MRB RADIATION SAFETY PROGRAM MANUAL

TEXAS A&M UNIVERSITY SYSTEM

HEALTH SCIENCE CENTER

COLLEGE OF MEDICINE

MEDICAL RESEARCH BUILDING

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INTRODUCTION

The radiation safety program at The Texas A&M University System Health Science Center College of Medicine Medical Research Building (MRB) Temple exists to protect employees, students, and visitors as well as the public and the environment from the harmful effects of exposure to ionizing and non-ionizing radiation. The University is committed to meeting all applicable regulatory requirements imposed by the State of Texas or the United States government and to keeping doses from licensed sources of radiation As Low As Reasonably Achievable (ALARA) - social, technological and economic factors taken into account.

This Program Manual has been approved by the Texas A&M University System Health Science Center College of Medicine Radiation Safety Committee (RSC) and the Texas Department of State Health Services, and is issued and maintained by The Texas A&M University System Health Science Center College of Medicine Office of Research Laboratory Compliance (ORLC).

Laboratory Procedure Manuals that contain radiation safety related procedures and guides for use by laboratory personnel are printed as separate manuals and are available from the ORLC upon request.

The rules, responsibilities, and procedures which comprise the MRB radiation safety program also apply to those personnel and operations authorized in a license or by registration issued to the MRB and administered by the TAMUSHSC COM ORLC.

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SECTION 1

PURPOSE AND SCOPE

The purpose of this manual is to establish the requirements for the use of licensed radioactive materials at the MRB, in any physical or chemical form. The provisions do not apply to radiation producing devices (x-ray machines, electron microscopes, etc.) or lasers.

This manual is intended for persons applying for or holding a Permit for the use of radioactive materials. Such Permits are issued by the MRB under authority granted to the MRB by the State of Texas. Permit holders must conform to all applicable regulations and to any conditions placed on the applicable license. Conditions may include, but are not limited to, restrictions on radionuclides, quantity (radioactivity), location of work, and type of experiments authorized. Following is the radioactive material license issued to the MRB.

License Number	Issuing Agency
L05494	Texas Department of State Health Services

Current version of this license is available through the TAMUSHSC COM Office of Research Laboratory Compliance (ORLC).

SECTION 2

ORGANIZATION AND RESPONSIBILITIES

A. Radiation Safety Committee (RSC)

The RSC advises The Texas A&M University System Health Science Center College of Medicine administration on matters related to radiation safety and recommends policies and procedures it deems appropriate to ensure an adequate radiation safety program.

1. The RSC consists of at least six voting members, including the Chair, appointed by the Dean of the College of Medicine and comprised of:
   a. three members of the scientific staff who hold license or have extensive experience with radioisotopes (one of which must be the chair)
   b. two members of the laboratory technical staff from laboratories where the use of radioisotopes is common
   c. a representative of research lab operations such as Faculty, Administrator, Assistant Dean for Research (or designee).
2. The MRB Radiation Safety Officer (RSO) will be an Ex Officio (non-voting) member.
3. A quorum shall consist of 50% or more of the voting members and requires the presence of the Chair (or Vice Chair), and RSO, and a representative of administration such as Dean or Assistant Dean for Research or his designee.
4. The RSC shall meet at least two times annually and upon request of the Committee Chair. The RSO or designee shall brief the RSC on the status of the radiation safety program, including
   a. changes in radiation safety staff
   b. changes in regulations
   c. review of incidents and emergencies

   d. proposed field research protocols
   e. review of procedural changes
   f. radiation safety program operations, including future needs and requirements.

5. Specific responsibilities of the RSC include
   a. reviewing and approving applications for possession and use of radioactive materials.
   b. notifying and advising the Dean of the College of Medicine of any event which results in a violation of Severity Level I or II as defined in Texas Department of State Health Services regulations or any violation of federal regulations which might result in imposition of fines or penalties. Such notifications should include a description of any subsequent corrective actions taken by the RSC.
   c. reviewing field study proposals wherein radioactive materials will be intentionally released, either directly or indirectly, into the environment.
   d. serving as the appeals board for persons
      i. desiring relief from radiation safety program or RSC policies or requirements,
      ii. desiring that a request for exemption from state or federal regulations be submitted to the regulatory agency on their behalf
      iii. desiring to resume work or activities which were halted under a "stop work order" issued by the staff of the radiation safety program.
   e. reviewing or auditing radiation safety program operations at the ORLC annually.

B. Radiation Safety Officer (RSO)

The RSO is charged by the University to direct the radiation safety program for Texas A&M University and supported Texas A&M University System agencies. Specifically, the RSO shall be responsible for:

1. serving as an ex-officio member of the RSC
2. advising University College of Medicine Research Building personnel on matters related to radiation safety
3. empowerment to impose conditions of work, restrictions on work, and termination of work involving sources of radiation as necessary to protect University personnel, the public, or the environment or to ensure regulatory compliance
4. reviewing the radiation safety program at least annually
5. serving as the College of Medicine Medical Research Building point of contact with state regulatory agencies on all matters related to radiation safety
6. applying for new or maintaining existing licenses required by state and federal agencies to support the use of radioactive material in teaching or research and development
7. maintaining a personnel dosimetry program, including evaluating the need for issuance of dosimetry, maintaining a contract for commercial dosimetry services, maintaining dose records, and providing reports to individuals as per regulations
8. reviewing applications for Permits to use radioactive material prior to submitting the application to the RSC
9. maintaining Permit records including approved applications, amendments, and renewals
10. overseeing receipt inspections of radioactive material shipments
11. packaging radioactive materials for transport
12. maintaining inventories of radioactive materials
13. performing routine inspections of Permitted Users

14. disposing of radioactive materials
15. providing support in the event of an incident or emergency and reporting same to the appropriate regulatory agency, as appropriate
16. arranging for leak testing of sealed sources
17. arranging for calibration of portable survey instruments
18. providing radiation safety training for MRB personnel
19. providing information and consultation on matters related to radiation safety

C. Permit Holder (Permittee)

The Permit Holder is at all times responsible for all radioactive materials which he or she possesses and for all operations in his or her laboratory which involve radioactive materials. This responsibility extends to the actions of all employees, students and visitors who enter the Permittee's radioactive material work area. Furthermore, Permittees should only undertake those uses of radioactive materials that are reasonably expected to yield benefits that outweigh the risks associated with that use of radioactive material. Specifically, Permittees shall:

1. ensure that all activities involving licensed sources of radiation are authorized under the Permit, as amended
2. ensure that radioactive materials are secured from unauthorized removal or access
3. maintain an accurate list of employees and students authorized to work with radioactive materials
4. develop and maintain written procedures/protocols involving radioactive materials
5. ensure that laboratory personnel receive ORLC-approved training in radiation safety and emergency response before being authorized to work unsupervised with radioactive material
6. ensure that laboratory personnel complete refresher training required by the ORLC

7. ensure that exposures to ionizing radiation and releases of radioactive materials are maintained As Low As Reasonably Achievable (ALARA)
8. conduct and document surveys for radiation levels and/or contamination in accordance with Section 7 of this Part
9. inform the ORLC, in writing, if extended leave (more than 4 weeks away from the normal work location) is planned
10. notify ORLC immediately in cases of
    a. personnel contamination
    b. lab contamination which remains after decontamination efforts
    c. high doses (known or suspected) to any person
    d. intake of radioactive materials by any person (known or suspected)
    e. deceptive or false exposure of personnel dosimetry (known or suspected)
    f. alleged or known violations of the rules prescribed in this document or of the applicable regulations of the State of Texas
11. conform to any conditions placed on the Permit by the ORLC or RSC
12. comply with the provisions of this manual and the Laboratory Procedure Manual for Radioactive Materials

D. <u>The Individual</u>

Each employee or student within the MRB who works with radioactive material under a license listed in Section 3 of this manual must take responsibility for their own protection and for reporting any condition which, in the individual's opinion, constitutes unsafe or improper working conditions. Each individual is responsible for:

1. maintaining their own exposures to radiation and radioactive materials ALARA
2. following procedures and accepted safe work practices so as not to endanger themselves, the public, or the environment

3. reporting any unsafe working conditions, violations of the rules prescribed in this document, or violations of the applicable regulations of the State of Texas to their supervisor and/or to the TAMUSHSC COM ORLC

SECTION 3

LICENSING REQUIREMENTS AND REGULATIONS

A. License

1. The primary license, number L05494, is a specific license with limited-scope authorizations and is typical of large medical and academic institutions which have many Permitted Users and widely varied uses for radioactive materials. This license is issued by the Texas Department of State Health Services (DSHS). All permitted users within The Texas A&M University System (TAMUS) Health Science Center College of Medicine Medical Research Building are permitted under license number L05494.
2. A Permitted User at the MRB may occasionally find that the license listed above does not allow the use of radionuclides in a quantity, location or manner desired by the researcher. Amendments to these licenses may be requested by any Permitted User by submitting such a request to the ORLC. Depending upon the request, the ORLC may or may not agree to submit a request to the appropriate licensing agency. If not, the Permitted User may appeal that decision to the Radiation Safety Committee.
3. A copy of the latest version of any license may be obtained from the ORLC.

B. Authorization to Use Radioactive Materials

1. Any faculty or staff member in the MRB may apply for a permit to use radioactive materials. Application forms are available from the ORLC.
2. A Permit is issued to one person, never to a group, department, or facility.
3. Permits for radioactive material use are not transferable.
4. Permits are only valid for two years. At least 30 days prior to the end of the two year period, the ORLC shall notify the Permittee, in writing, of the need for renewal.

5. A second and final notice shall be sent to Permittees not responding to the first notice.
6. Failure to respond within 14 days of the date of the second notice shall be cause for the ORLC to send written notice to the Permittee that his/her Permit has been terminated requiring cessation of all work previously authorized under the Permit and confiscation of all radioactive materials covered by the expired Permit. Exceptions may be granted by the RSO where circumstances warrant.
7. Requests for renewal shall be submitted to the ORLC, in writing, signed by the Permittee. Properly signed copies received by fax are acceptable.
8. The RSO or the RSC may at any time place additional conditions or restrictions on a Permit for reasons of safety and/or compliance.
9. Only work that is authorized under the applicable Permit may be performed. The Permit may include restrictions or limits on
   a. radionuclide(s) authorized for possession/use
   b. activity per radionuclide
   c. chemical or physical form of each the radionuclide
   d. location of use and/or storage of radioactive materials
   e. types of experiments authorized
10. Radioactive materials shall not be used in or on humans.

C. Application for Permit to Use Radioactive Materials

1. Applicants shall complete and submit two copies of the application form, “Application for a Permit for the Use of Radioactive Material at MRB,” each bearing an original signature of the applicant.
2. The ORLC and the RSC shall review the application for the following
   a. location - applicant’s proposed use/storage location(s) must be authorized under an appropriate MRB license.
   b. position and authority of applicant - Permitted Users must have sufficient authority to control the use of the radioactive materials

authorized. That is, a subordinate should not be the Permitted User if that person's supervisor is to be designated as a user on the application.

c. radionuclides, activities, and form - should be consistent with the "statement of use"

d. statement of use - list or categorize the experiments in which radioactive materials are to be used. Describe in detail if toxic compounds will be used or if volatile materials will be involved. Are releases of radioactive materials possible? Are extra precautions warranted? Will mixed (hazardous and radioactive) waste be generated?

e. handling and storage procedures - should be consistent with the level of hazard associated with the radionuclides, activities and intended uses

f. radiation safety training - applicants shall be required to demonstrate or verify that they have a minimum of 40 hours of combined training and experience in the use of radioactive materials. In addition, all applicants and each person who uses or supervises the use of radioactive materials (Item No. 11 on application) shall be required to satisfactorily complete ORLC-approved training in radiation safety before beginning unsupervised work with radioactive materials. Satisfactory completion of training shall be determined by achieving a grade of at least 70% on a test given or approved by the ORLC.

g. survey instrumentation - each applicant must possess instrumentation appropriate for monitoring radiations from the radionuclides and quantities requested (Permit will not be issued until instrumentation is in the lab)

   i. for beta/gamma emitters except H-3 and I-125 - Geiger-Mueller (GM) survey meter with a thin window

ii. for H-3 - access to a liquid scintillation counter

iii. for sub-millicurie quantities of I-125 - access to a liquid scintillation counter or a solid scintillator (e.g. a NaI well counter)

iv. for millicurie quantities of I-125 - a portable, thin-window NaI detector

v. exceptions to this requirement include applicants requesting possession of only moisture/density gauges and/or gas chromatographs with Ni-63 foil sources. Other exceptions may be granted if approved by the RSO and the RSC.

h. facilities - must be adequate for the radionuclides and quantities requested

i. occupancy of adjacent or adjoining spaces

ii. availability of shielding and/or remote handling equipment, as appropriate

iii. availability of appropriate fume hoods

iv. availability of drains connected to the sanitary sewer

v. potentially conflicting uses of laboratory space

vi. locations of radionuclide use and storage (including waste storage)

i. security - radioactive materials shall be secured against unauthorized removal or access. Describe under Permit Application Item 13, how security will be maintained in your laboratory including radioactive materials in storage, radioactive materials in a protocol that is in-progress, and radioactive waste.

3. Reviewed applications, along with ORLC recommendations, shall be forwarded to three RSC members for review and approval. Approval is contingent upon written approval by all three RSC members. Unless directed otherwise by the RSC Chair, ORLC staff shall select three RSC

members to review the application based upon the expertise and availability of the members.

4. If the application is denied, the ORLC shall contact the applicant with information regarding the reasons for denial. At the applicant's discretion, he/she may revise the Permit application to meet the inadequacies or criticisms and resubmit the application.

D. <u>Amendments to Permits</u>

1. A request for an amendment to a Permit shall be submitted in writing to the ORLC.
2. Permit amendments are required for changes in
   a. authorized radionuclides,
   b. possession quantity limits of any radionuclide (increases only),
   c. physical or chemical form of the radionuclide,
   c. storage or use location,
   d. type of experiment, or
   e. any other condition or restriction placed upon the Permit by the ORLC or the RSC.
3. Amendment requests that involve significant changes to the Permit shall require written approval of a subcommittee of three of the RSC.

E. <u>Termination of Permits</u>

1. Permittees who intend to terminate a Permit shall notify the ORLC, in writing, at least ten working days prior to leaving, moving, or relinquishing control of the licensed facility.
2. Prior to terminating a Permit, Permittees shall transfer licensed materials in their possession to a TAMUSHSC COM Permittee (approved by the ORLC), to another non-TAMUS licensee (approved by the ORLC), or to the ORLC for disposal.
3. Disposal costs may be the responsibility of the Permittee or his/her department. Contact the ORLC for further information.

4. When the license is terminated, the OLRC will perform a clearance survey in accordance with Texas Administrative Code (TAC) §289.252(y).

F. <u>Termination of Permits for Cause</u>

1. An inactive Permittee (defined in a. and b. below) shall be notified in writing that their Permit will be terminated unless they provide written justification, co-signed by the appropriate department head, for maintaining an active Permit. A Permittee who has been terminated because of inactivity may reapply for a Permit at any time. Inactive Permittees are defined as
   a. users of unsealed sources that have not received radioactive materials and/or disposed of radioactive wastes within the preceding two years.
   b. users of sealed sources whose sources have not been used (as determined through the inspection process) within the preceding two years.
2. Any Permittee who willfully and/or negligently violates any applicable University, State, or Federal regulation governing the use of radionuclides as determined by the RSO shall have their Permit modified, suspended, or revoked. Radionuclides in their possession shall be impounded by the ORLC.
3. Reinstatement of a Permit following suspension or revocation shall require approval by a two-thirds majority of all voting members of the RSC.

G. <u>Sabbaticals and Absences (of 4 weeks or greater</u>)

Permittees shall notify the ORLC at least one month prior to the beginning of the sabbatical or extended leave. The Permittee shall:

1. arrange for another Permittee to oversee ongoing operations and records keeping and be available to laboratory personnel for routine or emergency assistance. Documentation shall be required by the ORLC.

   \- OR -

2. transfer all radioactive materials to the ORLC for disposal. The ORLC may store radioactive materials for the Permittee, if storage space is available.

SECTION 4

PROCUREMENT, TRANSFER, DISPOSAL, AND INVENTORY OF RADIONUCLIDES

Radioactive materials must be tracked from receipt at the MRB to final disposal. Accurate inventories and thorough documentation are fundamental controls necessary for the ORLC to demonstrate compliance with state and federal regulations.

A. Procurement of Radionuclides

Each Permittee is responsible for ordering radionuclides directly from the vendor. Each Permittee shall be responsible for ensuring that ORLC procedures for procurement of radioactive materials are followed (refer to the Laboratory Procedure Manual for Radioactive Materials).

1. Prior to ordering radionuclides, the Permittee or a designee shall obtain ORLC approval to place the order (by telephone or fax or by routing purchase requisitions through ORLC for approval).
2. When placing orders, ensure that the "bill to" address is appropriate for the source of funds (never ORLC) but the "ship to" address given to the vendor is the address of the ORLC **but sent to your (the Permittee's) attention.**
3. Standing Orders may be established with the ORLC for repetitive orders of the same radionuclide, compound, activity, vendor, etc. Contact the ORLC for additional information.

B. Receipt of Radionuclide Shipments

In this section, and the term "shipment", applies to receipt of any licensed radioactive materials whether they are purchased from a commercial vendor, loaned by a colleague from another institution, or otherwise brought into the MRB.

1. All incoming shipments of licensed radioactive material must be received, inspected, and inventoried according to ORLC procedures.
2. Radioactive materials received at the ORLC shall normally be delivered to the Permittee's laboratory the same day, if laboratory personnel are available to acknowledge receipt. Permittees shall keep records of receipts on file for at least 1 year after the material is transferred to the ORLC for disposal.
3. Radioactive material shall be delivered to laboratories, not to offices.
4. Deliveries to the ORLC on weekends and on TAMUS holidays are prohibited.
5. Radioactive material shipments will be delivered through the service elevator directly to room 320. There they will surveyed and checked in. This room has been designed and designated to house RAM. Within this room there is a 20 cu.ft. -40C freezer and a refrigerator dedicated to storage of only RAM.

C. <u>Inventory of Radionuclides</u>

1. Each Permittee shall maintain accurate inventory records at all times.
2. The ORLC shall send a printout of the radioactive material inventory to each Permittee, typically once each six months. These inventories shall include those radioactive materials that the Permittee has discarded as waste, but has not been collected by the ORLC.
3. The Permittee, or designee, shall physically locate each item on that inventory,

   sign and date the inventory, return the inventory bearing the original signature, and keep a copy for the Permittee's records until superseded.
4. Discrepancies between the printed inventory from the ORLC and the radionuclides on-hand shall be noted by the Permittee, explained in writing and via supporting documentation (if available), and returned to the ORLC with the inventory records.

D. Transfers of Radioactive Materials

"Transfer" of radioactive material, as used in this section, does not include transfer of radioactive materials to the ORLC for disposal. "Transfer" refers to a change in custody or control of radioactive material even if there is no change in ownership.

1. Transfers require prior ORLC approval.
2. Transfer procedures are provided in the Laboratory Procedure Manual for Radioactive Materials.

E. Disposal of Radioactive Materials

1. No Permittee may dispose of any radioactive materials except
   a. by transfer to the ORLC, or
   b. as specifically authorized by the ORLC
2. All Permittees are hereby authorized to wash contaminated glassware, lab coats, etc. and discharge the rinse water to the sanitary sewer system. No radioactive materials, including those in rinse water may be discharged into any drain that is not connected to a sanitary sewer system.
3. Liquid radioactive waste transferred to ORLC from the Permittees may be discharged by release into the sanitary sewerage if the conditions established in TAC§289.202(gg)(1) for both the annual activity limits and the monthly concentration limits are satisfied. The monthly average volume of water released to the sanitary sewer will be estimated from the incoming water volumes to the building and the average usage of the building. The procedure for release by sanitary sewerage including the release activity, release volume and the calculations to meet with the agency conditions are provided in the RSO procedure manual. Appropriate documentation of the release and other associated records will be maintained by the RSO.
4. All radioactive waste containers (carboys, bags, trashcans, etc.) shall follow the labeling requirement of TAC§289.202(cc). Labels with the

smallest dimension being less than 2 inches will not normally be adequate.

5. Procedures for requesting waste collections, for proper segregation and packaging of radioactive wastes, and for documentation of radioactive waste disposals are provided in the Permittees's Laboratory Procedure Manual.
6. Disposal documentation must be maintained on-file for the 1 year after final disposal.
7. Solid wastes of half-lives less than 88 days will be held for decay-in-storage at ORLC for a minimum of 10 half-lives for the longest lived isotope from the date of closure. Waste will be disposed of as "non-radioactive" if the following conditions are met:

   7.1. When final surveys made on contact with the waste container with appropriate survey instruments (GM and NaI) that are sensitive for radiation type and energies reflect readings equivalent or less than the background.

   7.2. If all radioactive labels have been removed or defaced.

   Procedure for disposal of non-radioactive waste is provided in RSO procedure manual and the documentation for release and other associated records will be maintained by the RSO.
8. All other solid radioactive waste will be contracted for disposal by a commercial low level radioactive waste handler.

SECTION 5

CONTROL AND LIMITATION OF RADIATION EXPOSURES

The effects of chronic low doses of radiation (in the range of 0 - 5000 millirem per year), as typically received by occupationally exposed persons, are not well known. Conversely, acute high doses of radiation (>100,000 millirem in one exposure) are known to increase the risk of stochastic effects such as cancer in the exposed individual or genetic effects in the progeny of the individual. By extrapolating the dose-effect relationship from high doses to low doses using the linear nonthreshold theory, increased risks for stochastic effects can be estimated even for very low radiation doses. (Reference USNRC Regulatory Guide 8.29)

These data and models lead to the conclusion that there is no dose which is one hundred percent "safe", i.e., completely without risk. However, natural and man-made background radiation is ubiquitous, providing an average annual radiation dose of 360 mrem to every U.S. citizen. Large fluctuations in background radiation, by geographical location, have not been shown to result in any measurable increase in risk of any health effect. Nevertheless, any radiation dose received occupationally will be in excess of the background radiation dose received and will be assumed to carry with it additive risk of deleterious effect.

State and federal regulations therefore establish a system of dose **limitation** and **minimization**. Individual doses are **limited** to ensure that deterministic effects (such as cataracts) are avoided and that total lifetime risks of stochastic effects (such as cancer and hereditary effects) do not exceed overall health risks for those persons working in safe industries. However, regulations also require that licensees further **minimize** radiation doses to individuals and to groups of individuals to the extent practical, social, economic and technological factors taken into account. This concept or philosophy is given the special name ALARA that is an acronym for As Low As is Reasonably Achievable.

A. Radiation Dose Limits

1. Occupationally Exposed Adults:
    a. Total Effective Dose Equivalent (TEDE) - 5 rem/y (5,000 mrem/y)
    b. Total Organ Dose Equivalent (TODE) - 50 rem/y (50,000 mrem/y)
    c. Shallow Dose Equivalent (SDE) -50 rem/y (50,000 mrem/y)
    d. Extremity Dose Equivalent -50 rem/y (50,000 mrem/y)
    e. Lens (of Eye) Dose Equivalent (LDE) - 15 rem/y (15,000 mrem/y)
2. Individual Members of the Public
    a. 2 mrem in any one hour
    b. Total Effective Dose Equivalent (TEDE) - 0.1 rem/y (100 mrem/y)
3. Occupational Dose Limits for Minors (under 18 years of age) *
    a. Ten percent (1/10) of any applicable limit in item 1 above
4. Dose to an Embryo/Fetus of a Declared Pregnant Woman **
    a. Total Effective Dose Equivalent (TEDE) - 500 mrem over entire pregnancy
    b. TEDE should not vary substantially above 50 mrem in any month

* Permitted Users are discouraged from allowing minors (persons under 18 years of age) from working with radioactive materials or other chemical or biological hazards. Contact ORLC for assistance with radiation dosimetry and informed consent issues if employment of minors is necessary.

** Accommodations for Declared Pregnant Women (see definitions) should be made when possible to reduce doses to the unborn. Contact ORLC for assistance.

B. Routes of Exposure and Means of Exposure Control

Exposures may be received from radioactive materials that are external to the body (external exposure) or from radioactive materials that are inside the body (internal exposure) or both.

1. Control of External Exposure

   Common external exposure controls include the use of time, distance, and shielding to minimize radiation doses. These concepts are thoroughly presented in ORLC radiation safety training courses but should also be continually reinforced by the Permitted User in the laboratory. In addition, doses may also be reduced by minimizing the amount of radioactive materials on-hand (e.g., procure only the amount needed) or by substituting for radioactive materials (e.g., use P-33 instead of P-32 or use non-radioactive tracer techniques).

2. Control of Internal Exposure

   The only reasonable method by which internal exposures can be controlled or minimized is by preventing the intake of radioactive materials. The four routes by which radioactive materials can be taken into the body are 1) inhalation, 2) ingestion, 3) absorption through the skin, and 4) injection through wounds. To protect against these routes of intake, Permitted Users are expected to utilize good laboratory safety practices as identified in the Laboratory Procedure Manual for Radioactive Materials. Of particular importance are the following:

   a. proper use of a fume hood which is suitable for use of radioactive materials - particularly when using volatile radioactive compounds (those which could reasonably become airborne).

   b. no smoking, eating or drinking in a laboratory in which radioactive materials (other than sealed sources) are used or stored. This includes smokeless tobacco and chewing gum. Furthermore, food, drinks, eating utensils, cups, drinking glasses, etc. shall not be used or stored in rooms or refrigerators where use of radioactive material is authorized. Microwave ovens and ice machines in laboratories are not for personal uses.

   c. wear protective clothing, including gloves and closed-toe shoes. Laboratory coats are required when using activities greater than

1 mCi. Laboratory coats and eye protection are recommended at any level.

d. required precautions and contamination prevention techniques are prescribed in the Laboratory Procedure Manual for Radioactive Materials.

SECTION 6

RADIATION DOSIMETRY

The purpose of the radiation dosimetry program is to measure radiation dose equivalent received by occupationally exposed individuals at the MRB. The results serve to verify and document compliance with the applicable dose limits (see Section 5) as well as to identify problems and monitor the effectiveness of existing radiation safety controls.

Radiation doses may be received in two ways: 1) from radioactive materials which are external to the body (external dose) or 2) from radioactive materials which are inside of the body (internal dose). These doses shall be monitored when required by regulation, as described below:

A. <u>External Radiation Dosimetry</u>

1. Radiation dosimeters appropriate for the radiations to be monitored shall be issued by the ORLC to the individual and shall be required to be worn by
   a. adults, minors and declared pregnant women likely to receive, in one year from sources external to the body, a dose in excess of 10% of the applicable dose limits (ref. Section V); and
   b. individuals entering a High Radiation Area or a Very High Radiation Area.
2. The ORLC shall determine the "likely to exceed 10%" status of an individual (ref. 1.a above), the dosimeter type, the wear period, etc. Dosimeters are generally incapable of monitoring doses from low energy (E_{max} less than 200 keV) beta emitters such as H-3, C-14, S-35 and Ni-63.
3. The Permittee shall immediately notify the ORLC of changes in radioactive materials uses that could significantly increase or decrease radiation

doses to laboratory personnel or which could otherwise affect the need for external dosimetry.

4. Radiation dosimeters shall not be issued for wear periods greater than 3 months.
5. Radiation dosimeters shall not be deceptively exposed.
   a. Dosimeters are issued to only one person. Dosimeters shall not be shared.
   b. Dosimeters in storage and not being worn shall not be stored near sources of radiation.
   c. Dosimeters should not be exposed to high heat, chemical or physical insults, or washed in a washing machine.
   d. No person shall wear dosimeters issued by the TAMUSHSC COM ORLC while working for another employer or institution without prior approval from the ORLC. Permittees shall notify the ORLC if employees are concurrently working for another (non-TAMUS) employer and working with sources of ionizing radiation.
   e. Dosimeters shall not be worn during medical or dental x-ray examinations.
   f. Dosimeters shall not be worn after medical administration of radioactive materials (thyroid ablation therapy, cardiac stress tests, diagnostic nuclear medicine tests, etc.) until approved by the TAMUSHSC COM ORLC.
   g. Permittees shall notify the ORLC immediately upon learning of possible deceptive exposures of dosimeters.
   h. <u>Intentional</u> deceptive exposures of dosimeters are forbidden and may result in enforcement actions.
6. Lost or damaged dosimeters shall be reported to the ORLC as soon as possible.

7. Persons who have lost or damaged their dosimeters shall be required to provide documentation of work activities and radioactive material uses as necessary for the ORLC to assess doses.
8. Where to Wear Dosimeters
   a. whole body dosimeters shall be worn at the location on the whole body likely to receive the highest dose (refer to definition of “whole body” in glossary)
   b. for persons performing diagnostic x-ray and/or fluoroscopy procedures, the dosimeter should normally be worn at the collar
   c. **for fetal monitoring for declared pregnant females**, whole body dosimeters should be worn on the abdomen. If a leaded apron is worn (as in veterinary radiology), the dosimeter should normally be placed on the abdomen, under the apron.
   d. if a leaded apron is worn, workers should wear whole body dosimeters outside of any leaded apron
   e. TAMUS normally uses ring dosimeters for extremity monitoring. Ring dosimeters should be worn on the (R)ight or (L)eft hand, as indicated on the dosimeter, with the sensitive portion of the dosimeter turned toward the source of radiation
   f. ring dosimeters should be worn beneath protective gloves to reduce the likelihood of contaminating ring dosimeters
9. Permittees or their designees shall collect and return used dosimeters to the ORLC promptly after receiving replacement dosimeters at the beginning of a new wear period.
10. Any person who works with any source of radiation at the MRB (or did so in the past) may request a copy of their dose records at any time. These records are maintained by and are available from the ORLC upon written request.

11. After termination of employment, a dose report (termination report) shall be provided to all persons who received doses exceeding 10% of any radiation dose limit in the applicable reporting period.
12. The ORLC shall recover costs for dosimetry services by charge-back to users. Contact the ORLC for additional information.

B. Internal Radiation Dosimetry

1. Intakes of radioactive materials and the resulting radiation doses shall be monitored by the ORLC to determine compliance with applicable regulations for
    a. adults likely to receive, in one year, an intake in excess of 10% of the Annual Limit on Intake (ALI, refer to table VI-2); and
    b. minors and declared pregnant women likely to receive, in one year, a committed effective dose equivalent (CEDE) in excess of 0.05 rem (50 mrem).
    c. based upon a. and b. above and regulatory guidance from the U.S. Nuclear Regulatory Commission, cumulative (annual) activity use levels have been calculated for any given laboratory above which internal dose monitoring is required. These levels are presented in Table VI-1.
2. Internal dose monitoring may be accomplished by any of the following methods
    a. bioassay - direct measurement of radioactive material in the body (*in vivo* bioassay) or in bodily excretions (*in vitro* bioassay)
    b. airborne radioactive surveys combined (as necessary) with time and motion data.
    c. calculations based upon estimates of airborne concentrations and time and motion studies. This approach is only to be used in the absence of data necessary to support methods in a. and b. above.
    d. any combination of a, b, and c above.

3. Internal dose assessment shall be performed by the ORLC.
4. Permittees shall ensure that personnel using radioactive materials in excess of the activity levels in Table VI-1 contact the ORLC to arrange for bioassay procedures.
5. Bioassays are normally performed (or bioassay samples should normally be collected) 24-48 hours after potential exposure.
6. Measurements or calculations that confirm intakes and/or doses in excess of 2% of the annual dose limit shall be re-measured or recalculated as deemed appropriate by the ORLC.

Table VI-1 Activity Levels Above Which Internal Dose Monitoring is Required.

Radio-nuclide	Type of Confinement	Activity Handled in Unsealed Form: Volatile or Dispersible	Activity Handled in Unsealed Form: Bound to Non-Volatile Agent
I-125 or I-131	Glovebox	2,000 mCi/y	20,000 mCi/y
	Hood	200 mCi/y	2,000 mCi/y
	Open bench, normal ventilation	20 mCi/y	200 mCi/y
	Special operations, ventilation unknown	2 mCi/y	20 mCi/y
H-3	Glovebox	4,000 Ci/y	40,000 Ci/y
	Hood	400 Ci/y	4,000 Ci/y
	Open bench, normal ventilation	40 Ci/y	400 Ci/y
	Special operations, ventilation unknown	4 Ci/y	40 Ci/y
****	Glovebox	> 10 Ci/y	> 10 Ci/y
	Hood	> 10 Ci/y	> 10 Ci/y
	Open bench, normal ventilation	> 10 Ci/y	> 10 Ci/y
	Special operations, ventilation unknown	> 10 Ci/y	> 10 Ci/y

**** C-14, S-35 P-32, P-33, Ca-45, Tc-99m, Cu-64, Cr-51, Cs-137, Co-60
Contact the ORLC for radionuclides not on this list.

For minors or declared pregnant women, divide the activity levels above by 10.

C. Summation of Internal and External Doses

1. The ORLC shall sum internal and external doses to determine the Total Effective Dose Equivalent (TEDE) and/or the Total Organ Dose Equivalent (TODE) received by any exposed individual for whom monitoring is required pursuant to both A.1 and B.1 above.
2. The ORLC shall sum internal and external doses to determine the Total Effective Dose Equivalent (TEDE) and the Total Organ Dose Equivalent (TODE) received by the exposed individual for whom monitoring is not required pursuant to A.1 and B.1 above, but for whom doses were measured or estimated and shown to exceed 10% of the applicable annual dose limit.
3. Dose-related data is maintained on file at the ORLC. That data is available to Permittees and the exposed individual upon written request.

Table VI-2. Annual Limits on Intake for Selected Radionuclides

Radionuclide	(Form)	Annual Limits on Intake (µCi) Ingestion	Inhalation
H-3	(any)	8 E+4	8 E+4
C-14	(carbon monoxide)	-----	2 E+6
	(carbon dioxide)	-----	2 E+5
	(compounds)	2 E+3	2 E+3
P-32	(all compounds except specific phosphates below)	6 E+2	9 E+2
	(phosphates of Zn^{2+}, S^{3+}, Mg^{2+}, Fe^{3+}, Bi^{3+})	-----	4 E+2
P-33	(all compounds except specific phosphates below)	6 E+3	8 E+3
	(phosphates of Zn^{2+}, S^{3+}, Mg^{2+}, Fe^{3+}, Bi^{3+})	-----	3 E+3
S-35	(vapor)	-----	1 E+4
	(sulfides & sulfates except specific compounds below)	1 E+4	2 E+4
	(elemental sulfur, sulfides of Sr, Ba, Ge, Sn, Pb, As, Sb, Bi, Cu, Ag, Au, Zn, Cd, Hg, W, & Mo. sulfates of Ca, Sr, Ba, Ra, As, Sb, & Bi)	6 E+3	-----
Ca-45	(all compounds)	2 E+3	8 E+2
Cr-51	(all compounds except as below)	4 E+4	5 E+4
	(halides, nitrates, oxides and hydroxides)	-----	2 E+4
Fe-55	(all compounds except as below)	9 E+3	2 E+3
	(oxides, hydroxides, and halides)	-----	4 E+3
Fe-59	(all compounds except as below)	8 E+2	3 E+2
	(oxides, hydroxides, and halides)	-----	5 E+2
Tc-99m	(all compounds)	8 E+4	2 E+5
I-125	(all compounds)	4 E+1	6 E+1
I-131	(all compounds)	3 E+1	5 E+1

SECTION 7

RADIATION SURVEYS, POSTINGS, AND INSTRUMENTATION

Radiation surveys are used to identify and quantify radiological hazards and to document regulatory compliance. The ORLC and the Permittee must work together to ensure safety in the workplace and to protect both the public and the environment from the harmful effects of radiation.

A. Types of Surveys

1. Radiation surveys - may be performed to measure exposure or dose rates from sources of radiation which are in storage, in waste, or in use. Radiation surveys
    a. are required to be performed in laboratories using millicurie quantities of radionuclides including Cr-51, Na-22, Na-24, Mn-54, Co-60, Cu-67, Tc-99m, I-125, I-131, Cs-137, Pu-Be, Am-Be, or Cf-252.
    b. are required to be performed in laboratories using one or more of the radionuclides shown in step a. above when
        i. new and significantly higher activity sources are received,
        ii. radioactive material storage areas are relocated,
        iii. radioactive waste containers are relocated, and/or
        iv. radioactivity levels in storage are changed significantly.
    c. shall be performed and documented in accordance with the Laboratory Procedure Manual for Radioactive Materials.
2. Contamination surveys - used to determine levels of radioactive contamination on surfaces in the laboratory or on personnel. Contamination surveys may involve the use of a portable instrument or the use of wipes that can subsequently be counted using a suitable radiation detector.

a. Surveys shall be performed at a frequency necessary to demonstrate compliance with the regulations. Regulatory guidance recommends:

i. not less frequently than once per month in areas where in vitro tests are performed, samples (<100 µCi) analyzed, etc.

ii. not less frequently than once per week in areas where millicurie amounts of radioactivity are used.

iii. not less frequently than once per day in areas where active solutions are stored or prepared, fume hoods, etc. (usually for curie quantities)

b. Documented post-op surveys, those performed immediately upon completing an operation using radioactive materials, are of vital importance in identifying contamination and preventing its spread.

c. Contamination surveys shall be performed and documented in accordance with the Laboratory Procedure Manual for Radioactive Materials.

3. Airborne radioactivity surveys shall be performed by the ORLC on an “as needed” or “on-request” basis.

4. Fume hood surveys are required annually or after maintenance that could affect fume hood face velocity. Fume hood surveys are performed by the ORLC.

B. Limits

1. Radiation levels

a. < 2 mrem in any one hour in unrestricted areas - applies to short term (typically less than 24-hour) exposures.

b. < 50 mrem in any one year in unrestricted areas (< 5.7 µrem/hr) - applies to long-term (typically greater than 8-hour) exposures. Exceptions may be granted by the ORLC.

c. in restricted areas, exposure rates should be kept ALARA (As Low As is Reasonably Achievable). Refer to Section 5, Control and Limitation of Radiation Exposures.

2. Contamination levels on laboratory surfaces (removable) as determined by either wipe survey or instrument survey:
   a. no detectable contamination above background, i.e., not more than twice background levels
   b. the determination of “no detectable contamination above background” must be made with a detector which has been response checked within the past 12 months and which is suitable for measuring the type(s) of radiation expected
   c. if detectable contamination (greater than twice background) remains after decontamination efforts, contact the ORLC for assistance
3. Contamination levels on personnel or clothing - no detectable contamination above background

C. Postings

1. **Caution (or Danger) Radiation Area** - any area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 5 mrem in 1 hour at 30 centimeters from the source of radiation or from any surface that the radiation penetrates.
2. **Caution (or Danger) High Radiation Area** - any area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 100 mrem in 1 hour at 30 centimeters from the source of radiation or from any surface that the radiation penetrates.
3. **Caution (or Danger) Airborne Radioactivity Area** - any room, enclosure, or area in which airborne radioactive materials exist in concentrations in excess of levels specified in the regulations.

4. **Caution (or Danger) Radioactive Material(s)** - all doors or entrances to rooms or areas in which licensed radioactive materials are used or stored (ORLC may grant exceptions to this requirement as is consistent with state and federal regulations).
5. Signs and postings listed in 1 through 4 above should be removed when conditions no longer warrant that posting.
6. Signs and postings listed in 1 through 4 above shall conform to regulatory specifications on wording, symbol, and colors.

D. Labeling

1. **Caution (or Danger) Radioactive Material** labels shall be placed on radioactive materials containers holding radioactive materials in quantities (activities) greater than those specified in 25 TAC 289.202 Appendix C (refer to Appendix B of this manual) unless
   a. the containers are attended by an individual who takes the precautions necessary to prevent the exposure of individuals in excess of the applicable dose limits (refer to Section 5), or
   b. containers that are in transport and properly labeled for such.
2. **Caution (or Danger) Radioactive Material** labels should be placed on containers holding radioactive materials in quantities (activities) greater than 0.1 times the values specified in 25 TAC 289.202 Appendix C (refer to Appendix B of this manual) except as exempted in D.1.a and b above.

E. Requirements on Maintaining Radiation Detection Instrumentation

1. Each Permittee must possess radiation detection equipment that is appropriate for detecting the types of radiations emitted by the radionuclides for which the Permittee is authorized.
   a. for authorization to possess any quantity of H-3 (tritium) or quantities of C-14 of 250 µCi or less, Permittees must possess or have access to a liquid scintillation counter. Portable radiation

detectors are not useable for detection of H-3 unless specifically designed as a tritium contamination detector;

b. for authorization to possess any other beta emitting radionuclide, for C-14 in quantities exceeding 250 µCi, and for any gamma emitting radionuclide, the Permittee must possess a properly operating portable radiation detector appropriate for detecting those radiations;
    i. a thin window Geiger-Mueller (GM) detector is normally the best choice for most alpha and beta emitting radionuclides;
    ii. a portable scintillation detector (e.g. NaI or plastic) is required for Permittees authorized to possess I-125 in activities greater than 1 mCi.

c. EXEMPTIONS - radiation detectors are not required for those Permittees who possess only
    i. Ni-63 sources in electron capture detector (ECD) cells used in gas chromatography
    ii. uranium or thorium in compounds in total quantities of 3 kilograms (6.6 pounds) or less
    iii. sealed sources in moisture/density gauges
    iv. exceptions may be granted by the ORLC on a case-by-case basis.

2. Portable radiation detectors shall be calibrated or response checked, as appropriate for the use of the instrument, at least annually or after repair of the instrument. Battery replacement is not cause for performing a calibration. The ORLC will arrange for such calibrations and response checks at the request of the Permittee.

3. Prior to purchasing a portable instrument, Permittees are invited to contact the ORLC for recommendations on instruments and vendors.

SECTION 8

RADIOACTIVE MATERIAL SECURITY

Permittees are responsible for securing radioactive materials from unauthorized removal or access at all times. In an academic environment, meeting this requirement can be difficult. Following are generally acceptable practices. If other security measures are employed, Permittees should consult with the ORLC.

A. The exterior entrance into the MRB receiving dock area will be secured by magnetic lock and pass card. All other public doors into the facility will have signs prohibiting delivery of RAM or hazardous materials through them. Vendors delivering RAM must use the receiving dock and will use the receiving dock phone to call the RSO or designate to request entry into facility. They will be escorted directly to room 320 for RAM check-in.
No unauthorized staff will be permitted in any restricted laboratories. Doors into any laboratory containing RAM will be locked whenever authorized staff isn't present. The door into the RAM receiving and storage room (320) will remained locked at all times and entry will be through a coded lock.

B. If radioactive materials are accessible (unsecured) in a laboratory, laboratory doors should be locked to prevent unauthorized access; or

C. During periods when the laboratory is not locked, security may be maintained by direct surveillance. The person watching the lab or area shall be instructed to question unauthorized and/or unrecognized persons who enter the laboratory; or

D. If the Permittee chooses not to lock the laboratory doors or cannot be assured of adequate security when the laboratory is locked, the Permittee shall ensure that all radioactive materials are locked in a cabinet, drawer, refrigerator, freezer, etc. during periods when there is no direct surveillance by trained personnel.

E. Exceptions shall be granted for:

1. experiments-in-progress wherein the total activity is less than 2 millicuries; or
2. radioactive waste containers in which the total activity present in that individual waste container is less than 5 millicuries; or
3. foil or sealed sources which are installed in a fixed/non-portable instrument or device, e.g., Ni-63 sources in ECD cells installed in a gas chromatograph.

SECTION 9

TRAINING

All individuals who work with or near licensed or registered sources of radiation are required to complete radiation safety training. The depth of the training must be commensurate with the level of hazard to which the individual is exposed. **All training must be documented.** No individual shall be allowed to work unsupervised with licensed or registered sources of radiation until that person completes appropriate radiation safety training.

A. Basic Radiation Safety Training

1. All individuals, including principal investigators, who work with or are authorized to possess licensed or registered sources of radiation are required to satisfactorily complete the radiation safety training course and/or demonstrate competence on that subject matter by scoring at least 70% on the test. The following standard courses are offered individually or as a combined course:
    a. General Radiation Safety Training for Open Isotope Users - a broad-based training course for users of unsealed radioactive material
    b. Site-Specific Radiation Safety Training – site-specific safety and procedures for the Medical Research Building
2. Each Permittee is responsible for providing and documenting laboratory-specific training to individuals (including students) who work with licensed or registered sources of radiation under the Permittee’s control. This training shall address, as applicable,
    a. Area restrictions - where radioactive materials are to be used within the lab(s) and restrictions on that use
    b. Location and procedures for radioactive material storage and security
    c. Posting locations for required signs and notices

d. Walk-through review of protocols involving radiation sources

e. Special handling techniques which will minimize exposures when handling radionuclides

f. Availability of protective equipment and clothing

g. Radioactive material accountability

3. Radiation safety training shall be provided to persons who frequent areas where radioactive materials are used or stored, but who do not work with those materials. Examples include custodians, clerical personnel, etc. Except for the custodial staff, this training shall be the responsibility of the Permittee. Custodial staff shall receive radiation safety training through their administrative department. Such training shall include

   a. a brief discussion of hazards of radiation and radioactive materials

   b. recognition of warning signs

   c. areas from which such persons are restricted

   d. person(s) to contact in the event of incident or emergency

4. ORLC provided refresher training shall be conducted at least once every two years for all individuals, including Permittees, who work with licensed sources of radiation or who are authorized to possess same.

5. All training shall be documented and maintained on file by the Permittee. Training documentation shall include

   a. content of the training (outline, course description, etc.)

   b. instructor name and Permittee name

   c. date of training

   d. printed name of trainee(s)

   e. signature or initials of trainee(s)

6. Copies of individual employee training records from ORLC training courses are available from the ORLC.

SECTION 10

TRANSPORTATION OF RADIOACTIVE MATERIAL

Radioactive materials shall packaged and transported in accordance with all applicable rules and regulations specified by the U.S. Department of Transportation (DOT), the U.S. Nuclear Regulatory Commission (NRC), the Texas Department of State Health Services (DSHS), and the International Air Traffic Association (IATA).

For the purposes of this manual, “transport” shall refer to the movement of radioactive materials in any vehicle on public roadways (including campus streets) or by air, water, or rail. Radioactive material which is hand carried or transferred on a moveable cart between laboratories or buildings on the same campus is not considered “in-transport”.

A. Training Requirements

1. Any person who packages, transports, or receives radioactive material shipments and any person who prepares hazardous material transport documents or signs for the same, shall be trained to do so by the TAMUSHSC COM ORLC.
2. Training shall be commensurate with the job duties of the individual.

B. Persons who are not properly trained and certified shall contact the ORLC for assistance in packaging, labeling and/or transporting radioactive materials.

C. At no time shall any Permittee or any person acting on behalf of a Permittee carry radioactive material aboard a passenger-carrying aircraft. Contact the ORLC for more information and possible exceptions.

SECTION 11

INSPECTIONS OF PERMITTEE OPERATIONS

Permittees may be inspected at any time by either the TAMUS ORLC or the Texas Department of State Health Services. The following information is intended to make the Permittee aware of the inspection program and to provide general information on what is expected of the Permittee.

A. Inspections by the Texas Department of State Health Services

1. Annual inspections of the ORLC by the Texas Department of State Health Services may include spot inspections of individual Permittees. Such inspections are typically unannounced.
2. Permittees should keep in mind that the ORLC may have duplicates of any records found to be missing. By calling the ORLC during the inspection and having those duplicates faxed, the Permittee may avoid being cited for violations.

B. Inspections by the Office of Research Laboratory Compliance

1. ORLC inspections of Permittees on the TAMUS main campus are of two types
    a. Quarterly inspection - typically involves
        i. performance of a contamination survey
        ii. survey instrument check
        iii. check on postings in laboratory
    b. Annual inspection - involves review of all items reviewed in the quarterly inspection and may include:
        i. review of training records
        ii. review of worker list
        iii. review of procedures

iv. review of Permit authorizations and conditions

v. performance of radiation area surveys in restricted and unrestricted areas, as appropriate for the radionuclides and activities present

vi. review of Permittee inventory

vii. review of radioactive material security

viii. review of Permittee's survey records

2. ORLC reserves the right to inspect any Permittee with no advance notice. However, all routine inspections shall be announced and scheduled at a time that is mutually acceptable with the Permittee.
3. Inspection reports shall be generated by the ORLC and a copy sent to the Permittee.
4. Permittee responses, if any, shall be filed with the ORLC inspection report and maintained on-file at the ORLC.

SECTION 12

INCIDENTS AND EMERGENCIES

In the event of a radiological incident or emergency, the TAMUS ORLC must be notified immediately. In instances where there is doubt about whether such notification is necessary, contact should be made to allow the ORLC staff member on duty to assess the situation and initiate the appropriate response.

The staff of the ORLC is "on-call" for emergency response 24-hours per day, seven days per week. Any individual may contact the ORLC to obtain assistance. Emergency telephone numbers shall be posted in every laboratory in which radionuclides are used.

During normal business hours:
(254) 724-7774 (ORLC Main Office)
(254) 718-0265 or (254) 721-0824 (RSO assistant cell phones)
(979) 845-7551 (RSO)
After normal business hours, weekends and holidays:
(254) 718-0265 (ORLC cell phone) or (979) 450-2586 (RSO cell phone)

A. What Constitutes an Incident or Emergency

1. Loss or theft of any radioactive material or radiation producing device.
2. High or potentially high radiation exposure to an individual or to a member of the public. For example
    a. greater than 500 mrem in one month or less to any occupationally exposed individual
    b. greater than 5000 mrem in one month or less to the extremity of any occupationally exposed individual
    c. greater than 10 mrem to any member of the public
3. Intake or potential intake of radioactive materials by inhalation, ingestion, absorption through skin, or injection through skin or wound
4. Deceptive or potentially deceptive exposure of a dosimeter

5. Personnel contamination that cannot be completely removed after two washes with only soap and water.
6. Spills involving any quantity of alpha emitting radionuclide, more than 1 microcurie of iodine-125 or iodine-131, or spills involving more than 10 microcuries of any other radionuclide.
7. Any spill which is not or cannot be completely decontaminated before the end of that workday.
8. Identification of any contamination which is outside of the restricted area, such as spills tracked or otherwise spread into offices, hallways, vehicles, etc.
9. Accidental releases of radioactive material to the environment including those released via the fume hood.
10. Fires or floods which threaten to release radioactive materials to the environment or which threaten to expose emergency response personnel.
11. Any transportation accident, whether on-campus or off-campus, involving radioactive materials.
12. Any personnel injuries which may involve radioactive contamination or radiation exposure.

B. <u>Personnel Injury Involving Actual or Suspected Contamination or Exposure to Radiation</u>

1. Provide first aid immediately for serious injuries.
2. Call 9-911.
3. Notify the ORLC or RSO from the numbers as per the previous page.
4. As possible, without doing harm to the victim, monitor the injured individual and remove contaminated clothing and gross personal contamination.

C. <u>Decontamination of Personnel</u>

1. Remove and bag all contaminated clothing.

2. Skin contamination should be cleaned using mild soap and tepid water. Use portable survey meter to monitor for remaining contamination. If not free of contamination, rewash and resurvey. Decontamination solutions which are formulated for use on skin may be used, if available.
3. Call the ORLC to report the incident even if the decontamination was successful.
4. Survey for contamination elsewhere on body as well as on clothes, shoes, floor, door handles, telephone, etc. Document the surveys.
6. If the contamination is in a wound (e.g., a cut from contaminated glassware) rinse the wound with copious quantities of water.
7. Write an account of the incident, <u>signed by the author and the Permittee</u>, and send a copy to the ORLC.

D. <u>Radioactive Spills or Releases</u>

Decontamination shall be the responsibility of the group that caused the spill. For large spills (i.e., greater than 10 microcuries) or spills that are difficult to clean up, the work should be carried out under the supervision of the ORLC. Appropriate protective clothing shall be worn during decontamination activities. Steps to respond to spill incidents are:

1. Stop work and confine the spill immediately using an absorbent, enclosure, etc.
   Call ORLC immediately.
2. Warn others of the hazard and isolate the area.
3. Monitor personnel during and after cleanup for contamination.
4. Collect all used cleanup materials as radioactive waste. Remove and bag all contaminated clothing or cleanable items for removal by the ORLC.
5. Commence wipe surveys and decontamination. Ensure surveys of surrounding areas are performed to ensure that all contaminated areas are identified.
6. Prepare a written report on the incident. Send one copy to the ORLC.

SECTION 13

PERMITTEE RECORDS

Record keeping requirements vary depending upon whether the Permittee conducts licensed activities on the TAMUS campus or elsewhere. For those on the Temple MRB campus, many records are maintained at the ORLC thereby relieving the Permittee of some responsibilities. For those not on the Temple MRB campus, additional records must be available for inspection by the Texas Department of State Health Services and, therefore, more records must be kept on file by the Permittee.

A. General Record-Keeping Requirements

1. All Permittees on the TAMUSHSC COM MRB campus in Temple shall maintain the following records in a clear, concise and orderly format. Retention periods are included in parentheses.
    - a. permit records (life of permit)
        - i. approved application for permit with original RSC signatures
        - ii. all amendments, requests for amendment, and Permit renewals
    - b. receipt, transfer and disposal records for every licensed source of radiation (1 year after final disposal)
    - c. copies of inventory reports (1 year)
    - d. radiation surveys (1 year)
        - i. contamination surveys
        - ii. radiation field surveys in restricted areas
        - iii. radiation field surveys in unrestricted areas
    - e. survey instrument calibrations performed by anyone other than the ORLC (3 years)

f. personnel records (1 year)
   i. worker/user lists
   ii. training records
g. operating and emergency procedures (current)
h. procedure manuals from ORLC (current)
i. records of radiation safety training performed by the Permittee (3 years)

2. In addition to maintaining duplicates of all records in step 1 (except 1.d, 1.g, and 1.i above), the ORLC shall maintain the following records which are available for review during normal office hours.
   a. original copy of all radioactive material licenses issued to TAMUSHSC COM MRB in Temple
   b. copies of current state and federal regulations relating to radioactive materials
   c. official inventory records
   d. inspection reports and copies of all “Notices of Violation” issued by state or federal regulatory agencies and the TAMUSHSC COM MRB responses to those Notices.
   e. current version of all policy manuals and procedure manuals
   f. calculations and reports as required for compliance with the Clean Air Act for radionuclide releases from TAMUSHSC COM MRB facilities
   g. dosimetry records
   h. leak test results
   i. survey instrument calibrations
   J. Radiation Safety Program review

B. Information Required on Specific Records Maintained by ORLC

1. Radioactive material receipt surveys, radiation surveys, & contamination surveys
   a. records shall be in units of dpm, becquerels (Bq), µCi, mR/h, mrem/h, etc., as appropriate. Units of "cpm" or "counts" are not acceptable for quantitative survey records.
   b. records shall uniquely identify the source of the radiation
   c. records shall clearly indicate the areas surveyed (include a map)
   d. records shall indicate the person performing the survey and date of survey
   e. records shall uniquely identify the survey instrument used, i.e., serial number, or other unique description
2. Training records are specified in Section 9.

SECTION 14

SPECIAL REQUIREMENTS FOR USERS OF SEALED SOURCES

Sealed sources are those which are permanently bonded or fixed in a capsule or matrix designed to prevent release and dispersal of the radioactive material under the most severe conditions that are likely to be encountered in normal use and handling. Within TAMUSHSC research laboratories, the most common use of sealed sources is in electron capture detector (ECD) cells.

Some sealed sources may be capable of generating significant radiation fields when in use or when removed from storage. However, sealed sources should never leak radioactive materials if used in accordance with the manufacturer's guidance. For this reason, radioactive contamination is highly unlikely. Sealed source leak tests are used to confirm and document the integrity of the source encapsulation and the absence of contamination.

A. Special Requirements Sealed Sources

Permitted Users authorized to possess sealed sources are required to

1. Perform sealed source leak tests when and as prescribed by ORLC procedures as scheduled by ORLC.
2. Define a storage area that has adequate security.
3. Conduct or arrange for the TAMUSHSC COM ORLC to conduct storage area surveys
   a. on initially establishing the storage location,
   b. when changing a storage location,
   c. when adding a gauge to a storage location, or
   d. when the occupancy of the areas adjacent to the storage location are changed.

4. Ensure that only persons who have been properly trained may have access to or operate a device containing a sealed source.
5. Ensure that the source(s) are transported in accordance with U.S. Department of Transportation regulations and procedures provided by the TAMUSHSC COM ORLC.

SECTION 15

GLOSSARY OF TERMS

"Absorbed dose" means the energy imparted by ionizing radiation per unit mass of irradiated material. The units of absorbed dose are the rad and the gray (Gy). 1 Gy = 100 rad.

"Activity" means the rate of disintegration or transformation or decay of radioactive material. The units of activity are "disintegrations per second (or minute)" (dps or dpm), curie (Ci) and the becquerel (Bq). 1 Ci = 37,000,000,000 dps (3.7×10^{10} dps)
1 Ci = 2,220,000,000,000 dpm (2.22×10^{12} dpm)
1 Bq = 1 dps

"Adult" means an individual 18 or more years of age.

"Agreement State" means a state which has executed an agreement with the U.S. Nuclear Regulatory Commission transferring to the state the responsibility for regulating uses of certain radioactive materials within its borders. Texas is an agreement state.

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

"Airborne radioactivity area" means a room, enclosure, or area in which airborne radioactive materials exist in concentrations:

(1) in excess of the derived air concentrations (DACs) specified in 25 TAC 289.202, as shown in Appendix B, Table I, Column 1; or

(2) to such a degree that an individual present in the area without respiratory protective equipment could exceed, during the hours an individual is present in a week, an intake of 0.6 percent of the annual limit on intake (ALI) or 12 DAC-hours.

"Annual Limit on Intake (ALI)" means the derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year.

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

"Background radiation" means radiation from cosmic sources; non-technologically enhanced naturally occurring radioactive material, including radon, except as a decay product of source or special nuclear material, and including global fallout as it exists in the environment from the testing of nuclear explosive devices or from past nuclear accidents, such as Chernobyl, that contribute to background radiation and are not under the control of the licensee. "Background radiation" does not include radiation from sources regulated by the Texas Department of State Health Services.

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

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

"Byproduct material" means:

(1) any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material; and

(2) the tailings or wastes produced by or resulting from the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content, including discrete surface wastes resulting from uranium solution extraction processes.

"CFR" means Code of Federal Regulations.

"Committed dose equivalent ($H_{T,50}$ or CDE)" means the dose equivalent to organs or tissues of reference (T) that will be received from an intake of radioactive material by an individual during the 50-year period following the intake.

"Committed effective dose equivalent ($H_{E,50}$ or CEDE)" means the sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to each of these organs or tissues ($H_{E,50} = \Sigma W_T, H_{T,50}$).

"Curie (Ci)" means a unit of measurement of activity. One curie (Ci) is that quantity of radioactive material that decays at the rate of 3.7×10^{10} disintegrations per second (dps). Commonly used sub-multiples of the curie are the millicurie and the microcurie. One millicurie (mCi) = 1×10^{-3} curie = 3.7×10^{7} dps. One microcurie (µCi.) = 1×10^{-6} curie = 3.7×10^{4} dps. One nanocurie (nCi) = 1×10^{-9} curie = 3.7×10^{1} dps. One picocurie (pCi) = 1×10^{-12} curie = 3.7×10^{-2} dps.

"Declared Pregnant Woman" means a woman who voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception.

"Deep dose equivalent (H_d or DDE)," which applies to external whole body exposure, means the dose equivalent at a tissue depth of 1 centimeter (1000 mg/cm^2).

"Depleted uranium" means the source material uranium in which the isotope uranium - 235 is less than 0.711 weight percent of the total uranium present. Depleted uranium does not include special nuclear material.

"Derived Air Concentration (DAC)" means the concentration of a given radionuclide in air which, if breathed by Reference Man (1.2 cubic meters of air per hour) for a working year of 2,000 hours under conditions of light work, results in an intake of one ALI.

"Dose" is a generic term that means absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, total organ dose equivalent, or total effective dose equivalent.

"Dose equivalent (H_T)" means the product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. The units of dose equivalent are the sievert (Sv) and rem. 1 Sv = 100 rem.

"Dose limits" means the permissible upper bounds of radiation doses established in accordance with these rules. For purposes of the rules, "limits" is an equivalent term.

"Dosimeter" means devices designed to be worn by a single individual for the assessment of dose equivalent. Examples of individual monitoring devices are film badges, thermoluminescent dosimeters (TLDs), and pocket ionization chambers.

"Effective dose equivalent (H_E)" means the sum of the products of the dose equivalent to each organ or tissue (H_T) and the weighting factor (W_T) applicable to each of the body organs or tissues that are irradiated ($H_E = \Sigma W_T H_T$).

"Embryo/fetus" means the developing human organism from conception until the time of birth.

"Entrance or access point" means any opening through which an individual or extremity of an individual could gain access to radiation areas or to licensed or registered sources of radiation. This includes portals of sufficient size to permit human access, irrespective of their intended use.

"Exposure" means the quotient of dQ by dm where "dQ" is the absolute value of the total charge of the ions of one sign produced in air when all the electrons (negatrons and positrons) liberated by photons in a volume element of air having mass "dm" are completely stopped in air. The unit of exposure is the coulomb per kilogram (C/kg) or the roentgen (R). $1\ R = 2.58 \times 10^{-4}$ C/kg.

"Exposure rate" means the exposure per unit of time

"External dose" means that portion of the dose equivalent received from any source of radiation outside the body.

"Extremity" means hand, elbow, arm below the elbow, foot, knee, and leg below the knee. The arm above the elbow and the leg above the knee are considered part of the whole body.

"Eye dose equivalent (LDE)" means the external dose equivalent to the lens of the eye at a tissue depth of 0.3 centimeter (300 mg/cm^2).

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

"High radiation area" means an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.1 rem (1 millisievert) in 1 hour at 30 centimeters from any source of radiation or from any surface that the radiation penetrates.

"Human use" means the internal or external administration of radiation or radioactive material to human beings for healing arts purposes or research and/or development. Human use is specifically prohibited under all licenses issued to Texas A&M University.

"Internal dose" means that portion of the dose equivalent received from radioactive material taken into the body.

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

"License" means a form of permission given by the Texas Department of State Health Services, or the U.S. Nuclear Regulatory Commission, to an applicant (in our case, Texas A&M University) who has met the requirements for licensing set out by that Agency (Texas BRC)

"Licensed material" means radioactive material received, possessed, used, or transferred under a license issued by the Texas Department of State Health Services.

"Licensee" means any person or organization who is licensed by the Texas Department of State Health Services or the U.S. Nuclear Regulatory Commission. Texas A&M University is the licensee.

"Lost or missing source of radiation" means a source of radiation whose location is unknown. This definition includes licensed material that has been shipped but has not reached its planned destination and whose location cannot be readily traced in the transportation system.

"Member of the public" means any individual, except when that individual is receiving an occupational dose.

"Minor" means an individual less than 18 years of age.

"Natural radioactivity" means radioactivity of naturally occurring nuclides whose location and chemical and physical form have not been altered by man.

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

"Permit" means a form of permission given by the TAMUS Radiation Safety Committee to an applicant (faculty or staff of Texas A&M University) to possess, store, and/or use radioactive material or radiation producing devices under the authority granted to Texas A&M University in the applicable License. A Permit is issued to one individual; never to a department, office or group of individuals.

"Permittee" means the successful applicant, the individual named on the Permit. "Permittee" is synonymous with "Permitted User" or "Sub-licensee".

"Quality factor (Q)" means the modifying factor that is used to derive dose equivalent from absorbed dose.

Radiation	Quality Factor
beta	1
gamma	1
x-ray	1
alpha	20
neutron	varies from 3 - 10

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

"Radiation" means one or more of the following:

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

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

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

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

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

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

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

"Radioactivity" means the disintegration of unstable atomic nuclei with the emission of radiation.

"Radiobioassay" (See "Bioassay").

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

"Restricted area" means an area, access to which is limited by the licensee or registrant for the purpose of protecting individuals against undue risks from exposure to sources of radiation. Restricted area does not include areas used as residential quarters, but separate rooms in a residential building may be set apart as a restricted area.

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

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

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

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

"Source material" means:

(1) uranium or thorium, or any combination thereof, in any physical or chemical form;

or

(2) ores that contain by weight 0.05 percent or more of:
- (i) uranium,
- (ii) thorium, or
- (iii) any combination thereof.

and

(3) does not include special nuclear material.

"Special nuclear material" means:

(1) plutonium, uranium-233, uranium enriched in the isotope 233 or in the isotope 235, but does not include source material; or

(2) any material artificially enriched by any of the foregoing, but does not include source material.

"Survey" means an evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal, and/or presence of sources of radiation. When appropriate, such evaluation includes, but is not limited to, tests, physical examination of location of materials and equipment, and measurements of levels of radiation or concentration of radioactive material present, and evaluation of administrative and/or engineered controls.

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

TEDE = DDE + CEDE

"Total organ dose equivalent (TODE)" means the sum of the deep dose equivalent and the committed dose equivalent to the organ receiving the highest dose. TODE = DDE + CDE

"Unrestricted area" means an area, access to which is neither limited nor controlled by the licensee (or Permittee).

"Whole body" means for purposes of external exposure, head, trunk(including male gonads), arms above the elbow, or legs above the knees.

"Worker" means an individual engaged in work under a license or a Permit.

APPENDIX A

CURRENT VERSION OF FORMS

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APPENDIX B

QUANTITIES OF LICENSED MATERIAL REQUIRING LABELING

(3) Quantities of licensed material requiring labeling. The following tables contain quantities† of licensed material requiring labeling:

Radionuclide	Quantity (µCi)*	Radionuclide	Quantity (µCi)*
Hydrogen-3	1,000	Vanadium 47	1,000
Beryllium-7	1,000	Vanadium-48	100
Beryllium-10	1	Vanadium-49	1,000
Carbon-11	1,000	Chromium-48	1,000
Carbon-14	1,000	Chromium-49	1,000
Fluorine-18	1,000	Chromium-51	1,000
Sodium-22	10	Manganese-51	1,000
Sodium-24	100	Manganese-52m	1,000
Magnesium-28	100	Manganese-52	100
Aluminum-26	10	Manganese-53	1,000
Silicon-31	1,000	Manganese-54	100
Silicon-32	1	Manganese-56	1,000
Phosphorus-32	10	Iron-52	100
Phosphorus-33	100	Iron-55	100
Sulfur-35	100	Iron-59	10
Chlorine-36	10	Iron-60	1
Chlorine-38	1,000	Cobalt-55	100
Chlorine-39	1,000	Cobalt-56	10
Argon-39	1,000	Cobalt-57	100
Argon-41	1,000	Cobalt-58m	1,000
Potassium-40	100	Cobalt-58	100
Potassium-42	1,000	Cobalt-60m	1,000
Potassium-43	1,000	Cobalt-60	1
Potassium-44	1,000	Cobalt-61	1,000
Potassium-45	1,000	Cobalt-62m	1,000
Calcium-41	100	Nickel-56	100
Calcium-45	100	Nickel-57	100
Calcium-47	100	Nickel-59	100
Scandium-43	1,000	Nickel-63	100
Scandium-44m	100	Nickel-65	1,000
Scandium-44	100	Nickel-66	10
Scandium-46	10	Copper-60	1,000
Scandium-47	100	Copper-61	1,000
Scandium-48	100	Copper-64	1,000
Scandium-49	1,000	Copper-67	1,000
Titanium-44	1	Zinc-62	100
Titanium-45	1,000	Zinc-63	1,000

* To convert microcurie (µCi) to kilobecquerel, multiply the microcurie value by 37.

Radionuclide	Quantity (µCi)*	Radionuclide	Quantity (µCi)*
Zinc-65	10	Bromine-74m	1,000
Zinc-69m	100	Bromine-74	1,000
Zinc-69	1,000	Bromine-75	1,000
Zinc-71m	1,000	Bromine-76	100
Zinc-72	100	Bromine-77	1,000
Gallium-65	1,000	Bromine-80m	1,000
Gallium-66	100	Bromine-80	1,000
Gallium-67	1,000	Bromine-82	100
Gallium-68	1,000	Bromine-83	1,000
Gallium-70	1,000	Bromine-84	1,000
Gallium-72	100	Krypton-74	1,000
Gallium-73	1,000	Krypton-85	1,000
Germanium-66	1,000	Krypton-87	1,000
Germanium-67	1,000	Krypton-88	1,000
Germanium-68	10	Rubidium-79	1,000
Germanium-69	1,000	Rubidium-81m	1,000
Germanium-71 1	1,000	Rubidium-81	1,000
Germanium-75	1,000	Rubidium-82m	1,000
Germanium-77	1,000	Rubidium-83	100
Germanium-78	1,000	Rubidium-84	100
Arsenic-69	1,000	Rubidium-86	100
Arsenic-70	1,000	Rubidium-87	100
Arsenic-71	100	Rubidium-88	1,000
Arsenic-72	100	Rubidium-89	1,000
Arsenic-73	100	Strontium-80	100
Arsenic-74	100	Strontium-81	1,000
Arsenic-76	100	Strontium-83	100
Arsenic-77	100	Strontium-85m	1,000
Arsenic-78	1,000	Strontium-85	100
Selenium-70	1,000	Strontium-87m	1,000
Selenium-73m	1,000	Strontium-89	10
Selenium-73	100	Strontium-90	0.1
Selenium-75	100	Strontium-91	100
Selenium-79	100	Strontium-92	100
Selenium-81m	1,000	Yttrium-86m	1,000
Selenium-81	1,000	Yttrium-86	100
Selenium-83	1,000	Yttrium-87	100

* To convert microcurie (µCi) to kilobecquerel, multiply the microcurie value by 37.

Radionuclide	Quantity (µCi)*	Radionuclide	Quantity (µCi)*
Yttrium-88	10	Technitium-96m	1,000
Yttrium-90m	1,000	Technitium-96	100
Yttrium-90	10	Technitium-97m	100
Yttrium-91m	1,000	Technitium-97	1,000
Yttrium-91	10	Technitium-98	10
Yttrium-92	100	Technitium-99m	1,000
Yttrium-93	100	Technitium-99	100
Yttrium-94	1,000	Technitium-101	1,000
Yttrium-95	1,000	Technitium-104	1,000
Zirconium-86	100	Ruthenium-94	1,000
Zirconium-88	10	Ruthenium-97	1,000
Zirconium-89	100	Ruthenium-103	100
Zirconium-93	1	Ruthenium-105	1,000
Zirconium-95	10	Ruthenium-106	1
Zirconium-97	100	Rhodium-99m	1,000
Niobium-88	1,000	Rhodium-99	100
Krypton-76	1,000	Rhodium-100	100
Krypton-77	1,000	Rhodium-101m	1,000
Krypton-79	1,000	Rhodium-101	10
Krypton-81	1,000	Rhodium-102m	10
Krypton-83m	1,000	Rhodium-102	10
Krypton-85m	1,000	Niobium-89	
Niobium-94	1	(66 min)	1,000
Niobium-95m	100	Niobium-89	
Niobium-85	100	(122 min)	1,000
Niobium-96	100	Niobium-90	100
Niobium-97	1,000	Niobium-93m	10
Niobium-98	1,000	Silver-104	1,000
Molybdenum-90	100	Silver-105	100
Molybdenum-93m	100	Silver-106m	100
Molybdenum-93	10	Silver-106	1,000
Molybdenum-99	100	Silver-108m	1
Molybdenum-101	1,000	Silver-110m	10
Technitium-93m	1,000	Silver-111	100
Technitium-93	1,000	Silver-112	100
Technitium-94m	1,000	Silver-115	1,000
Technitium-94	1,000	Cadmium-104	1,000

* To convert microcurie (µCi) to kilobecquerel, multiply the microcurie value by 37.

Radionuclide	Quantity (µCi)*	Radionuclide	Quantity (µCi)*
Cadmium-107	1,000	Silver-104m	1,000
Cadmium-109	1	Antimony-116	1,000
Cadmium-113m	0.1	Antimony-117	1,000
Cadmium-113	100	Antimony-118m	1,000
Cadmium-115m	10	Antimony-119	1,000
Cadmium-115	100	Antimony-120	
Cadmium-117m	1,000	(16m)	1,000
Cadmium-117	1,000	Antimony-120	
Indium-109	1,000	(5.76d)	100
Indium-110m		Antimony-122	100
(69.1m)	1,000	Antimony-124m	1,000
Indium-110m		Antimony-124	10
(4.9h)	1,000	Antimony-125	100
Indium-111	100	Antimony-126m	1,000
Indium-112	1,000	Antimony-126	100
Indium-113m	1,000	Antimony-127	100
Indium-114m	10	Antimony-128	
Indium-115m	1,000	(10.4m)	1,000
Indium-115	100	Antimony-128	
Indium-116m	1,000	(9.01h)	100
Indium-117m	1,000	Antimony-129	100
Indium-117	1,000	Antimony-130	1,000
Indium-119m	1,000	Antimony-131	1,000
Tin-110	100	Tellurium-116	1,000
Tin-111	1,000	Tellurium-121m	10
Tin-113	100	Tellurium-121	100
Rhodium-103m	1,000	Tellurium-123m	10
Rhodium-105	100	Tellurium-123	100
Rhodium-106m	1,000	Tellurium-125m	10
Rhodium-107	1,000	Tellurium-127m	10
Palladium-100	100	Tellurium-127	1,000
Palladium-101	1,000	Tellurium-129m	10
Palladium-103	100	Tin-117m	100
Palladium-107	10	Tin-119m	100
Palladium-109	100	Tin-121m	100
Silver-102	1,000	Tin-121	1,000
Silver-103	1,000	Tin-123m	1,000

* To convert microcurie (µCi) to kilobecquerel, multiply the microcurie value by 37.

Radionuclide	Quantity (µCi)*	Radionuclide	Quantity (µCi)*
Tin-123	10	Cesium-137	10
Tin-125	10	Tellurium-129	1,000
Tin-126	10	Tellurium-131m	10
Tin-127	1,000	Tellurium-131	100
Tin-128	1,000	Tellurium-132	10
Antimony-115	1,000	Tellurium-133m	100
Antimony-116m	1,000	Tellurium-133	1,000
Iodine-131	1	Tellurium-134	1,000
Iodine-132m	100	Iodine-120m	1,000
Iodine-132	100	Iodine-120	100
Iodine-133	10	Iodine-121	1,000
Iodine-134	1,000	Iodine-123	100
Iodine-135	100	Iodine-124	10
Xenon-120	1,000	Iodine-125	1
Xenon-121	1,000	Iodine-126	1
Xenon-122	1,000	Iodine-128	1,000
Xenon-123	1,000	Iodine-129	1
Xenon-125	1,000	Iodine-130	10
Xenon-127	1,000	Lanthanum-140	100
Xenon-129m	1,000	Lanthanum-141	100
Xenon-131m	1,000	Lanthanum-142	1,000
Xenon-133m	1,000	Lanthanum-143	1,000
Xenon-133	1,000	Cerium-134	100
Xenon-135m	1,000	Cerium-135	100
Xenon-135	1,000	Cerium-137m	100
Xenon-138	1,000	Cerium-137	1,000
Cesium-125	1,000	Cerium-139	100
Cesium-127	1,000	Cerium-141	100
Cesium-129	1,000	Cerium-143	100
Cesium-130	1,000	Cerium-144	1
Cesium-131	1,000	Praseodymium-136	1,000
Cesium-132	100	Praseodymium-137	1,000
Cesium-134m	1,000	Praseodymium-138m	1,000
Cesium-134	10	Praseodymium-139	1,000
Cesium-135m	1,000	Praseodymium-142m	1,000
Cesium-135	100	Praseodymium-142	100
Cesium-136	10	Praseodymium-143	100

* To convert microcurie (µCi) to kilobecquerel, multiply the microcurie value by 37.

Radionuclide	Quantity (µCi)*	Radionuclide	Quantity (µCi)*
Praseodymium-144	1,000	Europium-152	1
Praseodymium-145	100	Europium-154	1
Praseodymium-147	1,000	Europium-155	10
Neodymium-136	1,000	Europium-156	100
Neodymium-138	100	Europium-157	100
Neodymium-139m	1,000	Europium-158	1,000
Neodymium-139	1,000	Gadolinium-145	1,000
Cesium-138	1,000	Gadolinium-146	10
Barium-126	1,000	Gadolinium-147	100
Barium-128	100	Gadolinium-148	0.001
Barium-131m	1,000	Gadolinium-149	100
Barium-131	100	Gadolinium-151	10
Barium-133m	100	Gadolinium-152	100
Barium-133	100	Neodymium-141	1,000
Barium-135m	100	Neodymium-147	100
Barium-139	1,000	Neodymium-149	1,000
Barium-140	100	Neodymium-151	1,000
Barium-141	1,000	Promethium-141	1,000
Barium-142	1,000	Promethium-143	100
Lanthanum-131	1,000	Promethium-144	10
Lanthanum-132	100	Promethium-145	10
Lanthanum-135	1,000	Promethium-146	1
Lanthanum-137	10	Promethium-147	10
Lanthanum-138	100	Promethium-148m	10
Samarium-153	100	Promethium-148	10
Samarium-155	1,000	Promethium-149	100
Samarium-156	1,000	Promethium-150	1,000
Europium-145	100	Proemthium-151	100
Europium-146	100	Samarium-141m	1,000
Europium-147	100	Samarium-141	1,000
Europium-148	10	Samarium-142	1,000
Europium-149	100	Samarium-145	100
Europium-150		Samarium-146	1
(12.62h)	100	Samarium-147	100
Europium-150		Samarium-151	10
(34.2y)	1	Dysprosium-166	100
Europium-152m	100	Holmium-1155	1,000

* To convert microcurie (µCi) to kilobecquerel, multiply the microcurie value by 37.

Radionuclide	Quantity (µCi)*	Radionuclide	Quantity (µCi)*
Holmium-157	1,000	Dysprosium-155	1,000
Holmium-159	1,000	Dysprosium-157	1,000
Holmium-161	1,000	Dysprosium-159	100
Holmium-162m	1,000	Dysprosium-165	1,000
Holmium-162	1,000	Hafnium-173	1,000
Holmium-164m	1,000	Hafnium-175	100
Holmium-164	1,000	Hafnium-177m	1,000
Holmium-166m	1	Hafnium-178m	0.1
Holmium-166	100	Hafnium-179m	10
Holmium-167	1,000	Hafnium-180m	1,000
Erbium-161	1,000	Hafnium-181	10
Erbium-165	1,000	Hafnium-182m	1,000
Erbium-169	100	Hafnium-182	0.1
Erbium-171	100	Hafnium-183	1,000
Erbium-172	100	Hafnium-184	100
Thulium-162	1,000	Tantalum-172	1,000
Thulium-166	100	Tantalum-173	1,000
Thulium-167	100	Tantalum-174	1,000
Thulium-170	10	Tantalum-175	1,000
Gadolinium-153	10	Tantalum-176	100
Gadolinium-159	100	Tantalum-177	1,000
Terbium-147	1,000	Tantalum-178	1,000
Terbium-149	100	Tantalum-179	100
Terbium-150	1,000	Tantalum-180m	1,000
Terbium-151	100	Tantalum-180	100
Terbium-153	1,000	Thulium-171	10
Terbium-154	100	Thulium-172	100
Terbium-155	1,000	Thulium-173	100
Terbium-156m		Thulium-175	1,000
(5.0h)	1,000	Ytterbium-162	1,000
Terbium-156m		Ytterbium-166	100
(24.4h)	1,000	Ytterbium-167	1,000
Terbium-156	100	Ytterbium-169	100
Terbium-157	10	Ytterbium-175	100
Terbium-158	1	Ytterbium-177	1,000
Terbium-160	10	Ytterbium-178	1,000
Terbium-161	100	Lutetium-169	100

* To convert microcurie (µCi) to kilobecquerel, multiply the microcurie value by 37.

Radionuclide	Quantity (µCi)*	Radionuclide	Quantity (µCi)*
Lutetium-170	100	Tungsten-176	1,000
Lutetium-171	100	Tungsten-177	1,000
Lutetium-172	100	Tungsten-178	1,000
Lutetium-173	10	Tungsten-179	1,000
Lutetium-174m	10	Tungsten-181	1,000
Lutetium-174	10	Tungsten-185	100
Lutetium-176m	1,000	Tungsten-187	100
Lutetium-176	100	Tungsten-188	10
Lutetium-177m	10	Rhenium-177	1,000
Lutetium-177	100	Rhenium-178	1,000
Lutetium-178m	1,000	Rhenium-181	1,000
Lutetium-178	1,000	Rhenium-182	
Lutetium-179	1,000	(12.7h)	1,000
Hafnium-170	100	Rhenium-182	
Hafnium-172	1	(64.0h)	100
Rhenium-188	100	Rhenium-184m	10
Rhenium-189	100	Rhenium-184	100
Osmium-180	1,000	Rhenium-186m	10
Osmium-181	1,000	Rhenium-186	100
Osmium-182	100	Rhenium-187	1,000
Osmium-185	100	Rhenium-188m	1,000
Osmium-189m	1,000	Mercury-194	1
Osmium-191m	1,000	Mercury-195m	100
Osmium-191	100	Mercury-195	1,000
Osmium-193	100	Mercury-197m	100
Osmium-194	100	Mercury-197	1,000
Iridium-182	1,000	Mercury-199m	1,000
Iridium-184	1,000	Mercury-203	100
Iridium-185	1,000	Thallium-194m	1,000
Iridium-186	100	Thalllium-194	1,000
Iridium-187	1,000	Thallium-195	1,000
Tantalum-182m	1,000	Thallium-197	1,000
Tantalum-182	10	Thallium-198m	1,000
Tantalum-183	100	Thallium-198	1,000
Tantalum-184	100	Thallium-199	1,000
Tantalum-185	1,000	Thallium-200	1,000
Tantalum-186	1,000	Thallium-201	1,000

* To convert microcurie (µCi) to kilobecquerel, multiply the microcurie value by 37.

Radionuclide	Quantity (µCi)*	Radionuclide	Quantity (µCi)*
Iridium-188	100	Francium-223	100
Iridium-189	100	Radium-223	0.1
Iridium-190m	1,000	Radium-224	0.1
Iridium-190	100	Radium-225	0.1
Iridium-192m	1	Radium-226	0.1
Iridium-192	10	Radium-227	1,000
Iridium-194m	10	Thallium-202	100
Iridium-194	100	Thallium-204	100
Iridium-195m	1,000	Lead-195m	1,000
Iridium-195	1,000	Lead-198	1,000
Platinum-186	1,000	Lead-199	1,000
Platinum-188	100	Lead-200	100
Platinum-189	1,000	Lead-201	1,000
Platinum-191	100	Lead-202m	1,000
Platinum-193m	100	Lead-202	10
Platinum-193	1,000	Lead-203	1,000
Platinum-195m	100	Lead-205	100
Platinum-197m	1,000	Lead-209	1,000
Platinum-197	100	Lead-210	0.01
Platinum-199	1,000	Lead-211	100
Platinum-200	100	Lead-212	1
Gold-193	1,000	Lead-214	100
Gold-194	100	Bismuth-200	1,000
Gold-195	10	Bismuth-201	1,000
Gold-198m	100	Bismuth-202	1,000
Gold-198	100	Bismuth-203	100
Gold-199	100	Bismuth-205	100
Gold-200m	100	Bismuth-206	100
Gold-200	1,000	Bismuth-207	10
Gold-201	1,000	Bismuth-210m	0.1
Mercury-193m	100	Bismuth-210	1
Mercury-193	1,000	Bismuth-212	10
Astatine-207	100	Bismuth-213	10
Astatine-211	10	Bismuth-214	100
Radon-220	1	Polonium-203	1,000
Radon-222	1	Polonium-205	1,000
Francium-222	100	Polonium-207	1,000

* To convert microcurie (µCi) to kilobecquerel, multiply the microcurie value by 37.

Radionuclide	Quantity (µCi)*	Radionuclide	Quantity (µCi)*
Polonium-210	0.1	Uranium-233	0.001
Neptunium-234	100	Uranium-234	0.001
Neptunium-235	100	Uranium-235	0.001
Neptunium-236		Uranium-236	0.001
(1.15x10y)	0.001	Uranium-237	100
Neptunium-236		Uranium-238	100
(22.5h)	1	Uranium-239	1,000
Neptunium-237	0.001	Uranium-240	100
Neptunium-238	10	Uranium-natural	100
Neptunium-239	100	Neptunium-232	100
Neptunium-240	1,000	Neptunium-233	1,000
Plutonium-234	10	Berkelium-246	100
Radium-228	0.1	Berkelium-247	0.001
Actinium-224	1	Berkelium-249	0.1
Actinium-225	0.01	Berkelium-250	10
Actinium-226	0.1	Californium-244	100
Actinium-227	0.001	Californium-246	1
Actinium-228	1	Californium-248	0.01
Thorium-226	10	Plutonium-235	1,000
Thorium-227	0.01	Plutonium-236	0.001
Thorium-228	0.001	Plutonium-237	100
Thorium-229	0.001	Plutonium-238	0.001
Thorium-230	0.001	Plutonium-239	0.001
Thorium-231	100	Plutonium-240	0.001
Thorium-232	100	Plutonium-241	0.01
Thorium-234	10	Plutonium-242	0.001
Thorium-natural	100	Plutonium-243	1,000
Protactinium-227	10	Plutonium-244	0.001
Protactinium-228	1	Plutonium-245	100
Protactinium-230	0.1	Americium-237	1,000
Protactinium-231	0.001	Americium-238	100
Protactinium-232	1	Americium-239	1,000
Protactinium-233	100	Americium-240	100
Protactinium-234	100	Americium-241	0.001
Uranium-230	0.01	Americium-242m	0.001
Uranium-231	100	Americium-242	10
Uranium-232	0.001	Americium-243	0.001

* To convert microcurie (µCi) to kilobecquerel, multiply the microcurie value by 37.

Radionuclide	Quantity (µCi)*	Radionuclide	Quantity (µCi)*
Americium-244m	100	Einsteinium-251	100
Americium-244	10	Einsteinium-253	0.1
Americium-245	1,000	Einsteinium-254m	1
Americium-246m	1,000	Einsteinium-254	0.01
Americium-246	1,000	Fermium-252	1
Curium-238	100	Fermium-253	1
Curium-240	0.1	Californium-249	0.001
Curium-241	1	Californium-250	0.001
Curium-242	0.01	Californium-251	0.001
Curium-243	0.001	Californium-252	0.001
Curium-244	0.001	Californium-253	0.1
Curium-245	0.001	Californium-254	0.001
Curium-246	0.001	Fermium-254	10
Curium-247	0.001	Fermium-255	1
Curium-248	0.001	Fermium-257	0.01
Curium-249	1,000	Mendelevium-257	10
Berkelium-245	100	Mendelevium-258	0.01
Einsteinium-250	100		
Any alpha-emitting radionuclide not listed above or mixtures of alpha emitters of unknown composition	0.001	Any radionuclide other than alpha-listed emitting radionuclides not listed above, or mixtures of beta emitters of unknown composition	0.01

* To convert microcurie (µCi) to kilobecquerel, multiply the microcurie value by 37.

NOTE: For purposes of subsections (aa)(5), (dd)(1), and (ww)(1) of this subsection where there is involved a combination of radionuclides in known amounts, the limit for the combination should be derived as follows: determine, for each radionuclide in the combination, the ratio between the quantity present in the combination and the limit otherwise established for the specific radionuclide when not in combination. The sum of such ratios for all radionuclides in the combination may not exceed "1" -- that is, unity.

†The quantities listed above were derived by taking 1/10th of the most restrictive ALI listed in Columns 1 and 2 of Table I of subsection (ggg)(2) of this section, rounding to the nearest factor of 10, and constraining the values listed between 0.001 and 1,000 microcuries (37 becquerels and 37 megabecquerels). Values of 100 microcuries (3.7 megabecquerels) have been assigned for radionuclides having a radioactive half-life in excess of E+9 years, except rhenium, 1,000 microcuries (37 megabecquerels), to take into account their low specific activity.

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APPENDIX C

RSO ORGANIZATIONAL CHART WITH REPORTING STRUCTURE

ORGANIZATION CHART

THE TEXAS A&M UNIVERSITY SYSTEM
HEALTH SCIENCE CENTER
COLLEGE OF MEDICINE
TEMPLE CAMPUS

January*, 2004*