{191}, Pt^{193}, Au^{196}, Au^{198}, Au^{199}, Tl^{200}, Tl^{204}, Pb^{203}, Hg^{197}.

Class IV (Slight Toxicity)

H^{3}, Be^{7}, C^{14}, F^{18}, Cr^{51}, Ge^{68}, Ge^{71}, Sr^{87m}, Tc^{99m}, In^{111}, Tl^{201}, U^{235}, U^{238}.

The toxicity ratings were extracted from various published data, but may change from these published values. **These ratings are to be used only as a guide.**

H^3 (Tritium) Information

Radioactive half-life	**12.4 years**
Decay mechanism	**Beta emission**
Energy	**E_{max} = 18.6 KeV**
Contamination monitoring	**Liquid scintillation counter for wipe surveys.**
Dosimetry	**Urinalysis bioassay**
Shielding	**Glass and plastic**

- Because the beta emitted has a very low energy, tritium can not be detected with the usual survey meters. Therefore, special care is needed to keep the work area from becoming contaminated. Tritium can be detected by doing a wipe survey and counting the wipes in a liquid scintillation counter.
- Beta particles from tritium travel a maximum of 6 mm in air
- The maximum permissible body burden to the whole body is 1 millicurie.

Safety Rules

- Designate a specific area of the laboratory for all tritium experiments.
- All personnel who handle tritium must wear full length laboratory coats.
- Many tritiated compounds readily penetrate gloves and skin. Wearing two pairs of gloves and changing the outer pair every fifteen or twenty

minutes will reduce the chance of contamination and absorption through the skin.

- Pipettes dedicated for the use of tritium should be used. These pipettes should not be used for other purposes as they are easily contaminated by H^3

Laboratory Cleanup After Use

- Conduct wipe tests using the liquid scintillation counter checking all work areas and equipment used. Check the floor at the area where the isotope was used.

- If any contamination is found, use a commercial radiation contamination remover such as Count Off with paper towels to clean the contaminated area.

- Place the contaminated paper towels in a receptacle labeled as radiation waste.
- If the contamination can not be removed, label the area or equipment as radioactive noting the isotope, the date of contamination and the maximum cpm found.

- If any unremovable radiation is found, contact the University Radiation Safety Officer.

- Check the normal trash container to ensure that no radioactive waste was placed there.

- Store all radioactive waste in specially marked containers.

- Send a Radiation Survey report to the University Radiation Safety Officer.

C^{14} Information

Radioactive half-life	**5730 years**
Decay mechanism	**Beta emission**
Energy	**E_{max} = 0.156 MeV**
Contamination monitoring	**thin window Geiger Mueller detector, liquid scintillation counter for wipe surveys.**
Dosimetry	**Urinalysis bioassay**
Shielding	**Glass and Plastic**

- C^{14} is not easily monitored during it's use and special precautions must be taken to keep the work environment clean.

- Most Geiger counters will not efficiently detect the presence of C^{14} but it is easily detected with a wipe test and liquid scintillation counting.

- Some C^{14} labeled compounds can penetrate gloves and skin. Wearing two pairs of gloves and changing the outer pair every fifteen or twenty minutes will reduce the chance of contamination and absorption through the skin.

- Beta particles from C^{14} travel a maximum of 22 cm in the air.

- C^{14} may be difficult to distinguish from S^{35}. If both nuclides are being used in the same laboratory, establish controls to ensure they are kept separate. If "unknown" contamination is found, treat it as C^{14}.

- The maximum permissible body burden to the whole body is 0.4 millicurie.

Safety Rules

- Designate a specific area of the laboratory for all C^{14} experiments.

- All personnel who handle C^{14} must wear full-length laboratory coats.

- Many C^{14} compounds readily penetrate gloves and skin. Wearing two pairs of gloves and changing the outer pair every fifteen or twenty minutes will reduce the chance of contamination and absorption through the skin.

- Pipettes dedicated for the use of C^{14} should be used. These pipettes should not be used for other purposes as they are easily contaminated by C^{14}.

Laboratory Cleanup after Use

- Conduct wipe tests using the liquid scintillation counter checking all work areas and equipment used. Check the floor at the area where the isotope was used.

- If any contamination is found, use a commercial radiation contamination remover such as Count Off with paper towels to clean the contaminated area.

- Place the contaminated paper towels in a receptacle labeled as radiation waste.

- If the contamination can not be removed, label the area or equipment as radioactive noting the isotope, the date of contamination and the maximum cpm found.

- If any unremovable radiation is found, contact the University Radiation Safety Officer.

- Check the normal trash container to ensure that no radioactive waste was placed there.
- Store all radioactive waste in specially marked containers.
- Send a Radiation Survey report to the University Radiation Safety Officer.

P^{32} INFORMATION

Radioactive half-life	**14.3 days**
Decay mechanism	**Beta emission**
Energy	**$E_{max} =$ 1.709 MeV**
Contamination monitoring	**thin window Geiger Mueller detector**
Shielding	**1 cm Lucite**
Dosimetry bioassay	**Film badge, TLD ring, urinalysis**

- The dose rate on contact on the side of a 1 mCi delivery vial will be on the order of 1000 mrem/hr. If possible, avoid direct hand contact with vials and sources.

- When working with 100 uCi or more of P^{32}, work should be done behind a 1 cm thick Lucite shield. If more than 1 millicurie of P^{32} is used, lead foil should be added to the exterior of the shield because of the formation of x-rays (bremstrahlung).

- Beta particles from P^{32} travel a maximum of 20 feet in the air.

- One uCi of P^{32} in direct contact with $1cm^2$ of bare skin gives a dose rate to the skin of about 2000 millirems/hr. This means that the quarterly NRC limit of 7500 millirems to the skin would be reached in 3 hours and 15 minutes.

- Radiation exposure in the air over an open vial containing 1 millicurie of P^{32} can be as high as 26,000 millirems per hour. The quarterly NRC limit of 18,250 millirems for the hands would be reached in 42 minutes.

- Always protect your skin when handling unsealed materials. Wear gloves, lab coats, and shoes.

- A thin window G-M survey meter should always be available. A survey should be made immediately after use and any "hot spots" should be decontaminated.

- Film badges must be worn for all P32 work. TLD rings should be worn for all P^{32} work, and are required when handling 1 millicurie or more.

- Handle and store your radioactive waste carefully.

Safety Rules

- Place the Plexiglas shield near a wall or in a hood away from the main flow of traffic.

- Designate a specific area of the laboratory for all P^{32} experiments.

- All personnel who handle P^{32} must wear full length laboratory coats.

- All personnel handling P^{32} must wear a ring badge on the hand which is most likely to handle vials, samples, pipettes, etc., containing P^{32}.

- All persons in the laboratory must wear whole body film badges, even those who are not handling P^{32}.

- A Geiger counter capable of detecting beta particles and secondary X-rays must be in operation during the experiment and preferably at all times. Place Saran Wrap around the counter to avoid contaminating the detector.

- Check the radiation level in front of the shield to determine if lead foil should be added to block out bremstrahlung x-rays formed by the interaction of the beta particles with the Plexiglas.

- Check your gloves frequently with the counter to detect contamination. If contaminated, immediately dispose of the gloves in a

- Do not work directly over an open container of P^{32}.

- Many P^{32} compounds readily penetrate gloves and skin. Wearing two pairs of gloves and changing the outer pair every fifteen or twenty minutes will reduce the chance of contamination and absorption through the skin.

- Pipettes dedicated for the use of P^{32} should be used. These pipettes should not be used for other purposes as they are easily contaminated by P^{32}.

Laboratory Cleanup After Use

- Use the Geiger counter to check your hands, shoes, clothing, all work areas and equipment used. Check the floor at the area where the isotope was used. If your clothing is contaminated, it will have to be removed and stored until the radiation level decays to background.

- If any contamination is found on your hands, wash thoroughly with soap and water. This will usually be sufficient to remove surface contamination. If it does not, contact the University radiation Safety Officer for assistance.

- If any contamination is found on the work area or equipment, use a commercial radiation contamination remover such as Count Off with paper towels to clean the contaminated area.

- Place the contaminated paper towels in a Plexiglas receptacle labeled as radiation waste.

- If the contamination can not be removed, label the area or equipment as radioactive noting the isotope, the date of contamination and the maximum cpm found.

- If any unremovable radiation is found, contact the University Radiation Safety Officer.

- Check the normal trash container to ensure that no radioactive waste was placed there.

- Store all radioactive waste in specially marked containers.

- Send a Radiation Survey report to the University Radiation Safety Officer.

P^{32} decay rate

Elapsed Time (days)	% Remaining Activity	Decay Factor
0	100	1.0
1	95.3	0.953
2	90.8	0.908
3	86.5	0.865
4	82.4	0.824
5	78.5	0.785
6	74.8	0.748
7	71.2	0.712
8	67.8	0.678
9	64.6	0.646
10	61.6	0.616
11	58.7	0.587
12	55.9	0.559
13	53.2	0.532
14	50.7	0.507
15	48.3	0.483
16	46.0	0.460
17	43.8	0.438
18	41.8	0.418
19	39.8	0.398
20	37.9	0.379
21	36.1	0.361
22	34.4	0.344
23	32.2	0.322
24	31.2	0.312
25	29.7	0.297
26	28.3	0.283
27	27.0	0.270
28	25.7	0.257
29	24.5	0.245
30	23.2	0.233
143 (10 half lives)	0.1	0.001

S^{35} INFORMATION

Radioactive half-life	**87.4 days**
Decay mechanism	**Beta emission**
Energy	**E_{max} = 0.167 MeV**
Contamination monitoring	**Thin window Geiger Mueller detector, liquid scintillation counter for wipe surveys.**
Shielding	**1 cm Lucite**
Dosimetry	**Urinalysis bioassay**

- Radiolysis of S^{35} labeled amino acids may lead to the release of S^{35} labeled volatile impurities. Delivery vials should therefore be opened in a fume hood.

- S^{35} may be difficult to distinguish from C^{14}. If both nuclides are being used in the same laboratory, establish controls to ensure they are kept separate. If "unknown" contamination is found, treat is as C^{14}.

- Beta particles from S^{35} travel a maximum of 24 cm in the air.

- Most Geiger counters can not detect S^{35} and special precautions must be taken to keep the work environment clean.

- The maximum permissible burden to the whole body is 400 micro curies.

Safety Rules

- Designate a specific area of the laboratory for all S35 experiments.

- All personnel who handle S^{35} must wear full length laboratory coats.

- Many S^{35} compounds readily penetrate gloves and skin. Wearing two pairs of gloves and changing the outer pair every fifteen or twenty minutes will reduce the chance of contamination and absorption through the skin.

- Pipettes dedicated for the use of S^{35} should be used. These pipettes should not be used for other purposes as they are easily contaminated by S^{35}.

Laboratory Cleanup After Use

- Conduct wipe tests using the liquid scintillation counter checking all work areas and equipment used. Check the floor at the area where the isotope was used.

- If any contamination is found, use a commercial radiation contamination remover such as Count Off with paper towels to clean the contaminated area.

- Place the contaminated paper towels in a receptacle labeled as radiation waste.

- If the contamination can not be removed, label the area or equipment as radioactive noting the isotope, the date of contamination and the maximum cpm found.

- If any unremovable radiation is found, contact the University Radiation Safety Officer.

- Check the normal trash container to ensure that no radioactive waste was placed there.

- Store all radioactive waste in specially marked containers.

- Send a Radiation Survey report to the University Radiation Safety Officer.

I^{125} Information

Radioactive half-life	**59.6 days**
Decay mechanism	**Electron capture (gamma and x-ray emission)**
Energy	**27-35 KeV**
Contamination monitoring	**Thin crystal NaI detector, liquid scintillation counter for wipe surveys.**
Shielding	**thin lead**
Dosimetry	**Film badge, TLD ring, thyroid scan.**

- You must schedule a thyroid bioassay after using 1mCi or more of NaI, or in cases of suspected contamination.

- The dose rate at 1 cm from a 1 mCi point source is about 1400 millirems/hr. The quarterly NRC limit of 18,250 millirems for the hands can be reached in 13 hours. The limit for the whole body, 1250 millirems, assuming the source is three feet from the body, can be reached in 7440 hours.

- The dose rate is inversely related to the square of the distance from the source. Thus, while a small amount of I^{125} held for a short time can result in a significant dose to the hands, a relatively short separation distance reduces the dose rate to an acceptable level.

Safety Rules

- The volatility of iodine requires special handling techniques to minimize radiation doses. Solutions containing iodide ions (such as NaI) should not be made acidic or frozen. Both lead to the formation of volatile elemental iodine. Once bound to a protein, the volatility of the radioiodine is tremendously reduced.

- Always work in a fume hood with a minimum face velocity of at least 125 linear feet per minute when working with NaI. The sash should be lowered as practical as possible.

- Do not work directly over an open container of I^{125}.

- Use lead to shield quantities of 1 mCi or more. Every 1.7 mm of lead will reduce the gamma radiation emitted from I^{125} by 50%. Place the shield near a wall or in a hood away from the main flow of traffic.

- Avoid opening the septum on delivery vials. It is preferable to remove radioiodine using a syringe.

- Designate a specific area of the laboratory for all I^{125} experiments.

- All personnel who handle I^{125} must wear full length laboratory coats.

- Film badges must be worn for all radioiodine work, and finger badges are required when handling 1 mCi or more of I^{125}.

- All personnel handling I^{125} must wear a ring badge on the hand which is most likely to handle vials, samples, pipettes, etc., containing P^{32}.

- All persons in the laboratory must wear whole body film badges, even those who are not handling I^{125}.

- A Geiger counter must be in operation during the experiment and preferably at all times. Place Saran Wrap around the counter to avoid contaminating the detector.

- Use shoulder length gloves with short vinyl gloves on top to minimize skin absorption.

- Check your gloves frequently with the counter to detect contamination. If contaminated, immediately dispose of the gloves in a radiation waste container.

- Wearing two pairs of gloves and changing the outer pair every fifteen or twenty minutes will reduce the chance of contamination and absorption through the skin.

- Pipettes dedicated for the use of I^{125} should be used. These pipettes should not be used for other purposes as they are easily contaminated by I^{125}.

Laboratory Cleanup After Use

- Use the Geiger counter to check your hands, shoes, clothing, all work areas and equipment used. Check the floor at the area where the isotope was used. If your clothing is contaminated, it will have to be removed and stored until the radiation level decays to background.

- If any contamination is found on your hands, wash thoroughly with soap and water. This will usually be sufficient to remove surface contamination. If it does not, contact the University radiation Safety Officer for assistance.

- If any contamination is found on the work area or equipment, use a commercial radiation contamination remover such as Count Off with paper towels to clean the contaminated area.

- Place the contaminated paper towels in a Plexiglas receptacle labeled as radiation waste.

- If the contamination can not be removed, label the area or equipment as radioactive noting the isotope, the date of contamination and the maximum cpm found.

- If any unremovable radiation is found, contact the University Radiation Safety Officer.

- Check the normal trash container to ensure that no radioactive waste was placed there.

- Store all radioactive waste in specially marked containers.

- Send a Radiation Survey report to the University Radiation Safety Officer.

I^{125} Decay Rate

Elapsed Time (days)	% Remaining Activity	Decay factor
0	100.0	1.0
10	89.1	0.891
20	79.4	0.794
30	70.7	0.707
40	63.0	0.630
50	56.1	0.561
60	50.0	0.500
70	44.5	0.445
80	39.7	0.397
90	35.4	0.354
100	31.5	0.315
110	28.1	0.281
120	25.0	0.250
600 (10 half lives)	0.1	0.001

Incoming Radiation Material Inspection and Log

Date: ____________________

Laboratory: ____________________

Radioisotope: ____________________

Supplier: ____________________

Condition of Package: ______________ **(Intact or damaged)**

If damaged, describe condition of package ________________________

____

____

____

Background Count Rate **(R_b)** ____________
Counting Time **(t_b)** ____________
***Minimum sensitivity (MDA)** ____________

Containment Swipes

Containment Description (Can, bottle, etc.)	**Net CPM for swipes** (R_s - R_b)	****Net Activity of swipes** (uCi)
a. ______________________	______________	______________
b. ______________________	______________	______________
c. ______________________	______________	______________
d. ______________________	______________	______________

*MDA (µc_i) = F (3R(S (2xRb, tb)), efficiency x 2.22 E^6 DPM/µci)

** Net Activity (µci) = F (R_s - R_b, efficiency x 2.2 E^6 DPM/µci)

Definitions *

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

Act means Texas Radiation Control Act, Health and Safety Code, Chapter 401.

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

Adult means an individual 18 or more years of age.

Agency means the Texas Department of Health.

Agreement State means any state with which the U. S. Nuclear Regulatory Commission has entered into an effective agreement under Section 274b. of the Atomic Energy Act of 1954, as amended (73 Stat. 689).

Airborne radioactive material means any radioactive material dispersed in the air in the form of dusts, fumes, particulates, mists, vapors or gases.

Alpha Particle. A positively charged particle ejected spontaneously from the nuclei of some radioactive elements. It is identical to a helium nucleus with a mass number of 4 and an electrostatic charge of +2. It has low penetrating power and a short range. The most energetic alpha particle will generally fail to penetrate the skin. Alphas are hazardous when an alpha emitting radionuclide is inhaled or ingested into the body. Examples are Americium-241 and natural uranium.

As low as reasonably achievable (ARLA) means making every reasonable effort to maintain exposures to radiation as far below the dose limits in these regulations as is practical, consistent with the purpose for which the licensed or registered activity is undertaken, taking into account the state of technology, the economics of improvements in relation to the state of technology, the economics of improvements in relation to the benefits to the public health and safety, the other societal and socioeconomic considerations, and in relation to utilization of ionizing radiation and licensed or registered sources of radiation in the public interest.

Background radiation means radiation from cosmic sources; non-technologically enhanced naturally occurring radioactive material, including radon, except as a decay product of source or special nuclear material, and including global fallout as it exists in the environment from the testing of nuclear explosive devices. Background material does not include sources of radiation from radioactive materials regulated by the Agency.

Becquerel (Bq) means the SI unit of activity. One becquerel is equal to 1 disintegration or transformation per second (dps or tps).

Beta Particle A charged particle emitted by the atomic nucleus during radioactive decay. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron. Large amounts of beta radiation will cause skin burns and beta emitters are harmful if they enter the body. Beta particles are generally easily stopped by thin sheets of metal or plastic. Examples are tritium (3H), carbon-14 and phosphorous-32.

Bioassay or radiobioassay means the determination of kinds, quantities, or concentrations, and, in some cases, the location of radioactive material in the body, whether by direct measurement, in vivo counting, or by analysis and evaluation of materials excreted or removed from the human body.

CFR means Code of Federal Regulations.

Certificate of Registration means a form of permission given by the Agency to an applicant who has met the requirements for registration set out in the Act and the Texas Regulations for the Control of Radiation.

Curie (Ci) means a unit of measure of radioactivity. One curie (Ci) is that quantity of radioactive material that decays at a rate of 3.7×10^7 disintegration's per second (dps).

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

Gamma Rays are high energy, short wavelength electromagnetic radiation emitted from the nucleus. Gamma radiation frequently accompanies alpha and beta emissions. Gamma rays are very penetrating and best shielded by lead or uranium. Gamma rays are more energetic than X-rays. E.g., Iodine-125.

Gray (Gy) means the SI unit of absorbed dose. One gray is equal to an absorbed dose of 1 joule per kilogram (100 rad).

Ionizing radiation means any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, in its passage through matter. Ionizing radiation includes gamma rays and X-rays, alpha and beta particles, high speed electrons, neutrons and other nuclear particles.

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

Public dose means the dose received by a member of the public from exposure to sources of radiation from licensed or registered operations.

Quality factor (Q) means the modifying factor listed in tables I and II of 11.5 that is used to derive dose equivalent from absorbed dose.

Rad means the special unit of absorbed dose. One rad is equal to an absorbed dose of 100 erg per gram or 0.01 joule per kilogram (0.01 gray).

Radiation means one or more of the following:

(1) Gamma and x-rays; alpha and beta particles and other atomic or nuclear particles or rays;

(2) Stimulated emission of radiation from any electronic device to such energy density levels as to reasonably cause bodily harm; or

(3) Sonic, ultrasonic or infrasonic waves from any electronic device or resulting from the operation of an electronic circuit in an electronic device in the energy range to reasonably cause detectable bodily harm.

Radiation area is any area accessible to individuals in which there exists ionizing radiation at such levels that a major portion of the body could receive in any one hour a dose in excess of 5 millirems, or in any five consecutive days (40 hours) a dose in excess of 100 millirems.

Radioactive decay means the decrease in the amount of any radioactive material with the passage of time due to the spontaneous emission from the atomic nuclei of either alpha or beta particles, or gamma radiation.

Radiation machine means any device capable of producing ionizing radiation except those devices with radioactive material as the only source of radiation.

Radiation Safety officer means an individual who has a knowledge of and the authority and responsibility to apply appropriate radiation protection rules, standards and practices, and who must be specifically authorized on a certificate of registration or radioactive material license.

Radioactive material means any material (solid, liquid or gas) that emits radiation spontaneously.

Rem means the special unit of any of the quantities expressed as dose equivalent. The dose equivalent in rem is equal to the absorbed dose in rad multiplied by the quality factor (1 rem = 0.01 sievert).

Restricted area means an area, access to which is limited by the licensee or registrant for the purpose of protecting individuals against undue risks from exposure to sources of radiation.

Roentgen (R) means the special unit of exposure. One roentgen (R) equals 2.58×10^{-4} coulombs/kilogram of air.

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

Sievert means the SI unit of any of the quantities expressed as dose equivalent. The dose equivalent in sievert is equal to the absorbed dose in gray multiplied by the quality factor (1 Sv = 100 rem).

Survey means an evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal and/or presence of sources of radiation. When appropriate, such evaluation includes, but is not limited to tests, physical examination of location of materials.

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

* Additional definitions may be found in the Texas Regulations for the Control of Radiation, Part 11, page 11-1.