Radiation Safety Manual

PURPOSE:

Radioactive materials and radiation machines are used by Baylor University faculty, staff, and students. These materials are highly regulated by local, state, and federal entities. This manual ensures the compliant and safe use of all such materials and machines as required by law.

SCOPE:

This manual defines the acceptable use and possession of all radioactive materials or radiation machines emitting ionizing radiation by all Baylor University faculty, staff, and students.

RESPONSIBILITY:

It is the responsibility of each individual department at Baylor University to ensure that its students, faculty and staff use materials and machines which emit ionizing radiation in a legal, safe and compliant manner. The University Radiation Safety Officer (RSO) shall act as an advisory point of contact and the Department of Environmental Health & Safety (EHS) shall also offer advice and support where applicable. The Department of EHS and University RSO will manage the application of this manual.

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INTRODUCTION

TEXAS RADIOACTIVE MATERIAL LICENSE AND RADIATION CONTROL REGULATIONS

The Texas Regulations for the Control of Radiation 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 isotopes and accelerator-produced radio nuclides is required. Registration of all equipment designed to produce x-rays or other ionizing radiation is required.

Radioactive materials are used at Baylor University under the authority of the Texas Department of State Health Services, Bureau of Radiation Control which delegates specific licensing authority to a technically qualified Radiation Safety Officer (RSO). This authority includes approval of applications for use, issuance of notices of violations of state regulations of 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 State Health Services, Bureau of Radiation Control Regulations, and requires approval of the Radiation Safety Officer.

I. Responsibility of the Radiation Safety Officer

A. Establishment of Radiation Safety Policy

1. The Baylor University Radiation Safety Officer will establish radiation safety policy in compliance with Texas Department of State Health Services radiation policies.

2. The policy will be designed to…

    a. keep the University in compliance with state and federal regulations and the conditions of the University license.

    b. protect faculty, staff, students, visitors, and the public from hazardous levels of radiation.

    c. maintain all radiation exposure as low as reasonably achievable (ALARA).

3. The Radiation Safety Officer will review policies and modify them as appropriate.

B. Licensing

1. The Radiation Safety Officer will add faculty members to the appropriate license through the Texas Department of State Health Services for the use of radioactive materials upon submission of a written application and determination that safety requirements will be met.

2. The applicant must have adequate training and experience to safely handle the types and quantities of radioactive materials requested.

3. The applicant must have adequate space and equipment to safely handle the radioactive materials requested.

4. The applicant must agree to comply with guidelines stipulated in the Baylor University Radiation Safety Manual.

5. The Radiation Safety Officer may deny or rescind approval of a faculty member who…

    a. does not, in the opinion of the Radiation Safety Officer, have the experience or facilities to safely handle the radioactive materials requested.

    b. demonstrates a serious or chronic disregard for safety regulations or radiation safety policy.

6. No person may bring radioactive materials on campus or remove radioactive materials from campus without prior written approval of the Radiation Safety Officer.

C. Oversight of the Radiation Safety Program

1. The Radiation Safety Officer will review and advise on corrective actions.

    a. Faculty members may appeal decisions made by the Radiation Safety Officer in the implementation of the Radiation Safety Program, to the Radiation Safety Committee.

    b. The Radiation Safety Officer may bring to the Department Chair for resolution, problems with faculty members who they feel are not in compliance with Baylor University Radiation Safety Procedures.

2. The Radiation Safety Officer will review annually the Radiation Safety Program, including the Radiation Safety Manual, to ensure its effective operation.

D. Investigation of Incidents

1. An incident that causes an excessive radiation exposure or a potentially excessive exposure will be reported to and investigated by the Radiation Safety Officer to determine the cause and necessary remedial action.

2. Remedial action will be initiated by the Radiation Safety Officer to prevent any recurrence of the incident.

3. In the event of a serious disagreement between the Radiation Safety Officer and a faculty member over the causes or circumstances of an incident, the Radiation Safety Committee may conduct an investigation.

II. The Radiation Safety Officer

A. A Radiation Safety Officer shall be a person qualified by training and experience to give guidance and assistance in the safe use of ionizing radiation. RSO qualifications are codified in the Texas Administrative Code.

B. The Radiation Safety Officer is designated by the President of the University to carry out the policies of the Radiation Safety Program, ensure that state and federal laws and regulations as well as University regulations are complied with, and advise the faculty and staff in matters of radiation safety.

C. Duties

1. The Radiation Safety Officer is available to assist and advise users of ionizing radiation, and to ensure that all ionizing radiation is used in accordance with policies.

2. The Radiation Safety Officer shall inspect users of regulated materials and machines annually in order to ensure that users are operating safely and in compliance with applicable regulations.

3. The Radiation Safety Officer ensures proper filing of all records required by state and federal regulations and rules of good practice including, but not limited to, the following:

    a. personnel dosimetry records

    b. radioactive waste disposal

    c. isotope inventory

    d. instrument calibration

    e. leak tests on sealed sources

    f. radiation safety surveys

4. The Radiation Safety Officer offers courses of instruction for users and potential users of ionizing radiation.

5. The Radiation Safety Officer may require that users of ionizing radiation offer safety training to appropriate students, faculty, and/or staff.

6. The Radiation Safety Officer shall suspend, as rapidly as possible, any operation causing an excessive radiation hazard.

D. Authority

1. State and federal codes regulate the use of radioactive materials to ensure that radiation exposure to employees or the public does not exceed specified levels.

    a. The University receives its radioactive materials license from the Texas Department of State Health Services with appropriate regulations to ensure the safety codes are met.

    b. The Texas Department of State Health Services adds requirements to ensure that environmental releases are kept within limits established by the Environmental Protection Agency.

    c. The Department of EHS administers the Radiation Safety Program under the authority and within policies established by the Board of Regents and the President of the University.

2. The Radiation Safety Officer shall implement the state, federal, and university radiation safety policies through guidelines established. In extreme cases where a serious radiation hazard threatens, the Radiation Safety Officer may and should report immediately and directly to the University's Chief Compliance and Risk Officer, through the Director of EHS.

3. The Radiation Safety Officer may suspend any operation which violates, or which may result in the violation of, the policies set forth in this manual.

III. The Authorized User (AU)

A. Any person who wishes to use ionizing radiation on the University campus must submit an application to the Radiation Safety Officer.

B. The application may be approved, provided that the potential user furnishes evidence that the individual has training, experience, and equipment necessary to handle the radioactive material or radiation producing device in such a manner that:

1. no person will be harmed by or overexposed to ionizing radiation.

2. no state or federal regulations will be violated.

3. the Authorized User will be in compliance with the policies set forth in this manual.

C. Duties – It is the responsibility of the Authorized User:

1. to ensure that the policies in this manual are observed by all personnel in his/her laboratory.

2. to properly train new personnel before allowing them to work in an installation using ionizing radiation. Training shall include:

a. reading of this manual.

b. general rules of radiation safety.

c. ALARA – maintaining radiation dose As Low As Reasonably Achievable.

d. special rules for the specific laboratory involved.

e. directions for contacting the Radiation Safety Officer for assistance.

f. directions for notifying the proper authorities in the event of an emergency.

3. to post a concise list of radiation safety procedures, to be observed in his/her particular installation.

4. to see that surveys are made and records kept as required by the Radiation Safety Officer and this manual.

5. to keep an up-to-date inventory of radioactive materials under control of the authorized user.

6. to prepare and store radioactive waste material properly for disposal. (See Section VII).

7. to post proper radiation signs. (See Section VI.)

8. to forward to the Radiation Safety Officer all survey records and inventory control sheets prior to terminating employment with the University, or terminating radioisotope usage.

9. to treat all areas of any licensed laboratory as a radioactive materials area and observe all safety requirements. Eating or drinking is prohibited in areas which use radioactive materials or radiation emitting machines.

10. to ensure that neither radioactive materials nor contaminated equipment is removed from the radioactive materials area.

11. to ensure that no furniture or equipment is removed from the laboratory until it has been cleaned, surveyed for contamination, and radioactive warning signs removed.

D. A faculty member on sabbatical leave or absent for a period greater than 60 days must assign responsibility for his/her program to another certified, Authorized User who will be in charge of the laboratory in his/her absence. This person will be:

1. another faculty member who agrees in writing to accept responsibility for the laboratory or,

2. a resident post-doctoral researcher.

   a. This alternative may be utilized for a period not exceeding 12 months.

   b. The faculty member will leave a phone number with the Radiation Safety Officer so that he/she can be reached.

   c. The post-doctoral researcher will be approved by the department head who will notify the Radiation Safety Officer, in writing, of the arrangement and assume overall responsibility for the laboratory.

   d. The arrangement will be approved by the Radiation Safety Officer.

E. If the faculty member does not choose one of the options listed under “D” above, his/her radioactive materials will be transferred directly to…

1. another AU faculty member after approval by the Radiation Safety Officer.

2. the Radiation Safety Officer for disposition.

F. An AU faculty member who does not maintain annual training requirements will have a period of 30 days to complete one of the following alternatives:

1. Complete the training process.

2. Transfer all radioactive materials to a current AU faculty member and properly dispose of all radioactive waste.

3. Transfer all radioactive materials to the Radiation Safety Officer for disposition.

G. A faculty member who does not complete annual training requirements within 30 days of the due date will be reported to his/her supervisor, following the university's corrective action procedure, and may have their AU status revoked.

H. Any radioactive materials left in any laboratory without an AU faculty member in attendance for a period of 30 days or more will be collected by the Radiation Safety Officer.

I. Graduate students, undergraduate students, and post-doctoral associates must work under the direction of an approved faculty member.

J. All faculty and staff who work with radioactive material must obtain approval as an Authorized User from the RSO. A faculty member may not work under the authority of another faculty member unless specifically approved by the Radiation Safety Officer.

K. When leaving the University,or terminating his/her AU approval for any reason, an AU faculty member may relinquish the radioactive materials in his/her possession by disposal, or by transfer to another faculty member who is approved for the material.

1. To dispose of the material:

    a. Package and label the material properly for disposal. Call for a routine pickup. (See Section VII.)

    b. Disposal of large sealed sources, or other radioactive materials requiring special handling and extra expense, must be funded by the researcher or his department.

2. To transfer the material to another AU faculty member:

    a. Prepare a list of the isotopes, giving the amount, chemical form, and bar code number for each.

    b. Submit the list to the Radiation Safety Officer with a request for the transfer.

    c. Enclose a letter from the proposed recipient. The letter must…

        (1) state that the proposed recipient wants the radioactive materials.

        (2) describe the research or teaching program in which the material will be used.

        (3) agree to accept responsibility for the proper storage, handling, and eventual disposal of the radioactive materials.

d. If the radioactivity is in such a quantity or form so as to require special funding for disposal, a letter from the department head must be enclosed specifying that such funding will be made available when the source is no longer needed.

3. The Radiation Safety Officer will inspect the laboratory to determine whether it is free of radioactive materials and/or contamination.

4. In the event that a faculty member abandons radioactive material upon leaving the University and fails to arrange for proper disposal or transfer, the radioactive materials become the responsibility of his/her department. The course of action for abandonment shall be as follows:

   a. The Radiation Safety Officer will clean up or arrange for the clean up and disposal of the abandoned radioactive materials and remediate contaminated areas at the cost of the individual department.

L. When a faculty member retires, with or without emeritus status, his/her radioactive materials AU approval will terminate. The faculty member may apply to the Radiation Safety Officer for a new AU. If the Radiation Safety Officer can ascertain that the faculty member will have adequate facilities to store and handle the materials safely and that funds will be available, if needed for disposal, the retired faculty member may submit a new AU application for a specific time period to be determined by the Radiation Safety Officer.

M. When an AU faculty member wishes to obtain a radioactive source that will require special funding for disposal, he/she must submit a letter from the department head stating that the department will accept responsibility for funding the disposal of the source when it is no longer useful.

IV. Laboratory Procedures

A. Laboratories Using Unsealed Sources of Radioactive Materials

1. Isotope Procurement and Storage

   a. See Part XI for procedures for ordering isotopes.

   b. Isotope shipments must be listed by bar code number on the "Usage and Survey Log". The CISPro inventory system tracks all radioactive containers in the Baylor Sciences Building.

   c. Store radioisotopes in such a manner as to prevent unauthorized use or removal. Storage must be in a secure area or under lock and key when the laboratory is vacant <u>for any reason</u>.

   d. Radioactive materials must not be stored in refrigerators used for food. Radioisotopes must not be stored in any containers in the hallways.

e. Where two or more isotopes are suitable for the same experiment, the less hazardous one should be ordered.

Examples: Cobalt-59 rather than Cobalt-60, Strontium-85 or 89 rather than Strontium-90.

2. Training of Personnel

a. Post a concise list of radiation safety procedures in each laboratory.

b. It is the responsibility of the authorized user to ensure that all personnel are entered as members of their laboratories in the BioRAFT lab management system, so that the system will trigger the appropriate radiation safety training. Training topics include:

(1) principles of radiation safety.

(2) use of monitoring instruments.

(3) protective equipment to be used.

(4) how to contact the Radiation Safety Officer.

(5) reading of the Radiation Safety Manual; access to the manual must be available at all times to laboratory personnel.

(6) proper packaging of waste.

(7) decontamination procedure.

(8) proper record keeping.

3. Protective Equipment

a. Radiation Monitoring Badges

(1) Badges will be provided by the Radiation Safety Officer for persons who have to enter a high radiation area.

(2) Badges will be provided for persons working in any area where any person has received over 25% of the maximum permissible quarterly exposure within the past two years.

(3) Badges will be provided for any person who, in the judgment of the Radiation Safety Officer, might receive as much as 10% of the maximum permissible exposure for the year.

(4) Badges will be provided to any persons working with ionizing radiation who requests one.

b. A lab coat or apron, safety glasses, and gloves are a minimum requirement and must be worn when handling unsealed sources. Shoes with closed toes are required.

c. Gamma samples producing more than 37.5mrem/hr (3.75×10^{-4} Sieverts/hr) at contact should be handled with tongs. Hard betas such as those from 32P should be handled with tongs if the quantity exceeds 1 millicurie.

d. Fume hood requirements

(1) 1 millicurie of non-volatile may be approved for a laboratory without a fume hood.

(2) Up to 50 millicurie may be used in a standard fume hood when approved by the Radiation Safety Committee.

(3) Over 50 millicuries may be used in a radioisotope fume hood when approved by the Radiation Safety Committee.

4. Contamination

a. Absorbent paper with waterproof backing shall be used to cover the working surface of tables and hoods used for radioactive materials. Place absorbent surface up.

b. Any worker, who through accident or design causes contamination of working surfaces or equipment, is responsible for decontamination of the same.

c. In the case of extensive or dangerous level of contamination, the Radiation Safety Officer shall be called for advice and assistance.

(1) Any wipe sample of $100cm^2$ which gives a count more than 3 times background indicates that the area should be decontaminated.

(2) The Radiation Safety Officer must be notified if a wipe sample indicates more than 10,000 decays per minute per $100cm^2$ above background. Notification must be in writing.

d. All cases of contamination of persons or laboratory space must be reported to the Authorized User and Radiation Safety Officer.

5. Monitoring of non-sealed sources

a. A survey instrument capable of detecting the isotopes in use shall be available in each laboratory.

(1) Each laboratory must have a dedicated survey meter.

(2) The survey instrument must have an audible signal not requiring earphones. For laboratories using a beta emitter, the instrument must have a thin end window tube.

(3) The meter must have a calibration sticker visible on the meter.

(4) The meter must read in units of rem, cpm, or sieverts.

b. Monitoring instruments must be calibrated at intervals no longer than 12 months.

c. Hands, feet, and clothes shall be monitored before leaving the laboratory after handling radioactive materials.

6. Transfer of Radioactive Materials

a. Radioactive materials may be transferred from one Authorized User to another Authorized User only after written authorization of the Radiation Safety Officer.

b. Transport of radioactive materials off the campus in private vehicles is not permitted.

c. Isotopes defined for common carrier must be approved by the Radiation Safety Officer before shipment to assure they are properly packaged and all shipping papers are completed.

7. Surveys of non-sealed sources

a. A survey including wipe samples and/or dose rates must be made monthly when radioactive materials are used in the area. More frequent surveys should be made as necessary. These surveys are carried out by the RSO, who maintains the records of the surveys.

8. Waste Disposal

a. Radioactive waste must be properly packaged and labeled for disposal. (See Section VII.)

b. Written authorization is required for disposal by sewer of any radioactive material.

9. Posting and Labeling

a. Proper signs must be posted in all working and storage areas. (See Section VI "Radiation Warning Signs and Labels".)

b. All containers of radioactive material must be marked with isotope quantity and date. Containers of less than one microcurie being used in the laboratory with the user constantly present are exempt from this requirement.

10. Miscellaneous Laboratory Rules

    a. Only persons with permission from the Authorized User or qualified safety personnel may enter the laboratory.

    b. Eating, drinking, and smoking in the laboratory or pipetting by mouth is PROHIBITED.

    c. Unnecessary materials should not be taken into the laboratory.

    d. Wounds which might contain contamination should be reported immediately to the Authorized User and the Radiation Safety Officer.

    e. Volatile or potentially volatile radioactive materials must be handled in a fume hood rated for the prescribed amount of material.

    f. Routine thyroid measurements are required for persons working with more than 1 millicurie of Iodine-125 or Iodine-131.

B. Installations of X-Ray Producing Devices

1. All x-ray installations shall comply with the Texas Regulations for Control of Radiation. Also see section IX "Radiation Producing Devices".

2. All persons must be properly trained before being allowed to operate radiation producing equipment. Evidence or training must be documented and available for inspection.

3. Post the Texas Department of State Health Services Notice to Employees, BRC Form 203-1.

4. All radiation producing equipment that is in use must be surveyed periodically for leaks.

5. A proper radiation warning sign must be posted at all installations. (See Section VI.)

6. A concise list of safety procedures must be available at the installation. These instructions should include:

    a. who is responsible for the operation of the equipment.

    b. safe operating instructions.

    c. what monitoring device is to be used during operation.

    d. the defining of any laboratory access limitations during operation of the x-ray device.

e. an audible or visual indication of the radiation exposure when the equipment is on.

f. written emergency procedure in case of accident, injury, fire, or inability to normally stop x-ray production.

7. All persons who might receive more than 25 millirem (2.5×10^{-4} sieverts) in any one week must wear a film badge dosimeter.

8. In general, persons under age 18, (except those enrolled in x-ray training schools under the direct supervision of a qualified doctor of the healing arts) may be exposed to no more than 10 millirem (1.0×10^{-4} sieverts) per week.

9. The maximum radiation exposure in an uncontrolled area is 2.0 millirem (2.0×10^{-5} sieverts) in any 1 hour or 100 millirem (1.0×10^{-3} sieverts) in any 7 consecutive days.

10. Maximum exposure of workers in a controlled area is in general 100 millirem per week. (See Section V.)

11. Each radiation generator, except those used solely in the healing arts, which may produce more than 100 millirem in any 1 hour must have a warning signal or light at the generator.

12. All x-ray producing devices must be registered with the state of Texas.

13. For rules of specific installations, the Radiation Safety Officer should be consulted. Copies of the State Regulations are available.

C. Sealed Sources

1. A proper sign must be posted at each installation. (See Section VI.)

2. A concise list of safety instructions must be posted.

3. Post Notice to Employees.

4. Persons who, in the judgement of the RSO, may receive as much as 10% of the maximum permissible dosage for the year will be required to wear a monitoring badge.

5. Exposure levels in any uncontrolled area should not exceed 2 millirem per hour.

6. Radiation levels in a controlled area should not be such that any person could receive more than 100 millirem in any 1 week.

7. Persons under 18 must not be exposed to more than 10 millirem per week.

8. Licensed sealed sources must be checked for leakage every 6 months, with analysis of such tests performed by Suntrac, Inc. of League City, TX. Detection

of 0.005 microcuries or more on a leak test will be taken as evidence that the source is leaking. Leaks must be reported to the Texas Department of State Health Services immediately, followed up by a written report within 5 days. Sealed sources containing less than 100 microcurie of beta/ gamma or 10 microcuries of alpha emitters do not have to be tested. Leak tests will be performed by the RSO.

9. Any sealed source which is not fastened to, or contained in an exposure device must have permanently attached to it, a durable tag at least 1 inch square, bearing the radiation symbol and the words **"Danger-Radioactive Material – Do Not Handle – Notify Civil Authorities if Found."**

10. No sealed source may be removed from the University campus unless specific authorization is contained in the University license.

11. A physical inventory of all sealed sources will be performed by the RSO at intervals not exceeding 6 months.

D. Miscellaneous Regulations

1. The Radiation Safety Officer must be notified before any radioactive material or radiation producing device is brought on campus.

2. The Radiation Safety Officer will provide, upon request, a copy of any individual's exposure to that individual.

3. Any radioactive material shipped or transported must conform to US Department of Transportation Regulations.

4. Radioactive materials will not be used in any laboratory where general safety conditions are seriously deficient and might add to the radiation hazard in case of accident. Examples of such conditions are:

   a. excessive storage of flammables

   b. excessive storage of explosive materials

   c. unsecured compressed gas cylinders

   d. unsafe experimental techniques

   e. excessively cluttered laboratory

   f. no safety shower or eye wash

5. Quantities of radioactive materials or the use of procedures that exceed the laboratory facilities available for safe handling are specifically prohibited.

E. Decommissioning a Radioactive Material Work Area

1. Decommission – to remove a facility or site safely from service and reduce residual radioactivity to a level that permits release of the property for unrestricted use and/or termination of license requirements.

2. The responsible Authorized User shall notify the Radiation Safety Officer when a designated radiation work area will no longer be used for radioactive material.

   a. The Radiation Safety Officer shall conduct a final room survey to the indicating that the room is acceptable to be released for unrestricted use.

   b. Proper radiation safety postings and security shall be maintained until removal is approved by the Radiation Safety Officer.

3. The Radiation Safety Officer may terminate use of the work area by amending the Radioactive Material License and receiving approval from the Texas Department of State Health Services.

4. All records of decommissioning shall be maintained in the Department of EHS (RSO files).

V. Personal Exposure

A. Adults: The occupational dose to individual adults shall not exceed the following annual dose limits:

   1. total effective dose equivalent of 5 rem

   2. the deep dose equivalent and the committed dose equivalent to any individual organ tissue, other than the lens of the eye, of 50 rem

   3. eye dose equivalent of 15 rem

   4. skin or extremity shallow dose equivalent of 50 rem

B. Minors: The annual dose limits for minors shall not exceed 10% of the annual dose limits specified above for adult workers.

C. Declared pregnant women: Dose to the embryo / fetus of a pregnant woman shall not exceed 500 mrem during the entire pregnancy, nor 50 mrem per month. (See Section XIII.)

D. Exposure of individuals to airborne radioactive materials requires the approval of the Radiation Safety Officer.

E. In accordance with the ALARA policy, exposures must be maintained as low as reasonably achievable. Any time a person receives an exposure greater than 125 millirem in one monitoring badge reporting period, the exposure will be evaluated to determine if it could be reduced.

F. Annual dose limit to the public must be less than 100 millirem.

VI. Radiation Warning Signs and Labels

A. A radiation warning sign shall be posted at each laboratory entrance door where ionizing radiation may be present. Radiation signs, as well as other hazard signs, should be posted as required by the individual laboratory. Individual signs should be used as necessary within the laboratory. Sites where radioactive materials are stored or manipulated must be indicated by radiation signs or symbols.

B. The posted information shall include the standard symbol, special precautions to be observed when entering the area, and the name of a person to be contacted in case of emergency.

C. Sign requirements may be obtained from the Radiation Safety Officer.

D. In general, the following signs are used:

1. CAUTION RADIOACTIVE MATERIALS

    a. This sign should be posted wherever unsealed sources of radioactive materials are used or stored.

    b. It may also be used for sealed sources where the radiation exposure is less than 5 millirem per hour at 6 inches.

2. CAUTION RADIATION AREA

    a. This sign should be posted wherever radiation exposure is such that one might receive more than 2 millirem/hour, or a total of 5 millirem.

    b. If the source is in a container, the level may be measured at 6 inches from the container.

3. CAUTION HIGH RADIATION AREA

    a. This sign should be posted when radiation exposure is such that one might receive more than 100 millirem in any 1 hour.

    b. High radiation areas which will exist for 30 days or more require visible or audible warning signals.

    c. Any high radiation area which does not have an interlock to deny entry to the area should have an operator on duty at all times.

4. CAUTION HIGH RADIATION (when unit is operating)

    a. This sign is for devices which emit ionizing radiation only when turned on (x-ray devices, accelerators, etc.).

5. CAUTION RADIOACTIVE CONTAMINATION

a. This sign should be posted while decontamination procedures are being carried out.

b. Posting of the signs should never be allowed to replace immediate cleanup of the contamination.

c. The person responsible for contamination is responsible for decontamination.

d. In case of serious contamination, the Radiation Safety Officer should be notified.

6. CAUTION HIGH INTENSITY X-RAY BEAM

a. This sign shall be posted or adjacent to each x-ray tube housing so as to be clearly visible to any individual who may be working in close proximity to the beam path.

b. This sign applies to non-medical, open beam x-ray equipment.

E. Smaller signs of the stick-on type, tags, or radiation tape may be purchased by the AU faculty member to designate areas or containers used for radioactive materials. However, proper signs of the above types should be used to designate all areas where ionizing radiation is present.

1. All containers of radioactive materials should be labeled with…

a. isotope,

b. quantity,

c. date,

d. chemical form (where possible).

2. Containers being used in the laboratory with less than 1 microcurie and with the user constantly present need not be labeled.

3. Any Sealed source which is not fastened to or contained in a radiographic exposure device shall have permanently attached to it a durable tag at least 1 inch square bearing the radiation symbol and the following instructions: **“Danger—Radioactive Material—Do not Handle—Notify Civil Authorities if Found”**

VII. Waste Disposal

A. A 2.5 gallon linear polyethylene carboy for used liquid radioactive materials is recommended because of its portability, ease of storage, and resistance to corrosion.

B. Liquid radioactive materials will be collected in separate containers as follows:

1. Aqueous materials containing long half-lived isotopes

   a. Use this container for aqueous materials only.
   b. No organic solvents or hazardous chemical shall be placed in this container.
   c. No solids or any materials which are insoluble in water shall be placed in this container.
   d. No materials too viscous to pass through a 20 mesh sieve shall be placed in this container.

2. Aqueous materials containing short half-lived isotopes
   a. Use this container for aqueous materials only.
   b. No organic solvents or hazardous chemicals shall be placed in this container.
   c. No solids or any materials which are insoluble in water shall be placed in the container.
   d. No materials too viscous to pass through a 20-mesh sieve shall be placed in this container.

3. Biodegradable liquid scintillation fluid containing long half-lived isotopes other than H-3 and C-14 only
   a. No organic solvents shall be placed in this container.
   b. No solution containing more than 0.05 microcuries per gram may be placed in this container.
   c. No materials too viscous to pass through a 20-mesh sieve shall be placed in this container.

4. Biodegradable liquid scintillation fluid containing H-3 and C-14 only
   a. No organic solvents shall be placed in this container.
   b. The addition of any other radioactive materials to this container will prevent its proper disposal.
   c. No solution containing more than 0.05 microcuries per gram may be placed in this container.
   d. No materials too viscous to pass through a 20-mesh sieve shall be placed in this container.

5. Biodegradable liquid scintillation fluid containing short lived isotopes
   a. This material will be held for decay prior to disposal if the half-life is less than 90 days.

b. Only liquid scintillation fluid utilized as counting solution for short lived isotopes shall be placed in this container.

6. Non-biodegradable liquid scintillation fluid containing long half-lived isotopes other than H-3 and C-14 only

    a. No organic solvents other than those used as counting solution shall be placed in this container.

    b. No solution containing more than 0.05 microcuries per gram may be placed in this container.

    c. No materials too viscous to pass though a 20-mesh sieve shall be placed in this container.

7. Non-biodegradable liquid scintillation fluid containing H-3 and C-14 only

    a. No organic solvents other than those used as counting solutions for H-3 and C-14 labeled substances shall be placed in this container.

    b. The addition of any other radioactive materials to this container will prevent its proper disposal.

    c. No solution containing more than 0.5 microcuries per gram may be placed in this container.

    d. No materials too viscous to pass through a 20-mesh sieve shall be placed in this container.

8. Non-biodegradable liquid scintillation fluid containing short lived ($T_{1/2}$~<90 days) isotopes

    a. These materials will be held for decay prior to disposal if the half-life is less than 90 days.

    b. Only liquid scintillation fluid utilized as counting solution for short lived ($T_{1/2}<90$ days) isotopes shall be placed in this container.

9. Organic solvents other than liquid scintillation fluid containing long half-lived isotopes ($T_{1/2}>90$ days) shall be placed in a separate container.

10. Organic solvents other than liquid scintillation fluid containing short half-lived isotopes ($T_{1/2}<90$ days) shall be placed in a separate container.

C. Liquid scintillation vials containing counting solution with carbon-14 and/or tritium should be placed in a zip-lock bag for radioactive material disposal.

D. Liquid scintillation vials containing radioactive materials other than carbon-14 and/or tritium should be placed in a separate zip-lock bag for radioactive material disposal.

E. All liquid radioactive materials will be analyzed for content and activity upon pick-up. Any improperly packaged or labeled containers will be returned to the Authorized User for repackaging. Carboys will be recycled to the Principal Investigator when the contents have been properly disposed. This procedure may take some time and one should be aware that additional carboys may need to be purchased occasionally.

F. Used radioactive materials are collected by Baylor University EHS Department. Used radioactive materials are not officially designated as waste until they have been received and classified. Channels of disposal include storage for decay, minute amounts disposed via sewer, and shipment to a commercial disposal site.

G. Collection Procedures for Used Radioactive Materials

1. General Requirements

a. Each container must have a "Radioactive Waste Disposal Tag" available, either attached to the container or at a nearby location. (A clipboard hanging in a readily accessible spot is acceptable.)

(1) The room number, isotope identification and form, and date of first addition must be filled out when the container is placed in use.

(2) The sheet must be completely filled out before time for pickup of the container.

(3) It is recommended that the data be added to a separate waste log form each time that material is added to the container, rather than estimating when the container is full.

(4) Do not overfill carboys. The liquid level must be at least 1 inch below the top of the carboy.

(5) Do not place viscous materials in a carboy. The material must pass readily through a 20-mesh sieve.

b. Each waste container must have a radiation warning symbol attached.

c. Long and short lived radioactive materials must be collected in separate dry materials drums. Carbon-14 and tritium are long lived. Isotopes with half-lives less than 90 days are short lived. Contact the Radiation Safety Officer about materials which do not fall in either of these classes. Replacement drums will be furnished by the Radiation Safety Officer when available, as drums are emptied for compaction, or after storage for decay. It may occasionally be necessary for a researcher to buy a replacement drum.

2. Dry Solid Materials

   Place all dry solid materials in an approved 30 gallon drum marked "DRY SOLID MATERIAL ONLY." This drum must be lined with a bag of at least 6 mil thickness. Small amounts of water containing non-volatile radioactive materials may be absorbed on paper in these drums. However, no liquid of any kind can be accepted. The presence of one small vial containing a milliliter of solution may result in the entire drum being refused at the disposal site! Empty glassware, excluding liquid scintillation vials, may be disposed of as dry solids. No liquid scintillation vials or caps may be placed in this container! All radioactive materials labels must be defaced or removed before placing any object into the solid waste container.

3. Sharp Objects

   Hypodermics, broken glass, and other sharp objects must be packaged to avoid injury to persons who must handle the waste. Place such objects in a plastic jar or metal container and secure with tape before placing them with the solid materials. Do not use "RADIOACTIVE MATERIALS" tape to secure the container before it is placed in the solid materials container.

4. Uncontaminated Materials

   Do not place uncontaminated materials in the used radioactive container. Packing, boxes, and other such materials, when not contaminated, should be placed in the non-radioactive waste can for disposal at the city landfill.

5. Animal Carcasses and Animal By-Products

   Contact the Radiation Safety Officer for special packaging instructions before conducting any experiment which will produce animal carcasses or by-product.

6. When Materials are Ready for Pickup

   a. Make sure that the consolidated materials sheet contains all required information.

   b. Contact the Radiation Safety Office. Specify the type of material and size of container.

      (1) Improperly packaged materials will not be picked up.

H. No radioactive materials may be disposed of by sewer without specific approval. In case such disposal is approved, records must be maintained listing isotope, amount, and date of disposal.

I. Mixed waste is waste which contains hazardous chemicals in addition to radioactive material. Both the chemical and the radiation hazard must be considered in the disposal of this waste. Sometimes the hazardous chemical can be neutralized or otherwise rendered harmless so that the material can be disposed of as radioactive waste. Sometimes the radioactive material can be held for decay and the chemical then disposed of as a hazardous chemical.

If the radioactive material is long lived and the chemical not easily rendered harmless, a commercial waste disposal company must be found to dispose of the waste. The cost for disposal may be excessive. For some types of hazardous chemicals and radioactive materials mixtures, there are no approved methods of disposal.

Examples of hazardous waste that present severe disposal problems are the following:

1. Solvents containing chlorine, sulfur, or nitrogen and a long lived radioactive material. These materials cannot be incinerated in most incineration systems. While some organic materials, such as toluene, can sometimes be incinerated, they often need to be held for long periods of radioactive decay before incineration. This may be a violation of federal regulations on storage of hazardous materials.

2. Aqueous or organic solutions containing pesticides or other hazardous chemicals and long lived radioactive materials. All university faculty members are urged to avoid producing mixed waste when possible. The use of biodegradable liquid scintillation fluids can greatly reduce the quantity of mixed waste, since the biodegradable solutions do not contain substantial quantities of hazardous chemicals.

J. Supplemental Information on Disposal of Waste

1. General Information

   a. Used radioactive materials are designated as waste only after being collected, analyzed, if necessary, classified, and designated for specific methods of disposal. Some may be recycled.

   b. All used radioactive materials must be collected in approved containers. Typically, solid materials are collected in 30 gallon fiber drums and liquids are collected in 2.5 gallon carboys.

   c. A standard waste disposal sheet must be displayed on each container offered for disposal.

      (1) Display the disposal sheet open on the side of the carboy or the top of the drum. Do not fold.

      (2) Fill out all required information.

      (3) Write legibly. Use units specified at the top of the column.

      (4) Record all totals before offering the container for disposal.

d. Do not place any liquids in dry waste drums or any solids in liquid carboys.

e. The AU faculty member is responsible for all radioactive materials until pickup.

f. Once waste is picked up by the RSO, it will either be held for decay-in-storage (P-32) and then disposed of as regular or hazardous waste; or it will be held for pickup by Bionomics, Inc.

g. Biodegradable liquid scintillation fluid containing P32 may be held in the lab by the AU for decay-in-storage for a minimum of 10 half-lives (142 days) and then disposed of as regular nonhazardous liquid waste. Waste must be held in an area designated for radioactive materials, with appropriate shielding to prevent exposure. Verify dosage is at background before release as nonhazardous material.

2. Collection of Liquid Waste

a. Do not place any solid materials in liquid waste carboys. Filter papers, glass objects, and plant materials are prohibited. Materials too viscous to pour readily through a 20-mesh sieve cannot be accepted. Precipitates must be filtered out.

b. Do not overfill carboys. The liquid level should be approximately 1 inch below the top of the carboy. Most carboys have a 2.5 gallon mark. Carboys may be filled to this point.

c. Viable bacteria, yeast, or other biological materials are not permitted. Clorox or other appropriate material may be added to aqueous carboys to insure that no active microorganisms are present. Do not add over 10% Clorox.

d. Isotopes with half-lives greater than 90 days should not be mixed with isotopes having half-lives less than 90 days.

e. Carboys may be returned to the AU faculty member after disposal of waste. Since carboys may have to be held for decay or for scheduling of disposal by sewer or incineration, extra carboys should be purchased by the researcher if his/her supply is exhausted.

f. All material in aqueous carboys must be miscible with water. No layering is permitted.

g. Liquid scintillation fluid containing carbon-14 and/or tritium should be collected separately from other radioisotopes. Liquid scintillation fluid should contain no more than 0.05 microcurie per gram of carbon-14 and tritium combined.

h. Liquid scintillation fluid carboys should contain only counting samples and organic wash solution used to rinse counting vials. High level activity such as that from stock bottles cannot be disposed as liquid scintillation fluid.

i. No liquid scintillation vials or caps are permitted in solid waste drums.

j. The use of non-biodegradable liquid scintillation fluids is not recommended.

k. Organic liquids other than liquid scintillation fluid should be collected in a separate carboy for pickup. Small amounts of organic compounds which are included in liquid scintillation samples or used to rinse out scintillation vials may be included in liquid scintillation carboys for incineration.

3. Disposal by Sewer

   a. State regulations permit the disposal of small amounts of liquid containing radioactive materials by sewer, provided specific requirements are met.

   b. There are limits for both quantity and concentration which vary for different isotopes.

   c. In order that university researchers do not violate any regulations concerning sewer disposal, consult with the Radiation Safety Officer.

4. Collection of Solid Waste

   a. Solid radioactive waste must be collected in an approved container. A 6 mil plastic liner must be used.

   b. Each researcher should keep an adequate supply of drums on hand. Empty drums will be returned to laboratories when available.

   c. Drums will be held until the waste material is emptied. Long lived waste (half-life greater than 90 days) will be compacted for shipment to a commercial site. Short lived waste will be held for decay for 10 half-lives, then disposed of as non-radioactive waste.

   d. When no empty drums are available, the researcher will be responsible for procurement of more drums as needed. If the name of the researcher is written on the drum, the drum may be returned to his/her lab when empty.

   e. Empty drums will not be stored. If the faculty member who purchased the drum does not want it back when empty, the drum will be issued to a laboratory where an empty drum is needed.

   f. Under no circumstances should liquid scintillation vials or caps be placed in a dry waste drum.

   g. Sharp objects such as broken glass, Pasteur pipettes, and hypodermic needles must be secured in a box or metal container before being placed in a drum. Combustible waste (paper, plastic, rubber gloves) may be placed directly into the drum.

h. Long lived waste (half-life greater than 90 days) must be collected in a separate drum from short lived (half-life less than 90 days) waste.

i. Slightly damp paper can be placed in solid waste drums. No free running water can be accepted either inside containers or as wet objects in the drum. Glass, plastic, or other materials containing visible water droplets must be dried before being placed in the waste drum. Mud and wet plant materials are prohibited.

j. Paper or other materials that do not have detectable activity should not be disposed of as radioactive waste. This material should be disposed of as ordinary trash. Examples of this type of material are radioactive shipping containers and bench-cote which contain no detectable activity. Glassware and plastic ware may also often be disposed of as ordinary trash. Only materials with detectable activity should be disposed of as radioactive waste.

k. Washes should be collected and evaluated for waste status.

l. Contaminated dust which can become airborne must be sealed in a separate plastic bag inside the solid waste drum. Examples of this type of material include dust, sawdust, powders, and dry plant materials.

m. All radioactive materials stickers must be defaced or removed before being put into the solid waste drum.

VIII. Radiation Surveys

A. For Gamma Emitters

1. Wipe Survey (for highest sensitivity)

a. Use filter papers (about 1 inch in diameter).

b. Smear area approximately 100 square centimeters with each paper.

c. Use enough papers for thorough survey of suspected area.

d. Count samples with a gamma analyzer with sodium iodide crystal, placing sample as close as possible to the detector.

e. If a gamma analyzer is not available, a Geiger tube with scalar may be used although the efficiency is much less than with a gamma analyzer.

f. A liquid scintillation counter can also be used for gamma although the efficiency is lower than a gamma analyzer with a sodium iodide crystal.

2. Geiger Survey (for rapid information)

a. Use a thin window Geiger survey meter.

b. Indicates presence of contamination only – precision is very low.

B. For Beta Emitters

1. Wipe Survey (for highest sensitivity – a must for carbon-14 and tritium)

   a. Use 1 inch filter papers or cotton swabs.

   b. Smear an area approximately 100 square centimeters with each paper.

   c. Use enough papers for thorough survey of suspected area.

   d. Drop each paper into a vial containing liquid scintillation counting solution and count.

   e. If a liquid scintillation counter is not available, a windowless flow counter may be used for the filter papers.

   f. For high energy betas such as those from phosphorous-32, the samples can be counted with a Geiger counter and scalar. This system is poor for carbon-14 and useless for tritium.

2. Geiger Survey (P-32 only)

   a. Use a Geiger counter with thin end window probe. This method only works for high energy betas such as phosphorus-32. It is poor for carbon-14 and useless for tritium.

   b. Conduct the wipes as you would normally, but leave them dry and survey directly with the Geiger counter. Be sure to convert units to decays per minute to record on the survey form.

C. For Alpha Emitters

1. Take smears as for beta surveys and count by liquid scintillation or windowless flow counter.

2. A Geiger counter with thin end window can detect alpha radiation at close range.

D. A survey shall be made at least once per month where radioactive material is used and more often if conditions warrant.

E. Results shall be recorded on the form provided by the Radiation Safety Officer and kept available for inspection by the Radiation Safety Officer or state or NRC inspectors. NOTE: All radiation surveys must be documented with the following information:
   - instrument used and its calibration date
   - name of person completing the survey
   - date of survey

- location of survey
- survey results

F. Decontamination Requirements

1. If contamination on a wipe sample of $100cm^2$ is greater than 3 times background…

   a. decontaminate the area.

   b. resurvey after decontamination to verify the area is clean.

   c. record results on a standard survey form and retain for monthly survey records.

2. If contamination on a wipe sample is greater than 10,000 decays per minute per $100cm^{2}$…

   a. immediate decontamination is required.

   b. the Radiation Safety Officer must be notified in writing. The Radiation Safety Officer will provide advice and assistance if required.

   c. record results on a standard survey form (also include results after decontamination). Retain for monthly survey records.

3. Surveys performed by Radiation Safety Officer detecting greater than 2000 $dpm/100cm^2$ will result in immediate oral and written notification to the user.

   a. Immediate decontamination is required.

   b. Record results of decontamination on the form provided by Radiation Safety Officer. Failure to comply with (1) and (2) above will result in the withholding of all orders for radioactive materials until decontamination has been verified.

G. Decontamination procedures generally fall into two categories: chemical and physical removal.

1. Chemical

   a. Usually can be accomplished by using soap or detergent and water.

   b. Dilute acid, base, or other strong cleaning agent may be required.

   c. Any solution used in decontamination will be disposed of as liquid waste.

   d. Any paper towels, kim wipes, cloth or rags will be disposed of as solid waste.

2. Physical

a. Removal of the contaminant by chipping, grinding, abrasion, or by covering with tile, paint, etc. (depends on type of emitter and half-life)

b. Care must be exercised to avoid formation of aerosols or dusts.

3. Decontamination should be continued until a wipe sample taken on the surface indicates no more than 3 times above background.

IX. Radiation Machines

A. General Safety Provisions

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

2. 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 closed systems.

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

B. Texas Regulation of Radiation Machines

This section provides special requirements for analytical x-ray equipment. The requirements of this section 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 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 the 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.

1. 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 RSO for an exemption for 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 the devices cannot be used.

   (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.

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

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

   c. Ports

   (1) Unused ports on radiation machine sources housing shall be secured in the closed position in a manner which will prevent casual opening.

d. Required Labeling

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

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

e. Warning Lights

(1) 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.

(2) On equipment installed after the effective day of these regulations, warning lights shall have fail-safe characteristics.

2. Area Requirements

a. Radiation Levels

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 regulatory limits. These levels shall be met at any specified tube rating.

b. Surveys

Radiation surveys of all analytical x-ray systems sufficient to show compliance with state regulations 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 procedure requires 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.

(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).

(7) Radiation survey measurements shall be completed on an annual basis.

c. Posting

Each area or room containing analytical x-ray equipment shall be conspicuously posted with a sign or sign bearing the radiation symbol and the words "Caution-X-Ray Equipment" or words having a similar intent.

d. 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.

e. Bypassing: No person shall bypass a safety device unless such person has obtained the approval of the Radiation Safety Officer. When 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.

3. 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 precaution required in such cases.

(3) proper operating procedures for the equipment.

(4) radiation safety, including symptoms of an acute localized exposure.

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

b. Personnel Monitoring

Badge dosimeters 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.

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

C. Decommissioning of a Radiation Machine

1. Decommission – when a registrant decides to terminate all activities involving a radiation machine authorized under the Radiation Safety Program

2. The responsible user shall notify the Radiation Safety Officer when a radiation machine will no longer be used at Baylor University.

   a. The user and Radiation Safety Officer will determine disposition of the device.

   b. The Principal Investigator shall complete a Baylor University Equipment Release form as described in the Laboratory Equipment Decommissioning policy.

   c. A device may be transferred to another registered user following proper regulations for shipping and transfer.

   d. A device may be disposed of by first removing its capability of producing radiation. Deface all radiation signage prior to disposal.

3. The Radiation Safety Officer shall notify the Texas Department of State Health Services to ensure the University's registration is maintained current.

4. All records of decommissioning shall be maintained in the Department of EHS (RSO files).

X. Emergency Procedures

A. Contamination or spill

1. Notify the Authorized User and the Radiation Safety Officer.

2. Avoid spread of contamination.

   a. Keep persons who may be contaminated from leaving area until surveyed.

   b. Do not enter or allow any unauthorized persons to enter the area and become contaminated.

3. Begin decontamination after a proper survey and when decontamination equipment is available.

4. The Radiation Safety Officer will notify the Texas Department of State Health Services in the case of large spill as required by Rules and Regulations for Radioactive Materials.

5. Procedure for decontamination

   a. Wash with soap and water, or RadCon if available.

      (1) Use a minimum amount of water.

      (2) Wipe up the water with absorbent material.

      (3) Place the absorbent material in a plastic bag for disposal as contaminated waste.

      (4) Check by taking wipes and counting after each decontamination procedure.

   b. If contamination remains, repeat the above procedure using dilute hydrochloric acid or a commercial cleaning solution.

   c. If contamination still remains, repeat the procedure using dilute ammonia.

   d. Time may be saved by considering the chemical form of the radioactive material before decontamination is started, and choosing the appropriate cleansing agent.

B. Personal Injury

1. Primary concern is for care of the injured person.

2. Notify the Authorized User, the Radiation Safety Officer, and Baylor Police in the case of an emergency.

3. A person with a contaminated injury will be taken to Hillcrest Hospital for treatment.

4. Avoid the spread of contamination insofar as it is compatible with getting proper treatment for the injured person.

5. The Radiation Safety Officer will notify public health officials as required by Texas law.

C. Fire

1. Proper signs should be posted on all laboratory doors so that firemen or other emergency personnel can determine the extent of the hazard. It is important to fill out the spaces provided for…

   a. the type of hazard which is present.

b. special precaution to be observed.

c. name and phone number of the person to notify in case of emergency.

2. Notify the Department of EHS and/or Radiation Safety Officer.

3. A survey should be made as soon as possible after the fire is under control. From this point onward, the incident should be treated as any other spill with decontamination of personnel and prevention of the spread of contamination as the primary goals.

D. Immediate notification of the Texas Department of State Health Services by telephone and confirmation letter is required in the case of excessive exposure to individuals, large releases of radioactive materials, loss of working time, or property damage in excess of $100,000. Twenty four hour notification is required for lesser incidents. Exact details are spelled out in Texas Department of State Health Services regulations. The Radiation Safety Officer will normally be responsible for this notification. In the absence of the Radiation Safety Officer, the Authorized User is responsible for notification.

E. Notify the RSO immediately if radioactive material is lost or stolen from your laboratory. The RSO will notify the local authorities and Texas Department of State Health Services as required by regulation. In the absence of the Radiation Safety Officer, the Authorized User is responsible for notification.

XI. Procurement of Radioactive Materials

A. Policy

Under university policy, orders are placed for radioactive materials only after receiving approval of the Radiation Safety Officer. Direct purchases from suppliers by petty cash, COD, or otherwise, are prohibited regardless of the amount to be expended. Campus radioisotope deliveries will be made through the Radiation Safety Officer or Baylor Science Building stock room.

B. Ordering Procedure

To place an order for radioactive materials, users should first contact the Radiation Safety Officer and request authorization, using forms available on the Baylor Radiation Safety web site.

C. Order Placement

The AU must complete a Radioisotope Order Request and receive approval from the RSO prior to making an order. Each department is responsible for ordering radioisotopes for their Authorized Users.

D. Delivery

The chemical stockroom must be notified when making an order. All incoming radioisotope deliveries must be made directly to the Baylor Science Building stock room. The chemical stock room will immediately notify the Authorized User upon receipt. The Authorized User must collect the radioisotope from the stockroom and complete receipt inspection within 3 hours. The central receiving section will not be involved with such deliveries and therefore, will not perform any automatic follow-up function on outstanding isotope orders. The user, or his support staff, will be responsible for follow-up activity, and the University budget office should be notified by the user.

E. Inspection and Re-delivery

1. Each shipment must be surveyed for contamination (See Appendix F for the Standard Operating Procedure for Radioactive Material Receipt). A Survey and Usage Log must be used for each container. The Survey and Usage Log should be kept on file when the shipment has been used up and disposed of.

2. Any shipment of radioactive material with more than 2200 decays per minute of removable contamination on either the outside package or the inside container will be considered unacceptable. The RSO should be notified immediately, and the RSO will report the shipment to the TDHS. The vendor will be contacted and arrangements made for replacement shipment. The unacceptable shipment will be disposed of appropriately.

XII. Notices, Instructions, Reports to Workers, and Inspections

A. Posting Current Notices

1. Current copies of the Baylor University Radioactive Materials Licenses, Code of Federal Regulations, Radiation Safety Manual, Safety Procedure, and other information required by the Texas Department of State Health Services may be examined at the Baylor University EHS web site, in the Radiation Safety section.

2. Any notice of violations involving radiological working conditions must be posted within 2 working days after the receipt of the document from the Texas Department of State Health Services. The response submitted by the Radiation Safety Officer shall be posted for a minimum of 5 working days or until corrective action has been completed, whichever is later.

B. Instructions to all Individuals Working in or Frequenting a Portion of a Controlled Area

1. It is the workers' responsibility to report to the Radiation Safety Officer any condition which may lead to or cause a violation of Baylor University regulations or unnecessary exposure to radiation or radioactive materials.

2. Each individual shall be instructed in the appropriate response to warnings made in the event of any unusual occurrence or malfunction that may involve exposure to radiation or exposure to radioactive materials.

C. Notifications and Reports to Individuals

1. Upon request, exposure records will be forwarded within 30 days to any individual currently or formerly employed by Baylor University.

2. Each incident of overexposure shall be forwarded in writing to the Texas Department of State Health Services within 30 days.

D. Presence of the Baylor University Staff and Workers During Inspections

The Radiation Safety Officer or designated representative and workers may accompany the Texas Department of State Health Services inspector during inspections.

E. Consultation With Workers During Inspections

1. Texas Department of State Health Services inspectors may consult privately with workers concerning matters of occupational radiation protection and other matters related to state and federal regulations and licenses.

2. During an inspection, any worker may privately bring to the attention of the inspectors, either orally or in writing, any past or present condition which the individual has reason to believe may have contributed to or caused any violation of Baylor University regulations or license condition, or unnecessary exposure of an individual to radiation from licensed radioactive materials.

F. Requests by Workers for Inspections

1. Any worker who believes that a violation of Baylor University regulations or license conditions exists or has occurred with regard to working conditions in which the worker is engaged, may request an inspection by giving written notice of the alleged violation to the Texas Department of State Health Services, 1100 West 49th Street, Austin, Texas 78756. Such written notice should set forth the specific grounds for the notice, and be signed by the worker or representative of worker. Upon the request of the worker giving such notice, the individual's name and the names of the individuals referred to in the notice will be considered confidential, except for good cause shown.

2. The Texas Department of State Health Services shall cause an inspection to be made as soon a practicable if there are reasonable grounds to believe that the alleged violation exists or has occurred. Such inspections need not be limited to matters referred to in the complaint.

3. No licensee shall discriminate against any worker because such worker has filed any complaint.

XIII. Exposure to Pregnant Women

A. The Nuclear Regulatory Commission (NRC) has issued regulations which mandate the separate control of fetal dose when a pregnant worker submits a written declaration of pregnancy to her supervisor. In some cases adequate control of fetal dose may require that the pregnant worker be reassigned to a different position or that her job responsibilities be modified. For any reason, a pregnant worker may choose not to declare her pregnancy. If a written declaration of pregnancy is not submitted to the Radiation Safety Officer, then the worker's dose continues to be controlled under the normal dose limits for radiation workers. The following points summarize the NRC's fetal dose regulations:

1. The fetal dose regulations apply only to a woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception.

2. The dose to the fetus resulting from occupational exposure of a declared pregnant worker may not exceed 500 mrem for the entire pregnancy.

3. If the dose to the fetus has exceeded 450 mrem by the time a woman declares her pregnancy, the total additional occupational dose to the fetus for the rest of the pregnancy must not exceed 50 mrem.

4. The dose received by the fetus over the course of the pregnancy should be delivered at a reasonably uniform rate; the rate of exposure should avoid substantial variation, and in no case shall the dose exceed 50 mrem in any month.

5. Monitoring (personnel monitors and/or bioassays, as appropriate) shall be provided for any declared pregnant woman who is likely to receive a dose in excess of 10 % of the dose limits specified above.

B. To comply with NRC regulations, Baylor University has established a Declared Pregnant Worker Program which is available to all pregnant radiation workers. It is the responsibility of a pregnant radiation worker to decide whether to formally declare the pregnancy to Baylor University for the purpose of controlling radiation exposure to the unborn baby.

1. In order to make a declaration of pregnancy, a pregnant worker fills out the Baylor University Declaration of Pregnancy form and either submits it directly to her supervisor or sends the Declaration directly to the Baylor University Radiation Safety Officer. Copies of the form are available from the Baylor University EHS web site.

2. When a written declaration of pregnancy is received by the Office of Environmental Health and Safety, the Radiation Safety Officer meets with the declared worker and the worker's supervisor to discuss exposure history, job responsibilities, and research protocols in order to assess the dose the baby has received and is likely to receive. The Radiation Safety Officer will work with the worker and the worker's supervisor to recommend changes, if necessary, to job duties or research protocols. For the type of radiation work performed at Baylor

University, it is rarely necessary to recommend reassignment or changes to job duties.

3. The Radiation Safety Officer completes a fetal dose worksheet which becomes part of the worker's permanent dose history. The Radiation Safety Officer reviews dose reports for declared pregnant workers as the reports are received.

4. The fetal occupational dose limit will stay in effect until the declared pregnant worker…

   a. is known to be no longer pregnant.

   b. informs the Office of Environmental Health and Safety or Radiation Safety Officer that she is no longer pregnant.

   c. informs the Office of Environmental Health and Safety or Radiation Safety Officer that she is withdrawing her declaration of pregnancy.

5. No action will be taken to control fetal occupational dose unless a written declaration of pregnancy has been submitted to the Office of Environmental Health and Safety or Radiation Safety Officer.

XIV. Safety and Handling of Beta Emitters

A. The beta emitters most commonly used on campus are H-3, C-14, S-35, Ca-45, and P-32. The maximum energies of the betas emitted and their ranges in air are given in the table below:

Radionuclide	Emax (MeV)	Range in Air (Cm)
3H	0.018	Less than 1
14C	0.155	28
35S	0.167	33
45C	0.254	51
32P	1.71	635

B. The most hazardous, commonly used beta emitter on campus is P-32. Phosphorous-32 is used extensively in research and must be handled carefully. Phosphorous-32 emits beta particles with maximum energies of 1.71 Mev and average energies of 0.57 Mev.

1. Significant dose rates may be experienced when handling P-32. For example, the dose rate at the surface of a 1 ml solution containing 1 mCi of phosphorous-32 is approximately 13 rem/hr. The average dose rate to the hand while it is in contact with a glass shipment vial containing 1 mCi of P-32 is 439 mrem/hr. As a final example, the average dose rate at a 10 cm distance from the side of a glass shipment vial containing 1 mCi of P-32 is 5 mrem/hr.

2. Tritium, carbon-14, sufur-35, and calcium-45 are not external radiation hazards.

C. Estimates of dose rates should be conducted before handling high-energy beta emitters, such as P-32. The dose rate estimates can be calculated using the equations below. These equations were taken from The Health Physics and Radiological Health Handbook (1984).

Equation 1 – Dose Rate (rads/hr) at One Centimeter from a Point Source

DR1cm is approximately equal to 200 x A

Where DR1cm = the dose rate at 1 cm distance from the radioactive point source (rads/hr); and A is the quantity of radioactive material (mCi)

Equation 2 – Dose Rate (rads/hr) in a Solution

Dsol is approximately equal to 1.12 EC/p

Where Dsol = the dose rate in solution (rads/hr);
E = the average beta particle energy (Mev);
C = the concentration of radioactive materials ($\mu Ci/cm^3$);
And p is the density of the solution (g/cm^3)

Note: The dose rate is about one-half this value at the surface of the solution.

D. Follow the general lab practices and guidelines below to reduce radiation exposures:

1. Always keep radioactive and non-radioactive work separated as far as possible, preferably by maintaining rooms used solely for radioactive work.
2. Always work over a spill tray and in a ventilated enclosure (except with small (<1 mCi) quantities of 3-H, 35-S, or 14-C compounds in a non-volatile form in solution).
3. Always use the minimum quantity of radioactivity compatible with the objectives of the experiment.
4. Always wear protective clothing, safety glasses, and gloves when handling radioactive materials.
5. Always wash your hands and monitor yourself before leaving an area where radioactive materials are handled or stored.
6. Always work carefully and monitor the working area regularly to avoid ruining experiments by accidental contamination.
7. Always label containers of radioactive material clearly, indicating radionuclide, total activity, compound, and date.

8. Never eat, drink, smoke, or apply cosmetics in an area where unsealed radioactive materials are handled or stored.

9. Never use ordinary handkerchiefs to clean items or surfaces; use paper tissues and dispose of them as radioactive waste.

10. Never work with cuts or breaks in the skin unprotected, particularly on the hands or forearms.

11. Never pipette radioactive solutions by mouth.

12. In the event of a spill, it is essential to minimize the spread of contamination by adhering to the following steps:

    a. Cordon off the suspected area of contamination. Ascertain, if possible, the type of contamination, i.e. the nuclide(s) involved (as it may be necessary to use breathing apparatus, protective clothing, or other equipment).

    b. Determine the area of contamination by monitoring, after taking the necessary precautions.

    c. Decontaminate the area in convenient sectors by wiping and scrubbing, starting from the outer edge.

    d. Ensure that a sector is clean by monitoring before moving to another sector.

13. Use tongs or other remote handling equipment, where appropriate, to minimize dose to the extremities.

E. Specific practices to follow when handling P-32 and volatile radioactive materials are listed below. These practices are in addition to those stated in Item D.

1. <u>Phosphorous-32</u>

    a. Place containers of P-32 and materials/items contaminated with P-32 such as pipettes into Plexiglas or Lucite containers that are about 1 cm thick.

    b. If the measured exposure rate from a container with P-32 exceeds 1mR/hr at 1 ft, additional shielding in the form of 1/16-1/8 in. lead sheets should be used. This shielding should be placed exterior to the Plexiglas.

    Notes:

    a. Baylor University Machine Shop personnel can prepare blocks of Plexiglas with holes drilled to fit test tubes, vials, beakers, and other containers.

    b. Additional information on handling P-32 safely is provided in the Appendix to this manual.

2. <u>Volatile Radioactive Material</u>

a. Handle volatile radioactive materials in fume hoods that are operating properly.

b. Volatile radioactive materials include, but are not limited to, those compounds that are labeled with H-3, S-35, C-14, I-125, and I-131.

3. Handle radioiodine (I-125, I-131) in quantities greater than 10 mCi in fume hoods with activated charcoal filters.

Note: The above steps and many of those in Item D above will reduce the potential for ingestion and inhalation of radioactive materials.

XV. ALARA Policy

A. It is the policy of Baylor University that exposure to ionizing radiation be maintained as low as practicable, consistent with the teaching, research, and service missions of the institution.

B. External Exposure

1. Each person with the potential for significant exposure to x-rays, gamma, or hard beta radiation will be furnished with a personnel-monitoring badge.

2. University personnel will have an action limit of 125 millirem in any monitoring period (usually one quarter).

3. When a badge exceeds the action limit, the supervisor will report on the reason for the exposure and any actions taken to reduce future exposures.

4. Persons who submit 2 consecutive monitoring badges that are over the action limit will be individually counseled by the Radiation Safety Officer.

a. An effort will be made to determine the reason for the exposure and changes in procedures, work habits, or equipment will be recommended as appropriate.

C. If ingestion of any radioactive material in significant quantities is suspected, an appropriate bioassay will be performed and the person will be counseled on the need for precautions and methods of minimizing exposures.

XVI. Requirements for Fume Hoods Utilizing Radioactive Materials

A. Up to 1.0 millicurie of radioactive material may be used in a laboratory that does not have a fume hood, provided that…

1. the radioactive material is not volatile or readily dispensable (as dusts) or highly toxic.

2. the radioactive material has no characteristics that, in the judgment of the Radiation Safety Committee, would make it dangerous to use without a fume hood.

B. Up to 10 millicuries of radioactive material may be used in a standard fume hood, provided that in the judgment of the Radiation Safety Committee, the type of materials and procedures described in the protocol can be used safely in this type of hood and that the hood meets the requirements of item D below.

C. Up to 50 millicuries of radioactive material may be used in a radioisotope fume hood with stainless steel liner and HEPA filter, provided that in the judgment of the Radiation Safety Committee the types of materials and procedures described in the protocol can be used safely in this type of hood. Risk to the public as well as laboratory personnel will be considered. Use of over 50 millicuries will be decided on a case-by-case basis by the Radiation Safety Officer. In cases that do not present excessive risks, use of over 50 millicuries may be approved.

D. All fume hoods used for radioactive materials must have at least 100 linear feet per minute of face velocity with the sash in full-open position.

1. Hoods approved for operation at half-sash must be operated with the sash at or below this position at all times.

XVII. Requirements for Purchase of Radiation Sources That Cannot be Disposed of as Routine Radioactive Waste.

A. Examples of the type of sources covered under this procedure are:

1. large sealed sources

2. alpha sources

3. exceptionally toxic isotopes such as Strontium-90

4. any large quantity of radioactive material

B. The Radiation Safety Officer will obtain the following before approval of the purchase of any source that may present special problems or excessive expense for disposal:

1. a written statement justifying the need for the source from the faculty member who proposes purchase of the source

2. a letter from the department head, approving the purchase of the source and agreeing that funds will be made available for disposal when the source is no longer useful

3. approval by the Radiation Safety Officer upon consideration of:

a. the need for the source

b. availability of the expertise and facilities necessary for safe use of the source

c. assurances that funds will be available for disposal when the source is no longer useful

XVIII. Forms and Notices Used in the Radiation Safety Program

A. All current forms and notices are available on the EHS Department web site.

B. Forms/Procedures - The following forms are available:

1. Authorized User Application
2. Declaration of Pregnancy
3. Dosimeter Application
4. Minor Changes to Nuclide Authorization
5. Protocol Summary Sheet
6. Radiation Safety Training Certification
7. Radioisotope Order Request

The following procedures are available:

1. Operating and Safety Procedures for Radiation Machines
2. Radioactive Spill Procedure
3. Receipt of Radioactive Material

C. Licenses/Postings – Up-to-date required postings as described in 25TAC289.203: Notices, Instructions and Reports to Workers; Inspections. This page includes licenses, registrations, Notice to Employees (BRC Form 203-1), notice of violations, and a location list of various other required postings.

D. Radiation Safety Committee (RSC) – a copy of the committee charter, outlining the duties, responsibilities, and membership of the committee.

APPENDIX A
Principles of Radiation Safety and Review of Current Knowledge of Radiation Effects

A. Units of Radiation Dose

1. In 1896, x-rays were discovered by Roentgen and radioactivity by Becquerel. For some time, no one realized that radiation could cause harmful effects. It was recognized very soon that x-rays could be used in medical diagnosis, and early radiologists received large doses of radiation. Many of these radiologists later suffered severe injuries due to overexposure. (Radiation effects may appear years after exposure.) The first unit of dose was the erythema dose. This was the amount of x-radiation which would barely cause reddening of the skin. It was not a very satisfactory unit of dose, but indicates the early recognition by some scientists that radiation exposure can be harmful and should be limited. One erythema dose consisted of about 270 to 1,000 roentgens, depending upon the energy of the x-rays. The recommended limit was 1/1000 of an erythema dose per day (about 0.27 to 1.0 roentgen per day).

   Madame Curie, in her work with radium, received radiation exposure which eventually proved fatal. (It should be noted that Madame Curie received what would now be considered extremely high doses of radiation exposure and that she lived to be 67, a long lifetime for the period.) Radium-containing "tonics" were sold by unscrupulous persons as health aids and some of the persons taking these "tonics" died of radiation poisoning. Probably the most widely known example of radiation poisoning is the case of the watch dial painters who used radium to paint luminous dials. These workers ingested radium by using their lips to make a pointed tip on their brushes. Many of them died later of bone cancer. It should be emphasized that the persons noted above who suffered radiation damage received very large doses of radiation and followed no standards of exposure limitation.

2. In 1928, the International Commission on Radiation Protection (ICRP) was established. This group defined the roentgen as the unit of radiation dose. In 1934, a "tolerance dose" of 0.2 roentgens per day (60 roentgens per year) was agreed upon as the recommended limit for radiation exposure.

3. In 1936, the recommended limit was reduced to 0.1 roentgen per day (30 roentgens per year). In 1950, the National Council on Radiation Protection and Measurement (NCRP) and the ICRP introduced the concept of "permissible dose" and set the permissible exposure at 0.3 roentgen per week (15 roentgens per year). In 1956, this permissible dose was reduced to 0.1 roentgen per week (5 roentgens per year). This was not due to any observed ill effects at previous limits, but was based on the desire to be conservative and reduce the possibility of any long-range effects. At the present time, the limit for occupational exposure remains 5 roentgens per year or the equivalent. No ill effects have been noted at this exposure level.

4. The roentgen was not an ideal unit of radiation dose. It was defined as the amount of x or gamma radiation which produces ions carrying one electrostatic unit of charge of either sign in 1 cubic centimeter of dry air at standard temperature and pressure. Thus, the roentgen was defined as a given amount of ionization in air and applied only to x and gamma radiation. It did not indicate directly the damage within a biological system. It was soon realized that a given amount of ionization in air could result in different amounts of damage in an object being irradiated. Results of experiments using low energy x-rays could not be compared with those using high energy x-rays or gamma rays. This led to much confusion in the literature on radiation effects.

5. This resulted in establishment of the rad. A rad is 100 ergs of energy per gram, absorbed by any material from any type of ionizing radiation.

6. By this time it had also been established that radiation's effects depended not only upon the numbers of ions being formed, but also upon their distribution within living tissue. Dense trails of ions cause more damage than the same number of ions spread widely apart. Thus, the specific ionization (ions per unit distance) must be taken into consideration. X and gamma radiation and beta particles tend to produce ions spread relatively far apart, while alpha particles and neutrons tend to cause dense trails of ions. The x-ray, beta, and gamma radiation is referred to as low Linear Energy Transfer (low LET) radiation, while alpha particles and neutrons are called high LET radiation. One explanation for the difference in effect between high and low LET radiations is that the cells within a living organism can repair small amounts of damage caused by radiation. However, if there is too much damage within one cell, the repair mechanism may be overwhelmed and the cell may die or be irreparably damaged.

7. To correct for this effect the Quality Factor (QF) was invented. Radiation with the higher LET is given a higher Quality Factor. The rad (unit of absorbed dose) is multiplied by the Quality Factor to obtain the rem.

8. The rem is a unit of damage to a biological system. It is equivalent to the damage done by exposure to 1 roentgen of 250 keV x-radiation and is called the equivalent dose. Effects from any type of ionizing radiation may be compared using the rem.

9. We now have the:

   a. Roentgen – <u>exposure dose</u> based on ionization in air

   b. Rad – <u>absorbed dose</u> based on absorption of energy

   c. Rem – <u>equivalent dose</u> based on biological effects

10. It should be mentioned here that the ICRP and NCRP have recommended new units of dose. Applied health physicists in general feel that these new units are unnecessary and will cause much confusion, especially in record keeping. The

new units have not, at this time, been widely accepted. However, they may eventually become universally used. While we will continue to use the roentgen, the rad, and the rem, the following conversions can be made if desired:

New Unit
Coulomb per kilogram = 3876 roentgens Gray = 100 rad
Sievert = 100 rem

11. For x-rays of 250 KeV, the roentgen, rad, and rem are approximately equal. It is usually assumed, for practical purposes, that all x and gamma radiation from about 100 KeV to 3 MeV has a quality factor of 1 and that the roentgen, rad, and rem are equivalent in this range. Below are some examples of Quality Factors for different radiations.

Radiation	Q.F.
x-ray	1
gamma ray	1
beta particle	1
alpha particle	20
slow neutron	2.5
fast neutron	20
heavy ions	20

B. Effects of Radiation Exposure

Radiation in large doses causes observable damage. The following list gives some typical effects of radiation exposure by x or gamma rays given to the total body at a high dose rate over a short period of time.

0-25 rem	No observable effects on health of the individual. At 25 rem, a physician could probably see some changes in blood cells.
50-100 rem	Possible nausea and blood count depression. Recovery within days to weeks with no lasting ill effects.
500 rem	Nausea, weakness, anemia, internal bleeding, temporary sterility, susceptibility to infection, loss of hair. This is the LD^{50-30}. Half of the persons so exposed die within 30 days. The other 50% recover with a few lasting ill effects. Recovery takes months to years. Death is usually due to damage to the blood forming stem cells in bone marrow.
1,000 rem	Death within days to weeks, usually from damage to the gastrointestinal system.
10,000 rem	Death within hours to days from damage to the nervous system.
100,000 rem	Essentially instantaneous death from damage to the nervous system.

The above effects are observable within a short time after the exposure. They have been observed in persons exposed before the harmful effects of radiation were known, in persons exposed for medical treatment, in the watch dial painters, the atomic bomb survivors, and a few persons suffering accidental occupational overexposures.

1. In addition to the effects listed above, persons who are exposed to large amounts of radiation and recover have an increased incidence of some types of cancer, leukemia being the most readily observed. For the atomic bomb survivors who received 200 rem or more of gamma radiation, the incidence of cancer was approximately doubled over the following 25 years.

2. There is also the possibility of increased genetic damage in persons who recover from high doses. This is theoretically possible and has been observed in lower animals. However, there has been no observable increase in genetic defects among the atomic bomb survivors and this effect has not yet been observed in humans.

3. The effects from radiation exposure decrease as the dose rate is lowered. Spreading the dose over a longer period reduces the effects. Much of the controversy over radiation exposure centers on the question of how much damage is done by radiation delivered at low doses or low dose rates. It has been assumed that one could predict the maximum amount of damage that might be expected from low doses of radiation by extrapolating from the effects at high doses. Some persons have claimed that there is no damage at very low doses. This is called the threshold model.

   Since cancers caused by radiation do not generally appear until years after the exposure and are of the same types as naturally occurring cancers, it has been impossible to show any effects for exposure below about 100 rem. While there may be some increase in cancer from exposures below 100 rem, the number is too small to measure statistically.

4. It has been popular to assume that the straight line model is fact and that number of cancers depends strictly upon the number of person-rem of exposure to the population. If 10,000 persons are exposed to 100 rem each:

   Persons x rem = person-rem
   10,000 x 100 = 1,000,000

   Using this formula and data from persons exposed to high doses (such as the atomic bomb survivors) the report of the National Academy of Sciences' Committee on the Biological Effects of Ionizing Radiation (BEIR Report) predicts that there will be approximately 200-400 fatal cancers for each 1,000,000 person-rem of exposure. This estimate has varied from 100 to 400 over the years, as new estimates were made based on revised data. The estimate is probably reasonably accurate for exposures above 50 rem. The value may even be zero for individual exposures much below 50 rem. One may take the straight-line model and apply it to low-level radiation exposure. For instance:

persons x rem = person-rem
1,000,000,000 x 0.001 = 1,000,000

This implies that 1 billion persons exposed to 1/1000 of a rem each (1 millirem) would develop 200-400 fatal cancers. Since 400 cancers among 1 billion persons would be impossible to detect among the millions of cancers naturally occurring, it has been impossible to prove or disprove the straight-line model for low-level radiation. However, some persons have pointed out that if the straight-line model were correct for low-level radiation, background radiation would cause more cancers than those, which are actually observed. A few persons have claimed that low-level radiation causes up to 10 times the number of cancers predicted by the straight-line model. However, in view of the above observation concerning background radiation, little credence is given to these claims by most scientists.

5. In Report No. 64 issued in April 1980, the NCRP set forth evidence indicating that the straight-line model overestimates the effects of low-level radiation. According to this report, the response to radiation exposure by biological systems follows a curve composed of at least two parts: A linear component due to low-level radiation and a quadratic component due to high dose and high dose rate.

   The curve is described by the formula:
   $I = \alpha D + \beta D^2$
   I is the effectiveness per unit dose.
   D is the total dose given.

   α and β are constants, which depend upon the particular effect being studied and experimental conditions.

   The NCRP estimated that the straight-line model overestimates the effects of low-dose radiation by a factor of 2 to 10. This is called the Dose Rate Effectiveness Factor (DREF). The DREF may vary somewhat with the particular effect being studied. The most accurate data were obtained from plants and lower animals, but the same type of curves are presumed to apply to human beings. The above applies to low LET radiations. High LET radiations appear to follow the straight-line curve. Most occupational exposure is low LET radiation.

C. Established Dose Limits

1. Occupational Exposure

   Exposure to ionizing radiation through occupational exposure is limited by law to 5 rem per year. In accord with the observation that the effects are less if dose is spread over a longer period, the dose should be spread out as much as possible.

2. Medical Exposure

   There is no limit to medical exposure. The medical doctor should ensure that no patient is exposed to more radiation than is necessary to achieve the required medical diagnosis or treatment. Medical x-rays may be considered as part of the background exposure and cause an average of about 50 to 100 millirem each year to persons in the U.S.

3. Background Exposure

Natural background gives one good reference, which can be used in setting radiation limits. Human beings have been exposed to background radiation for millions of years and it can probably be assumed that this amount is not very harmful. (It may even be beneficial. Increased average life spans have been observed in rats exposed to 100 millirads per day of x-radiation.) In fact, some minimum level of background radiation may be essential to life on earth. A typical background exposure might be as follows:

Radiation	Millirem/year
Cosmic	40
Terrestrial	60
Potassium-40	20
Others	5
Total	125

Background radiation varies with location. Cosmic radiation increases with altitude, and terrestrial radiation varies with the types and quantities of minerals in the soil. Background in the United States may vary from approximately 90 millirem per year to more than 250 millirem per year. In some areas of Brazil and India, background may reach 3,000 millirem (3 rem) per year because of radioactive minerals in the soil. It has been impossible to show any ill effects, such as increase in cancer rate, among persons who live in these areas of high natural radioactivity. It is thus felt, that the exposure of a few people to occupational exposures of 5 rem per year is unlikely to cause any significant effects. The limit set for the general population is 100 millirem per year in addition to background.

4. ALARA

In addition to the specific limits set above, U.S. law requires that no one be unnecessarily exposed to ionizing radiation. Exposure must be kept As Low As Reasonably Achievable (ALARA) in order to minimize any possible ill effects.

D. Risk From Ionizing Radiation

Since many persons are particularly fearful of radiation, it may be helpful to compare the risk from radiation exposure to some other risks encountered in everyday life. Based on the straight-line model, a worker exposed to 1,000 millirem (1 rem) per year for 30 years would lose about 30 days of life expectancy due to increased risk of cancer. This is comparable to other “safe” jobs. For comparison, the loss of life expectancy for several other risks is given below.

Job or Other Risk	Days of Life Expectancy Lost
Manufacturing	43

Agriculture	277
Construction	302
Coal Mining	1100
Being 30% overweight	1300
Being President of the U.S.	1861
Being an average male smoker	2153

To put it another way, statistically the risk from 1 millirem of exposure is approximately equal to the risk from taking one puff on a cigarette or driving a car 0.15 miles on the highway. Many persons do not approach radiation risk rationally. Some tend to ignore the risk because they cannot see any immediate ill effects. Others have an irrational fear of radiation entirely out of proportion to the actual risk (Radiophobia). It should be noted that no ill effects have ever been observed in persons whose exposure remained within the limits recommended by the NCRP, and incorporated into current government regulations and university policy.

E. What levels of Radiation are dangerous?

1. 1,000 rem

   a. fatal to all exposed persons if received as total body exposure over a short period

   b. terminal case of radiation syndrome

2. 500 rem

   a. fatal to approximately one-half the exposed persons if received as total-body exposure over a short period

   b. severe case of radiation syndrome

   c. increased risk of cancer in survivors

3. 100 rem

   a. smallest dose that can definitely be shown to cause ill effects to adults

   b. may cause mild symptoms of radiation syndrome

   c. slightly increased risk of cancer

4. 25 rem

   a. smallest dose that will cause effects that can be detected by a physician

   b. no readily detectable signs of illness

   c. no long-range ill effects can be demonstrated

5. 5 rem (5000 mrem)
    a. limit for one year of occupational exposure
    b. not expected to cause any ill effects over a lifetime
    c. epidemiological studies cannot detect any harmful effects at this level
6. 3 rem (3000 mrem)
    a. maximum received in one year by the general population from natural radiation in the most radioactive areas of earth
    b. no demonstrated ill effects
7. 1 rem (1000 mrem)
    a. effective dose equivalent from living one year in a house with 4 picocuries per liter of radon in the air (the EPA limit)
    b. This value may vary considerably depending upon assumptions made in the calculations.
    c. no demonstrated ill effects
8. 0.3 rem (300 mrem)
    a. approximate effective dose equivalent from living in a house with 1 picocurie per liter of radon in the air
    b. may be near the average for U.S. homes
    c. no demonstrated ill effects
9. 0.125 rem (125 mrem)
    a. average dose received in one year from radiation (not including radon) in Waco, TX
    b. no demonstrated ill effects
10. 0.1 rem (100 mrem)
    a. annual limit for non-occupational exposure (general public)
    b. dose received each year by the average person from medical x-rays
    c. approximate dose received from background (excluding radon)
    d. no demonstrated ill effects

APPENDIX B

H-3 (TRITIUM) INFORMATION

Radioactive half-life	12.4 years
Decay mechanism	Beta emission
Energy	Emax = 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 cannot 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 15 or 20 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 cannot be removed, label the area or equipment as radioactive, noting the isotope, the date of contamination, and the maximum dpm found.
- If any un-removable 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.

APPENDIX C

C-14 INFORMATION

Radioactive half-life	5730 years
Decay Mechanism	Beta emission
Energy	Emax = 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 its 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 15 or 20 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 15 or 20 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 cannot be removed, label the area or equipment as radioactive, noting the isotope, the date of contamination, and the maximum dpm found.
- If any un-removable 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.

APPENDIX D

P-32 INFORMATION

Radioactive half-life	14.3 days
Decay mechanism	Beta emission
Energy	Emax = 1.709 MeV
Contamination monitoring	Thin window Geiger Mueller detector
Shielding	1 cm Lucite
Dosimetry	Film badge, TLD ring, urinalysis bioassay

- The dose rate on contact on the side of 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 by the high activity (bremstrahlung).
- Beta particles from P-32 travel a maximum of 20 feet in the air.
- One uCi of P-32 in direct contact with l cm^2 of bare skin gives a dose rate to the skin of about 2000 millirem/hr. This means that the quarterly NRC limit of 7500 millirem 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 millirem per hour. The quarterly NRC limit of 18,250 millirem 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 may be required for P-32 work. Dosimetry rings may be worn for 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 and safety glasses.
- Personnel handling P-32 may wear a ring badge on the hand which is most likely to handle vials, samples, pipettes, etc., containing 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 or gamma radiation.
- Check your gloves frequently with the counter to detect contamination. If contaminated, immediately dispose of the gloves in a Plexiglas receptacle labeled as radiation waste.
- 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 15 or 20 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 cannot be removed, label the area or equipment as radioactive, noting the isotope, the date of contamination, and the maximum dpm found.
- If any un-removable 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

APPENDIX E

S-35 INFORMATION

Radioactive half-life	87.4 days
Decay mechanism	Beta emission
Energy	Emax = 0.167 MeV
Contamination monitoring	Thin window Geiger Mueller detector, liquid scintillation counter for wipe
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 it as C-14.
- Beta particles from S-35 travel a maximum of 24 cm in the air.
- Most Geiger counters cannot 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 S-35 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 15 or 20 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 cannot be removed, label the area or equipment as radioactive, noting the isotope, the date of contamination and the maximum dpm found.
- If any un-removable 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.

APPENDIX F

Radioactive Material Receipt - Standard Operating Procedure

1. Initial Receipt:
   Radioisotopes are delivered to Baylor University and accepted at the chemical stockroom only during normal working hours. The radioisotopes are segregated from other stockroom items and notification is made for pickup.

2. Notification:
   A Chemical Stockroom personnel notifies the one who ordered, or Radiation Safety Officer, that the isotope(s) has arrived at the chemical stockroom.

NOTE: Per TAC 289.202, the radioisotope must be picked-up within three (3) hours of delivery to Baylor University.

3. Pick up:
   - The isotope recipient proceeds to the stockroom to pick up the isotope. A lab coat may be worn; ONE glove (NOT two) may be worn to handle the delivered package. If appropriate, a piece of shielding or a bench-top shield may be taken along to port the isotope behind, but the counts emanating from the container will be very small.
   - Pick up the chemical stockroom bar code that goes with that container of isotope.

4. Transport:
   - Transport the container to appropriate radioisotope lab. ONLY use your ungloved hand to open/close doors and touch other building parts.
   - Place behind the shield (if 32P) on a diaper/bench paper.

5. Survey:
   - Remove the isotope from the shipping box.
   - Prepare the survey materials - vials, scintillation cocktail, wipes, Usage and Survey Log.
   - Use G-M counter and verify no counts on the shipping container. (Note: G-M counter will only be effective in identifying 32P or very large quantities of other isotopes.)
   - Wipe-survey the shipping container on at least a couple of surfaces.
   - Wipe-survey the vial container on several surfaces - at least top and two sides.
   - Wipe-survey outside of vial itself with at least one sample.

6. Count survey samples using the Scintillation Counter – be sure to include a blank sample for comparison. If doing a survey of 32P (a high energy beta), the wipe sample can be counted with a G-M counter. Be sure to complete the Usage and Survey Log for the isotope you are using.

7. Assuming no contamination: (if contaminated, go to next step)
   - Affix bar code to vial container
   - Put vial into appropriate storage
   - Complete the Usage and Survey Log

8. In the unlikely event of contamination:
   - Notify RSO for follow-up with shipper.
   - Clean with radiacwash or radcon and resurvey.
   - Place cleaning materials in radioactive solid waste.

9. After defacing any radioactive symbols or signage, uncontaminated shipping container can be disposed of as regular trash.