POLICY AND PROCEDURES MANUAL

FOR THE USE OF RADIOACTIVE MATERIALS AT FLORIDA AGRICULTURAL AND MECHANICAL UNIVERSITY

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INTRODUCTION

The **Radiation Safety Program** was developed by Florida Agricultural and Mechanical University, Office of Environmental Health and Safety in support of its primary objective to provide and maintain a safe campus environment for work and study. The primary goals of the program are to ensure the radiological safety of all university personnel and the public; to ensure compliance with the conditions of the University’s radioactive materials license; to guarantee that radiation sources are procured and used in accordance with Federal and State regulations; and ensure that radiation exposures are as “**As Low as Reasonably Achievable**” (ALARA). Radiation Safety can only succeed when each Principal Investigator and user follows both the spirit of and the actual policies and procedures established herein.

Radioactive materials and radiation sources at Florida A&M University must be used in accordance with rules and regulations contained in the **Florida Administrative Code, Chapter 64-E-5, Control of Radiation Hazard Regulations** and with the conditions specified in the radioactive materials license issued by the State of Florida, Department of Health, Bureau of Radiation Control.

This guide is consistent with these regulations through policies and procedures approved by the **Radiation Control Committee (RCC)**. This guide is intended to protect all individuals with a minimum of interface in their activities. These policies and procedures applicable to all **Principal Investigators** and others who use radiation sources at Florida A&M University. Violations of the established policies and procedures may result in loss of the privilege to use radioactive materials.
EMERGENCIES

With regard to the use of radioactive materials, an emergency situation exists when one of the following occurs:

1. A person believes they have been exposed to more radiation than the “shall not exceed” doses listed under II. D. Limits, of this document.

2. Contaminated skin, clothing or laboratory items cannot be decontaminated by normal washing methods.

3. Any amount of radioactive material is accidently swallowed, injected or otherwise gets into the body of a person.

4. A container of radioactive materials shipped to the university is broken and the possibility of contamination or exposure is evident.

5. A theft or manipulation of radioactive materials is discovered.

6. A fire is discovered in a building that contains radioisotopes.

7. A person working with radioisotopes feels he can no longer control a situation because of a large spill, natural or man-made disaster; etc.

In such circumstances the PI and RSO (ext. 3442) shall be contacted immediately. Their names and phone numbers shall be posted on the doors of laboratories containing radioactive material.
1. DELINEATION OF RESPONSIBILITIES
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A. PRESIDENT:

1. Responsibilities for all matters pertaining to radiation safety and the assurance that Florida A&M University (FAMU) is in compliance with all applicable state and federal regulations.

2. Delegates authority for these matters to the Vice President for Academic Affairs.

B. VICE PRESIDENT FOR ACADEMIC AFFAIRS:

1. Assumes institutional responsibility, through the Radiation Safety Officer (RSO) and the Radiation Control Committee (RCC), to insure compliance with FAMU’s radioactive license.

2. Works with Deans, Directors and Department Chairpersons through the RSO and RCC in establishing and maintaining a radiation safety program.

3. Assures that there is a strong working relationship between the RSO and all other units of the University.

4. Delegates authority to the RCC to suspend an investigator’s use of radioactive materials.

5. Appoints the members of the RCC.

C. DEANS, DIRECTORS AND CHAIRPERSONS:

1. Responsible for compliance with the radiation safety programs pertinent to the personnel and facilities under their direction.

2. Holds all faculty, staff and students under their direction, responsible for proper and safe use of radioactive materials in accordance with the policies and procedures set forth in this manual.
D. RADIATION CONTROL COMMITTEE:

1. Reviews proposals requiring the use of radioisotopes or other sources of ionizing radiation and grants permission for their use at FAMU from the standpoint of radiation safety. Committee approval must be obtained before possession and initial use of radioisotopes or other ionizing radiation is undertaken or before substantially different use from those originally approved by the RCC is undertaken.

2. Establishes and implements policies and procedures as needed for use and disposal of radioactive materials at FAMU.

3. Delegates to the RSO the authority to act for the RCC between meetings. His/her action will be reported to the RCC for review at appropriate intervals.

4. Prescribes special conditions and requirements which may be necessary to ensure radiation safety.

5. Suspends work involving radioactive material when an investigator fails to observe radiation safety policies and procedures.

6. Provides advice to research groups, departments and Principal Investigators.

7. Holds a Radiation Control Committee meeting semi-annually.

E. RADIATION SAFETY OFFICER:

1. Administers FAMU’s day to day radioactive materials use program. Activities to include personnel monitoring; exposure record maintenance; surveys; waste disposal; radiation safety practices; maintains a current license and reviews requests for use of radioactive material to ensure that they comply with the license.

2. Approves all procedures that potentially could involve radiation exposure and all changes in such procedures.
3. Consults with potential radioactive material users and provides advice regarding safe practices.

4. Suspends any operation causing excessive radiation hazards as rapidly and safely as possible. Reports any such action to the RCC.

5. Assures that monthly surveys are performed and recorded (Pg. B11) for areas where radioactive materials are being used during that month. In areas where no work is underway, but radioactive materials are stored, background radiation levels shall be checked and the radioactive materials shall be visually inspected.

6. Keeps records of the approval for use of radioisotopes and other sources of ionizing radiation, communications, and reports involved in the work of the RCC.

7. Maintains inventory (Pg B-10) of all radioactive material received at FAMU, surveys all packages containing radioactive materials when they arrive at FAMU and supervises the storage and distribution of new shipments.

8. Provides arrangements for the following as per the license:
   a. Proper disposal of radioactive waste
   b. Leak testing of sealed radioactive resources as required by FAC 64E-5
   c. Source checks and calibration of survey instruments

9. Responds to emergencies related to radioactive materials and supervises decontamination.


F. PRINCIPAL INVESTIGATOR

1. Responsible for the proper and safe use of radioactive materials being used in projects under his/her direction in accordance with the established policies and procedures and any special conditions required by the Radiation Safety Officer and Radiation Control Committee. Responsible for ensuring that necessary safety equipment and supplies are available and in working order and that proper posting and labeling is accomplished.

2. Submits a description of all proposed research or changes in existing research, which involve the use of radioactive materials or equipment producing
significant ionizing radiation, to the Radiation Control Committee for approval before use.

3. Ensures that all purchases of radioactive materials are delivered to the Environmental Health and Safety Department, Plant Operations Building. No shipment may be delivered directly to the user, without prior approval from the RSO.

4. Notify the RSO:
   a. When radioactive material shipments are ordered
   b. Before beginning any project involving the use of radionuclides, so that the lab can be included in the monthly surveys
   c. Of any accident involving radioactive materials
   d. To arrange for disposal of radioactive waster, after it is properly packaged and labeled.

5. Ensures that radioactive materials are used and stored only in approved posted areas by approved personnel. Informs the RSO of all necessary changes in personnel working with radioactive materials and changes in facilities or locations of use.

6. Ensures that all personnel working with radioactive materials are properly trained and monitored. Ensures that they are aware of the potential health hazards and the necessary safeguards, which are established to guard against them. Distributes a copy of this manual to all personnel working with radionuclides under his/her direction and ensures that it read.

7. Performs proper surveys each week that radioactive materials are in use. Responsible for obtaining approved survey instruments for support of his/her project.

8. Monthly, submits an inventory of all radioactive materials on hand, including waste.

9. Prior to any extended leaves of absence or sabbaticals, the Principal Investigator must obtain the RSO's approval for transfer of responsibility for day-to-day supervision of work involving radioactive materials.

G. USERS OF RADIOACTIVE MATERIAL

1. Responsible for the proper and safe use of radioactive materials and equipment in accordance with these established policies and procedures and any special conditions required by the Radiation Control Committee.
2. If the user is issued personal monitoring device(s), they shall be worn whenever working with or handling radioactive materials.

3. Reports any problems with radioactive materials to the Principal Investigator.

4. Immediately reports any spills or contamination to the RSO (ext 3442)

5. Responsible for compliance with the policies and procedures contained in this manual.

6. Pregnant workers are responsible for completing a "Declared Pregnant Worker Form" if they wish to do so to lower the dose limit for an embryo/fetus, or they wish to revoke a previous declaration of pregnancy. The form is available in the Forms Appendix B of this document. The form should be presented to the employee supervisor and a copy to the Radiation Safety Officer.

*It is the user’s responsibility to ensure that equipment such as Scintillation Counters and Geiger counters are properly functional. The office of Environmental Health & Safety will provide one (1), calibrated Geiger counter to each Principal Investigator at no cost to the user. The cost of recalibration of Geiger counters purchased by the user will be borne by the user.
II. PROCEDURES
PROCEDURES

A. APPLYING FOR USE

Before engaging in experiments involving radioactive materials, a Principal Investigator (PI) must obtain approval from the Radiation Control Committee (RCC) by submitting the "Proposal for Use of Radioactive Materials" form to the Radiation Safety Officer (RSO).

The PI shall submit to the RSO: Names of those who will work with radioactive materials, their social security number and date of birth. His information may be needed for personal monitoring records.

B. PURCHASING RADIOACTIVE MATERIALS

The PI may order radioactive materials following approval of his/her proposal by the RCC, and notification to the RSO that materials are to be purchased. All shipments of radioactive materials must be delivered directly to the Environmental Health and Safety Department, Plant Operations Building, Suite 120, 2400 Wahnish Way.

C. SHIPMENT INSPECTIONS

Shipment packages containing radionuclides will be inspected for signs of breakage, leakage or damage to the external integrity of the shipping container by the RSO. In addition, surveys will be conducted as required by 64E-5-327 and the results recorded.

D. PERSONNEL TRAINING REQUIREMENTS

All persons applying for approval must have formal instruction and/or experience with radiation hazards. The level of training and/or experience shall be commensurate with the amount and type of radioactive material to be used. In addition, before any inexperienced graduate student, lab technician, research, etc., becomes involved in the use of radioactive material at FAMU, he/she must complete a short training course in the safe use of radioactive materials. Contact the RSO to arrange the training session.

E. LABORATORY REGULATIONS

1. The techniques of time, distance and shielding, when working with radioactive materials, shall be used at all times.
2. The PI is responsible for establishing high standards of cleanliness, for proper supervision, and for instructing personnel of radiation hazards and radiation safety procedures.

3. Depending upon radioactive materials to be used, some personnel may be issued personal monitoring devices. If such devices are issued, they must be used as directed. The RSO shall keep records of exposure for personnel who are issued such devices.

4. All working surfaces, to be used for experiments involving radioactive materials, are to be covered by absorbent paper with plastic backing. Such covering shall be used absorbent side up to absorb any spills that may occur. The absorbent paper shall be changed at regular intervals to prevent cross contamination. When working under conditions when a spill would not be confined to a small area, work shall be done over a tray or in a fume hood lined with absorbent paper.

5. Eating, drinking, smoking and applying cosmetics are prohibited when working with, or in the immediate vicinity of radioactive material and/or contaminated equipment. Hands and fingernails shall be routinely washed and monitored after working with radioactive material. Care shall be taken to prevent contamination of hair by brushing against radioactive material or contaminated laboratory equipment.

6. Storing food, drinks or personal effects in areas where radioactive materials are used or stored is prohibited.

7. Personnel must never allow radioactive material to enter the body by accidental ingestion, injection or through a wound. Such accidents shall be reported immediately to the RSO. Radioactive work shall not be undertaken if a person has a wound below the wrist.

8. Radioactive solutions MUST NOT be pipetted by mouth.

9. Protective gloves and lab coats must be worn whenever handling radioactive materials. Open-toed shoes shall not be worn in laboratory areas.

10. Chemical synthesis of labeled compounds or handling of bulk radionuclides will be confined to a hood using appropriate shielding to reduce radiation exposure levels.

11. When working with airborne radioactive material, or when engaged in activities with radioactive material that causes atmospheric distribution, such as boiling, washing, evaporating, or distilling the work must be done in a fume
hood with functional airflow. Work with fine powder must be done in a dry box.

12. Animal use with radioactive isotopes shall be in accordance with Section O of these procedures.

F. POSTING AND LABELING REQUIREMENTS

Note: Proper posting and labeling is the responsibility of the PI.

1. Radiation warning signs, bearing the American Standard Radiation Symbol (magenta tri-foil on a yellow background) and the words "Caution Radioactive Materials", must be posted in areas where radioactive materials are used and on the refrigerators or cabinets where they are stored. (Note: sign with the words "Radiation Area" or "High Radiation Area" indicate that radiation levels are at least mrem/hr and 100 mrem/h respectively. At FAMU there should not be radiation levels of that magnitude.)

2. On every door into areas where radioactive materials are being used, the radiation warning sign will include the home phone numbers of the PI(s) responsible for the laboratory and the RSO (ext. 3442).

3. The Florida Department of Health "Notice to Employees," (Appendix A), must be posted in areas where radioactive materials are being used.

4. Containers of radioactive materials, stock or waste, must be labeled with the American Standard Radiation Symbol, the name of the PI, the radionuclide and the activity and date the activity was calculated.

5. Containers, glassware and other equipment that are contaminated must be labeled "Radioactive", with the American Radiation Symbol (magenta tri-foil on a yellow background).

G. STORAGE

All radioactive materials must be stored in sound, suitable containers with tight fitting lids. Radioactive material is to be stored as far as practical from the normal working area and behind sufficient shielding to minimize chances of exposure of personnel exceeding the established limits. Security is important. Only responsible user shall have access to radioactive materials. Lockable storage cabinets and refrigerators are required. When radioactive material is not being used it shall be locked up. Radioactive materials shall not be stored in a refrigerator containing food.
H. TRANSFER AND TRANSPORTATION

1. When transporting radioactive materials from one room to building to another, a secondary container with absorbent packing material is to be used to insure that all liquid is absorbed in case of breakage of primary container.

2. The RSO shall be notified and grant approval before any transfer of radioactive material to another user or radionuclides occurs. The form, "Transferring Radioactive Material", shall be used.

3. Under no circumstances shall a person bring or remove radioactive materials onto or from campus without the approval of the RSO.

I. SURVEY REQUIREMENTS

Note: Laboratory areas, other than fume hoods and dry boxes, will be decontaminated if activity from wipe tests exceeds 50 cpm alpha (100 cm$^2$) or 100 cpm beta-gamma above background. The PI is responsible for decontamination.

1. The PI is to ensure that after every work session surfaces, equipment used and personnel are monitored. Measurement should be made with a thin end-window GM detector (less than 2 mg/cm$^2$) measured at a distance not greater than 1 cm surface to detector window.

2. The PI is to ensure that weekly contamination surveys are performed when radioactive materials are in use. The PI is responsible for procuring his/her own G-M detectors. The RSO should be informed of purchase of any new detectors so they can be scheduled for calibration.

3. Monthly, the RSO will inspect all areas where radioactive materials are used and/or used and/or stored to insure that safety regulations are followed. Monthly wipe tests will be performed. In laboratories where radioactive materials have been used within that month survey results will be recorded.

J. INVENTORIES

Each PI using radioactive material is required to submit a monthly inventory to the RSO, of all radioactive material on hand, including waste. It is important that the form be filled out completely and accurately. This inventory is due the last day of each month for that month. Investigators who do not submit the monthly inventory will not be permitted to purchase additional radionuclides.

K. BIOASSAYS
The use of tritium or radioactive iodine may require routine bioassays, depending on circumstances of use. The determination as to whether or not bioassays are needed is made by the RSO when reviewing proposals for use of radioactive materials (prior to commencement of use). Determination will be based upon recommendation in NRC regulator guides: "Guidelines for Bioassay Requirements for Tritium"; and "Applications of Bioassays for I-125 and I-131."

L. SPILLS

1. All spills of radioactive materials must be cleaned up as quickly as possible. The responsibility for cleaning up the spill rests on the individual working with the radioactive material and the PI. Under no circumstances shall an untrained person attempt to examine or clean up a spill. Plan ahead and ensure adequate supplies are available at all times to support the clean up effort.

2. If personal injury results from or during a spill the RSO must be notified immediately (ext. 3442). Care for the injured must take priority above cleaning of the spill.

3. **Major Spills** - Any radioactive spill meeting one or more of the following characteristics, a through d, is considered a "major" spill and the RSO the researcher responsible for the laboratory must be contacted immediately:

   a. The spill involves more 10 millicures of Sodium-22, Calcium-45, Iodine-131, Iodine-125, or Manganese-54.
   b. The spill involves more than 50 millicures of any radioactive material.
   c. The spill involves more than 10 microcuries, and is a volatile liquid of more than 100 milliliters volume.
   d. The research feels he/she no longer has control of the situation and may not be capable of safely handling the spill clean up without assistance.

   If characteristic (c.) above is present, involving volatile liquid, the room should be evacuated, the air-handler shut down and all room doors closed. Detain any potentially contaminated individual immediately outside the room until personal monitoring and any necessary decontamination is complete, as described below.
If any of the above characteristics a., b., or d. are present, the researcher shall secure a safe perimeter around the spill to keep personnel out of the spill area. Spill control and clean up should commence, as described under Item 5. below.

4. **Minor Spills** - In the event of a spill that does not have any of the characteristics described in a. through d. above, clean up should commence immediately as described in 5.

5. The following shall be used as a general guide when cleaning up a spill.

a. **Contain the spill:** If the material is a liquid, place an absorbent material (i.e. paper towels) over the spill to prevent its spread. If the material is a powder, attempt to contain the area with a protective barrier (i.e., drip tray, empty beaker, etc.). Redirect any ventilation that might be blowing on the area.

b. **Inform others of the spill:** Adjust your response to the seriousness of the situation. Ask those personnel who are not necessary to aid in cleaning the spill to stand clear and ensure that they do not spread any contamination. Do not eat, drink, smoke, etc. in the area until the spill is cleaned up.

c. **Decontaminate the area:** Wear gloves, keeping the get out of the spill area. Begin at the periphery, using paper towels, and work towards the center of the spill. Place all waste in a bag. After the spilled material has been wiped up, repeat the same procedure with a decontamination agent.

d. **Monitor the area:** Using appropriate survey techniques, check to see if the area has been decontaminated. If the activity from wipe tests exceeds 50 cpm alpha/100cm$^2$ or 100 cpm beta-gamma above background, repeat steps c. and d. as needed to decontaminate.

6. To assemble a spill kit the following items can be used:

a. Radiation warning labels and tape
b. Disposable gloves
c. Masking tape
d. Grease pencil or marker
e. Plastic bags (large or small)
f. Paper bags for sharps
g. Tongs and/or forceps  
h. Gauze sponges  
i. Paper towels (or other absorbent material)  
j. Decontaminating detergent  
k. Swipes and empty scintillation vials  

M. DECONTAMINATION  

1. Routine decontamination is the responsibility of the PI.  

2. Personal laboratory surfaces and apparatus shall be decontaminated by repeated washings if there is any detectable radioactive decontamination. Detectable radioactive shall be defined as activity from wipe tests that exceeds 50 dpm (or cpm) alpha/100 cm² or 100 dpm (or cpm) beta-gamma/100 cm² above background.  

3. Personnel contamination must be reported immediately to the RSO (ext. 3442), who will then supervise decontamination.  

4. Flat surfaces will be decontaminated by repeated washings with a commercial decontaminating agent. Special methods for individual materials should be used if this fails. For example, steel could be treated with Deoxidine 125 plus wetting agent, and waxed linoleum could be washed with xylene or be sanded.  

5. No person or object subjected to radiation contamination is to leave the laboratory without being monitored for radioactivity. Measurements will be made with a thin end-window GM detector (not exceeding 2mg/cm² thickness) at a distance not exceeding 1 cm from the object being monitored.  

N. RADIOACTIVE WASTE DISPOSAL  

All radioactive waste, liquid, solid, or biological, must be plainly labeled with the American Standard Radiation Symbol (magenta tri-foil on a yellow background), the of the PI, the radionuclide, the activity level and date the activity was calculated, before the RSO will make arrangements for disposal of radioactive waste by a licensed agency.
Radioactive waste areas should be managed with close attention to cleanliness. Housekeeping personnel shall be instructed not to move or empty radioactive waste containers, during the course of their duties. Non-radioactive waste must not be mixed with radioactive waste as this adds undue costs to the disposal. Recycle contaminated glassware and other equipment when feasible. Care should be exercised when disposing of waste in different physical or chemical forms (i.e. acids and bases).

1. Solid radioactive waste (i.e. work bench paper, contaminated glassware, syringes, paper towels, and gloves) is to be placed in a covered container lined with a plastic bag. **NO FREE-STANDING LIQUID SHALL BE PLACED IN THIS BAG.**
   When the container is full the plastic bag is to be closed, tied, and properly labeled as described above. Extra care must be taken to securely cover and wrap syringe needles and other sharp items to protect personnel from accidental injury.

2. Liquid radioactive wastes will be disposed of as follows:
   a. if the waste is readily soluble or dispersible in water; the waste has no hazardous properties other than its radioactivity; the activity is within limits specified in the FLORIDA STATE CONTROL of RADIATION HAZARD REGULATIONS (FSCRHR); and approval has been granted by the RSO or under his/her RSO’s supervision. (A record of every disposal into a sewer is to be kept by the TSO and entered on the monthly inventory form (pg B8))
   b. Liquid waste that is above the limits specified in the FSCHRG shall be placed in a container, with a lid and properly labeled for pick up by the RSO.

3. The PI shall include the radioactive waste on hand on the monthly inventory (pg. B8).

4. Biological radioactive waste must be stored in freezers in sealed plastic bags until it is picked up by the RSO. In addition to the labeling requirements above, the label must also include the type and number of specimens.

O. **ANIMAL USE WITH RADIOACTIVE MATERIALS**

1. Animal caretakers are subject to all rules and regulations in this manual when working with radioactive animals. Because of the nature of their work, special procedures and precautions must be carefully followed to insure radiation safety. Rubber gloves and laboratory coats will be worn.
whenever experimental animals containing radioisotopes, their cages, excreta are handled. Special care must be taken to avoid being bitten by such animals; the use of heavy leather gloves is suggested.

2. Hands shall be washed routinely. Personnel must check hands and clothing for contamination before leaving the animal room.

3. Radioactive animals must be confined to cages labeled with the American Radiation Symbol (magenta trefoil on a yellow background), until they contain only background amounts of radioactivity or until they are sacrificed. These animals must be isolated from non-radioactive animals.

4. The animal room shall be locked unless attended by an authorized person.

5. The animal room and laboratory must be surveyed for contamination by the researcher after each preparation or administration of radioisotopes. It will also be inspected monthly by the RSO.

6. All samples of byproduct material to be administered to animals will be prepared on easily decontaminated surfaces and in a ventilated room if necessary. Rubber gloves and laboratory coats will be worn by personnel during these preparations. When necessary, remote handling tools shall be used.

7. The animals will be injected with byproducts materials in the designated area. The animals will remain in cages until their excretions contain only background amounts of byproduct material, or until they are sacrificed.

8. All dry waste material, including bedding contaminated with urine and feces, will be accumulated in properly labeled containers, lined with plastic bags.

9. Sacrificed animals containing short-lived radionuclides will be properly labeled and stored in a freezer until the activity has decayed to background. The animals can then be disposed of by incineration under the RSO’s supervision. Solid long-lived wastes will be picked up by the RSO, who will arrange disposal with a licensed waste disposal company.

10. Animal cages will be decontaminated with detergent and scrub brushes. Contaminated water will be flushed down the sink in the animal room with copious amounts of water.
III. INSTRUCTIONS FOR USE OF PERSONNEL MONITORING DEVICES
Instructions for Use of Personnel Monitoring Devices

1. Wear our personnel monitoring device (badge) face forward between your waist and neck. If you are assigned a ring badge, wear it on a finger of the hand likely to receive the most radiation exposure. Wear the ring badge underneath disposable gloves.

2. Always wear your badge(s) whenever handling or working with radioactive materials, or whenever work is to be done in a designated radiation area.

3. Never wear another person’s badge.

4. When not in use, store your badge in a location where it is not likely to receive radiation exposure. Do not store your badge where it might be subject to excessive heat or light. Do not take your badge home, or away from your workplace.

5. If your badge should accidentally receive diagnostic X-ray exposure, or other non-work related radiation exposure, be sure to inform the RSO.
6. If you are to leave FAMU for more than two months at a time, turn your badge in to the RSO before leaving.

7. Your badge will be routinely picked up and replaced with a new one every three months. For this reason your badge should be kept in the workplace to facilitate pick-up and exchange.

If you have questions or concerns, contact the RSO at Campus Extension 3442.

Prepared by FAMU Environmental Health & Safety Department

IV. FAMU ALARA PROGRAM
1. Ensure that licensed material will be used safely. This includes review as necessary of training programs, equipment, facility, supplies and procedures.

2. Ensure that licensed material is used in compliance with department regulations and the license.

3. Ensure that the use of licensed material is consistent with the ALARA philosophy.

4. Identify program problems and solutions.

5. Must be familiar with all pertinent departmental regulations, the license application, and its subsequent amendments if necessary.

6. Review the training and experience of the proposed authorized users to determine that their qualifications are sufficient to enable the individuals to perform their duties safely and are in accordance with the regulations and the license.

7. Review on the basis of safety and approve or deny, consistent with the limitations of the regulations, the license and the ALARA philosophy, all requests for authorization to use radioactive material under the license.

8. Prescribe special conditions that will be required during a proposed method of use of radioactive material such as requirements for bioassays, physical examinations of users and special monitoring procedures.

9. Review at least quarterly the reports of the occupational radiation exposure records of all personnel, giving attention to individuals or groups of workers whose occupational exposure appears excessive.
10. Ensure that all persons whose duties may require them to work in or frequent areas where radioactive materials are used (e.g., security, housekeeping, physical plant) are appropriately instructed as required, as required, to include the ALARA philosophy.

11. Review at least annually the entire radiation safety program to determine that all activities are being conducted safely, in accordance with department regulations and the conditions of the license, and consistent with the ALARA program and philosophy. The review must include an examination of records, reports, results of department inspections, written safety procedures and the adequacy of the management control system.

12. Recommended remedial action to correct any deficiencies identified in the radiation safety program.

13. Ensure that the radioactive material license is amended if required prior to any changes in facilities, equipment, policies, procedures and personnel.

14. Investigate all known instances of deviation from good ALARA practices and, if possible, determine the causes. When the cause is known, the RSO will implement changes in the program to maintain doses ALARA.
Investigational Level

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<td>1. Total effective dose equivalent</td>
<td>125</td>
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<td>(Sum of deep dose equivalent and committed effective dose equivalent)</td>
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<td>2. Lens of the eye (eye dose equivalent)</td>
<td>375</td>
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<td>3. Skin or any extremity (shallow dose equivalent)</td>
<td>1250</td>
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<td>4. Individual organ or tissue (Sum of deep dose equivalent and committed dose equivalent)</td>
<td>1250</td>
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The RSO will review and initial the results of personnel monitoring not less than once in any calendar quarter. The following actions will be taken at the investigational levels as stated in the table of investigational Levels.

A. Personnel dose less than investigational Level I.
Except when deemed appropriate by the RSO, no further action will be taken in those cases where individual’s dose is less than values for the Investigational Level I.

B. **Personnel dose equal to or greater than investigational Level I but less than investigational Level II**

The RSO will review the dose of each individual whose quarterly dose equals or exceeds investigational Level I. If the dose does not equal or exceed investigational Level II, no action related specifically to the exposure is required unless deemed appropriate. However, review each such dose in comparison with those of others performing similar tasks as an index of ALARA program quality and record this review.

C. **Personnel dose equal to greater than Investigational Level II.**

The RSO will investigate in a timely manner the causes of all personnel doses equaling or exceeding Investigational Level II and, if warranted, will take action. A report of the investigation and actions taken, if any, will be recorded.
APPENDIX A

NOTICE TO EMPLOYEES
FLORIDA DEPARTMENT OF HEALTH

NOTICE TO EMPLOYEES
STANDARDS FOR PROTECTION AGAINST RADIATION; NOTICES, INSTRUCTIONS AND REPORTS TO WORKERS; INSPECTIONS

POSTING REQUIREMENT
THIS NOTICE MUST BE POSTED IN PLACES THAT PERMIT EMPLOYEES IN A RESTRICTED AREA TO SEE A COPY ON THE WAY TO OR FROM THEIR PLACE OF EMPLOYMENT.

The Department of Health has established standards for protection against radiation hazards in Chapter 64E-5, Florida Administrative Code.

YOUR EMPLOYER IS REQUIRED TO:
- Post or provide you a copy of the Department of Health rules and operating procedures that apply to your work and explain them to you.
- Apply the rules to work involving radiation sources.
- Post or provide you any Notice of Violation involving radiological working conditions, proposed civil penalties, and orders.

YOU ARE REQUIRED TO:
- Become familiar with the rules and the operating procedures that apply to your work.
- Observe the requirements to protect yourself and your co-workers.

WHAT IS IN THESE RULES:
- Limits on exposure to radiation and radioactive material in restricted and unrestricted areas
- Actions to take after accidental exposure
- Personnel monitoring, surveys, and equipment
- Caution signs, labels, and safety interlocks
- Exposure records and reports
- Options for workers about Department of Health inspections
- Related matters

REPORTS ON RADIATION EXPOSURE
Your employer must give you a written report if you receive an exposure above the limits in the rules or in the license. The maximum limits for exposure to employees are in Part III of the rules. However, your employer should keep your radiation exposure as low as reasonably achievable.

If you work where personnel monitoring is required:
- Your employer must give you a written annual report of your radiation exposures.
- Your employer must give you a written report of your radiation exposures when you terminate employment.

INSPECTIONS
Representatives of the Department of Health inspect all licensed and registered activities. Any worker or worker representative who believes that there is a violation of Chapter 404, Florida Statutes; Chapter 64E-5, Florida Administrative Code; or the terms of the employer’s license or registration can request an inspection by contacting the Bureau of Radiation Control, Bin C21, 4052 Bald Cypress Way, Tallahassee, FL 32399-1741 (850) 245-4266. The request must state specific reasons for the inspection. During inspections, Department of Health inspectors can confer privately with workers and any worker can bring to the attention of the inspectors any past or present condition that they believe contributed to or caused any violation.

Copies of Chapter 64E-5, F.A.C., the license or registration, operating procedures, any notice of violation about working conditions, penalty orders issued, and responses can be examined at:

Environmental Health and Safety
Plant Operations Building
2400 Wahnish Way, suite 100
Phone 599-3442
PROPOSAL FOR USE OF RADIOACTIVE MATERIALS

Please complete and submit for each proposed use of radioactive materials to: Office of Environmental Health and Safety, Plant operations Building, Suite 120, campus. Each proposal will be reviewed by the Radiation Control Committee from the standpoint of radiological safety. For use of radioactive animals, attach “Supplemental Proposal for use of Radioactive Animals.”

Name of PI:___________________ Building __________________ Lab Rm #______________
Radionuclides and maximum amounts to be on hand at any one time: ______________________
______________________________________________________________________________
______________________________________________________________________________
Brief description of use: ______________________
______________________________________________________________________________
______________________________________________________________________________
Number of exp./ month: _______________ Activity / exp. ______________________
Estimated duration of proposal: Date from: _______________ to ____________________________
Comment on the availability of the following, in the lab that you use:

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<tr>
<th>Impervious work surfaces</th>
<th>Yes</th>
<th>No</th>
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<tr>
<td>Shielding</td>
<td>Yes</td>
<td>No</td>
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<td>Security</td>
<td>Yes</td>
<td>No</td>
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<td>Ventilation</td>
<td>Yes</td>
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<td>Waste Receptacles</td>
<td>Yes</td>
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<td>Fume Hoods &amp; Glove Boxes</td>
<td>Yes</td>
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How will you dispose of radioactive waste? (Sewer, decay to background and dispose in normal trash, hold for licensed disposal service, etc.) ____________________________
______________________________________________________________________________
List all individuals working on this project and their experience and / or training in handling radioactive materials (use additional paper if needed)
______________________________________________________________________________
______________________________________________________________________________
Type of survey instruments available: _______________________________________________

The PI hereby assumes the responsibility for all users of radioactive materials under this proposal (i.e., that all users are competent, have the necessary experience and training, and have read the “Policy and Procedures Manual for use of Radioactive Materials at FAMU”). In addition, the PI shall be familiar with “Florida Control of Radiation Hazards Regulations,” and ensure that all requirements of the “Policy and Procedures Manual” are followed.

Radiation Control Committee Approval

______________________________
Signature of PI

1. _______________________________
2. _______________________________
SUPPLEMENTAL PROPOSAL FOR USE OF RADIOACTIVE ANIMALS

For each use of radioactive animals, complete and submit this form along with “Proposal for Use of Radioactive Materials”. Send to Environmental Health and Safety Office, Plant Operations Building, Suite 120, 2400 Wahnish way, Tallahassee, Fl. 32307.

P.I.’s Name:__________________________Building:__________Lab Rm#:_____

Radionuclide(s) to be used:__________________________Activity Level: _________μCi’s

CONDITIONS FOR USE OF RADIOACTIVE ANIMALS:

The P.I. must provide freezer storage for his/her radioactive animals. Animals shall be frozen in an elongated position to facilitate handling, packaging and storage. The necessary precautions shall be taken to prevent animals from freezing together into a large mass.

The State of Florida, Department of Health requires that “Good Housekeeping” shall be maintained throughout a freezer that is designated for the use of radioactive materials. This pertains to non-radioactive as well as radioactive items within such a freezer. Radioactive items shall be well separated from non-radioactive items.

Animal species:___________________Location of freezer:___________________________

Approximate volume of animals per month: __________________________ cu ft.
Approximate volume of animal litter per month:________________________ cu. ft.
Approximate activity per gram in animal carcass: __________________________ μCi/gram

The P.I. hereby assumes the responsibility for all radioactive materials under this proposal. In addition, the P.I. shall be familiar with the “Florida Control of Radiation Hazard Regulations” and ensure that all requirements of the “Policy and Procedures Manual” are followed.

Radiation Control Committee Approval

___________________________ 1. __________________________
Signature of P.I.

___________________________ 2. __________________________

TRANSFERRING RADIOACTIVE MATERIAL

INITIAL USER: ______________________  BUILDING: ______  RM#:______

ORGANIZATION: _____________________  LICENSE#:____________

NEW USER: _________________________  BUILDING: ______  RM#:______

ORGANIZATION: _____________________  LICENSE#:____________

RADIONUCLIDE: ______________________  ACTIVITY LEVEL:______

DATE OF ACTIVITY:__________________

Solid ( ) or Liquid ( )  QUANTITY:__________

__________________________________

RSO

Approved ( )  Disapproved ( )

__________________________________

DATE
A mandatory condition of the license to use radioactive materials, requires researchers to perform contamination surveys at the end of each week or after each use, if use is less often than every week. To perform the survey the area must be monitored with a G-M counter and wipes must be taken and counted with a scintillation counter. (Tabs of ordinary bond paper, approximately 0.25” x 0.75”, can be used for wipes.)

Start by taking and recording a background (control) reading with the G-M counter, followed by recording G-M counter readings at each location to be wiped, usually to include counter tops, surface where contamination is likely to occur shall be wiped. Countertops and floors should receive one wipe for about every 15 square feet of surface used.

Moisten all wipes with water, including the control wipe; wipe surfaces covering ~ 100 cm$^2$ with each wipe; place wipe in scintillation fluid in vial and count vials, including the control vial in the scintillation counter.

Record dpm readings on the “Researcher’s Laboratory Survey Record” form. If the readings exceeds 50 dpm alpha / 100 cm$^2$ or 100 dpm beta-gamma/100 cm$^2$ above background the applicable work area will be decontaminated and re-wiped.

Contact the RSO (ext. 3442) further information is needed.
LABORATORY SURVEY RECORDS
# Researcher's Laboratory Survey Record

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**Initials**

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34
INSTRUCTIONS FOR MONTHLY INVENTORY FORM

Our radioactive materials license requires every PI to submit monthly inventory reports of radioactive materials to the RSO. To insure compliance with these license conditions, the RCC has agreed that a PI who is delinquent in submitting his/her inventory reports, shall not have his/her radioactive waste picked up until the inventories are up-to-date. Delinquencies may also result in further action by the Committee.

These inventory forms are for reporting the receipts and disposal of radioactive materials that occur during the reporting month and the amount of activity “On hand” at the end of the month.

Following these instructions is a copy of “RADIONUCLIDE USERS MONTHLY INVENTORY” form, with each column identified with a letter. The following is an explanation of each column.

COLUMN A – (µCi received) record in this column, the microcurie of radioactive materials received within the reporting month. Report each receipt only once. Do not duplicate on succeeding reports.

COLUMN B – (Date Received) this is the date the material was received. It is not necessary to list the date each succeeding month. However, you may wish to do so for the purpose of identifying that particular sample.

COLUMN C – (Radionuclide) list the radionuclide.

COLUMN D – (Chemical and/or physical form) the chemical form of the solution is usually listed, (e.g. Thmidine, uridine, etc.) Sealed or semi-sealed sources: Encapsulated in metal, report as a sealed source, for others use the appropriate physical form (e.g. matrix, check source, electroplated rod, etc.)

COLUMN E – (Air) airborne activity escaping into the air through a vented hood or dry box. In most cases this is a calculated estimate of the amount of activity which is released from an experiment conducted in a fumehood or in a dry box.

COLUMN F – (Sewer) report the activity which was disposed of into a Sanitary Sewer System during the reporting month. Sinks used for such disposal should be approved by the RSO and posted with the maximum amount that may be disposed of per day, month and year.

COLUMN G – (Ani) list in this column the amount of activity in those animal(s) which have been picked up by the RSO during the reporting month. Account for the activity eliminated by the animal(s) and the amount of decay, if applicable, up to the day of pick-up.

COLUMN H – (Liq) liquid waste which cannot be disposed of in the sewer, because of the chemical form, will be disposed of by the RSO. Use this column to report such liquid waste, which has been picked up by the RSO during the reporting month. Account for decay, if applicable, up to the time of pick-up.

COLUMN I – (Solid) use this column to report the microcurie amount of solid waste (paper towels, work-bench paper, disposable gloves, disposable pipettes, etc.) which has been picked up by RSO during
the reporting month. Suggestion: Place pipettes in a cardboard container before placing in your plastic waste container to prevent puncturing of the plastic liner.

**COLUMN J** - (Decay) list the decay of all radioactive materials with a half line of \(<-1/2\) years, including the waste “On Hand”. For your convenience decay charts are available to assist you in your calculations. Calculate decay only for the time elapsed. If waste (animal, liquid or solid) remaining from last month is picked up on the 7th day of the reporting month, calculate the decay for the 7 days elapsed, etc.

**COLUMN K** - (Stock) list the amount of radioactive materials “On Hand” at the end of the month. Include stock and other usable materials not considered waste material.

**COLUMN L** – (Ani) list the radioactivity in all animals in your possession at the end of the reporting month. Include those animals under experiment and those stored in your freezer. Account for that portion of activity eliminated be the animals and if applicable, calculate for decay up to the date of pick-up.

**COLUMN N**- (Solid) this column is for reporting the amount of activity in solid waste, such as paper towels, disposable gloves, work-bench paper, etc., that is in your possession at the end of the report month. Plastic bag liners and plastic cans are provided by the RSO for this solid waste. It is suggested that pipettes be placed in cardboard containers, before being placed in the plastic bag, to prevent puncturing the bag. The amount of activity you place in the solid waste container is usually an estimate. You may estimate the amount by taking a percentage of the total activity used in the experiment, or calculate from the specific activity used, as the amount absorbed on the work-bench paper, paper towel, gloves remaining in pipettes, etc. The solid waste accumulated from month to month should be reported in this column, indicating the amount of decay each month (if applicable) until the date of pick-up, and then transfer to Column I, as solid waste disposal of and thereafter dropped from your inventory.

**TRANSFER OF RADIOACTIVE MATERIALS:**

All transfers of radioactive materials must be approved by the RSO who will ensure proper packaging, labeling and wipe-testing. (Please follow the section on transferring radioactive materials.) For reporting “On Campus” transfer of radioactive materials, report the transfer near the bottom of the inventory form and indicate, with an asterisk (*), the stock item from which the materials was taken. The PI to whom the material is transferred must have an approved “Proposal” to receive that particular radionuclide and quantity being transferred.

“Off campus” transfers may be reported in the same manner. The RSO must have the recipient’s license number, a copy of the license, or a signed statement as proof of authorization for the individual to receive the material.
Submit a copy to environmental health & safety, campus at the end of each calendar month. If the decay is >1% per month (half-life <5½ years) list the amount of decay. List animal, liquid, and solid waste separately. List all waste in your possession, as waste “on hand”.

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NOTICE
INCOMING RADIONUCLIDE MONITORING
FORM SHOULD GO IN THIS SPACE!
# MONTHLY SURVEY FORM

**Principal Investigator**

**Building**

**Room#**

**Year** 2006

**Radionuclides**

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**Comments**

RADSURVEYFORM2005/MS Excel/my documents

39
FIO RIDA A&M UNIVERSITY

RADIATION SAFETY

DECLARED PREGNANT WORKER (DPW) FORM

This form is used to formally declare status as a Declared Pregnant Worker (DPW), or to
revoke this status if it has been previously declared. Please read this form carefully;
Members of the Environmental Health and Safety, (EH&S) staff are available to answer
any of your questions.

1. Please check one of the following two boxes:

A. ☐ I am formally declaring that I am pregnant. In accordance with Paragraph 206 of 10
   CFR 835, I am voluntarily declaring that I am pregnant, for the purposes of lowering the
dose limit for my embryo/fetus. I realize that work restrictions may be imposed to ensure
that my embryo/fetus does not receive a dose in excess of that given in 10 CFR 835 (500mrem)
during the entire gestation). I authorize EH&S to release this information as
necessary to implement the dose limit for my fetus.

   Estimated date of conception: ______________________________.

B. ☐ I am withdrawing my previous declaration of pregnancy. I understand that, as a
   result of signing and submitting this form, any work restrictions that have been imposed
   as a result of my previously submitted ‘Declaration of Pregnancy’ will be lifted.

Printed Name: ______________________________

Signature: ______________________________

Date: ______________________________
Absorption – the process by which radiation imparts some or all of its energy to any material through which it passes.

Activation – the process of inducing radioactivity by irradiation.

Activity – the number of nuclear transformations occurring in a given quantity of material per unit time.

Acute Exposure – radiation exposure of short duration.

Alpha (α) Particle – a charged particle emitted from the nucleus of an atom having a mass and charge equal in magnitude of a helium nucleus; i.e., two protons and two neutrons.

Attenuation Coefficient (u) – the fractional number of photons removed from a beam of radiation per unit thickness of a material through which it is passing due to absorption and other factors.

Atom – smallest particle of an element which is capable of entering into a chemical reaction.

Beta (β) Particle – charged particle emitted from the nucleus of an atom with a mass and charge equal in magnitude to that of the electron.

Bremsstrahlung -secondary photon radiation produced by deceleration of charged particles passing through matter.

Cancer – any malignant neoplasm.

Cell (biological) – the fundamental unit of structure and function in organisms.

Chronic Exposure – radiation exposure of long duration.
Curie (Ci) – the unit of activity. One Ci equals $3.7 \times 10^{10}$ nuclear transformations per second.

-D-

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

Decay Constant ( ) – the fraction of the number of atoms of a radioactive nuclide which decays per unit time.

Detector, Radiation – any device for converting ionizing radiation to a form suitable for observation. An instrument used to determine the presence and the amount of radiation.

Dose – a general form denoting the quantity of radiation absorbed. If unqualified, it refers to absorbed dose.

Dose, Absorbed – the energy imparted to matter by ionizing radiation per unit mass of irradiated material. One rad equals 100 ergs per gram.

Dose, Accumulated – the total dose resulting from repeated exposures to radiation.

Dose, Equivalent – a quantity used to express all radiations on a common scale for calculating the effective absorbed dose.

Dose, Threshold – the minimum absorbed dose that will produce a detectable degree of any given effect.

Dose, Rate – absorbed dose per unit time.

-E-

Electron – an elementary particle having a charge equal to $-1 \ (1.602 \times 10^{-19} \text{ C})$. And a rest mass equal to $9.109 \times 10^{-31} \text{ kg}$.

Electrostatic Field – The region surrounding an electric charge in which another electric charge experiences a force.

Element – a category of atoms all of the same atomic number.
**Erg** – unit of work done by a force of one dyne acting through a distance of one cm. Unit of energy which can exert a force through a distance of one cm. (SI system).

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

**Film Badge** – a pack of photographic film which measures radiation exposure for personnel monitoring.

**Gamma (γ) Ray** – electromagnetic radiation of nuclear origin.

**Half-life (t1/2) (radioactive)** time required for a radioactive substance to lose 50% of its activity by decay. For each radionuclide there is a unique value.

**Half Thickness (s 1/2)** – the thickness of a specified substance which, when introduced into the path of a given beam of radiation, reduces the exposure by one-half.

**Ion** – atomic particle, atom or chemical radical bearing an electric charge, either negative or positive.

**Ionization** – the process by which a neutral atom or molecule acquires a positive or negative charge.

**Ionizing radiation** – any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, in its passage through matter.

**Ion Pair** – two particles of opposite charge, usually referring to the electron and positive atomic or molecular residue resulting after the interaction of ionizing radiation with the orbital electrons of atoms.
**Irradiation** – exposure to radiation.

**Isotopes** – nuclides having the same number of protons in their nuclei, and hence the same atomic number, but differing in the number of neutrons and therefore, in the mass number. Almost identical chemical properties exist between isotopes of a particular element. The term should not be used as a synonym for nuclide.

- **Joule (J)** – the unit for work and energy, equal to one newton expended over along a distance of one meter. (English system).

- **Molecule** – smallest quantity of a compound which can exist by itself and retain all properties of the original substance.

- **Monitoring** – periodic or continuous determination of the amount of ionizing radiation or radioactive contamination present in an occupied region.

- **Neoplasm** – a new growth of cells which is more or less unrestrained and no governed by the usual limitations of normal reproduction.

- **Nuclide** – a species of atom characterized by the constitution of its nucleus. The nuclear constitution is specified by the number of protons \( z \), number of neutrons \( N \), and energy content; or, alternatively by the atomic number \( z \) mass number \( A = z + N \), and atomic mass. To be regarded as a distinct nuclide, the atom must be capable of existing for a measurable time.

- **Neutron** – an elementary nuclear particle with a neutral charge and a mass of \( 1.674 \times 10^{-27} \) kg.
**Photon** – a quantity of electromagnetic energy.

Proton – an elementary nuclear particle with a positive electric charge of $+1 \ (1.602 \times 10^{-19} \text{C})$ and a mass of $1.672 \times 10^{-27} \text{kg}$.

- **Q** -

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

- **R** -

**Rad** – the unit of absorbed dose equal to $0.01 \, \text{j/kg}$.

**Radiation** – (1) the emission and propagation of energy through space or through a material medium in the form of waves. (2) the energy propagated through space through a material medium as waves.

**Radioactive Decay** – disintegration of the nucleus of an unstable nuclide by spontaneous emission of charged particles and/or photons.

**Rem** – a unit of dose equivalent. The dose equivalent in rems is numerically equal to the absorbed dose in rads multiplied by the quality factor (QF).

- **S** -

**Sealed Source** – radioactive source sealed in an impervious container which has sufficient mechanical strength to prevent contact with and dispersion of the radioactive material under the conditions of use and wear for which it was designed.

**Shielding** – material used to prevent or reduce the passage of particles or radiation.

- **T** -

**Tritium** – the hydrogen isotope with one proton and two neutrons in the nucleus.

- **U** -
- V -

- W -

- X -

_**X-rays**_ – penetrating electromagnetic radiations whose wavelengths are shorter than those of visible light. Originates from the resultant energy release of reactions that affect valence electrons.

- Y -

- Z -
APPENDIX D

RADIATION
RADIATION

A. FUNDAMENTAL CONCEPTS:

1. The Radioactive Atom:

A few naturally occurring elements consist of atoms which are unstable. These atoms undergo spontaneous transformation into more stable atoms. The instability of the atoms is due to certain proton/neutron combinations in the nucleus which cause an increased electrostatic force, from the like charges of the protons, to overcome the strong nuclear force, which binds the nucleons together.

These elements are radioactive and the transformation process they undergo is radioactive decay. Radioactive decay is the emission of radiation in the form of charged particles and/or energy. The radiation emitted can be one or more of three major types: alpha (a), beta (B), or gamma (γ). It should be noted that when a radioactive atom decays, it produces an atom of another element which may or may not be radioactive.

2. Types of Radioactive decay:

As stated above, proton/nucleon balance determines nucleus stability. As the number of protons increase the electrostatic force increases. As the number of nucleons (protons plus neutrons) increase, the strength of the strong nuclear force increases. At first glance it can be envisioned that as long as the number of neutrons outweighs the number of protons, the strong nuclear force will exceed the electrostatic forces ability to keep the nucleus stable. However, the strong nuclear force contributed by protons are not sufficient to overcome the electrostatic force with one proton next to another. Neutrons contribute an even smaller amount of strong nuclear force than protons. The neutrons provide separation between the protons in such a manner that the strong nuclear force
balances out the electrostatic force. (Note that as protons move apart, the electrostatic force weakens). From this it can be visualized that there must be a balance between the number of neutrons and protons where the nucleus is most stable. Atoms with nuclei above or below this balance are unstable and the atoms will attempt to adjust the number of protons and neutrons to achieve this balance. Radioactive decay is the adjustment made by these unstable atoms.

Again, the three major types of radioactive decay are: alpha ($\alpha$), beta ($\beta$), and gamma ($\gamma$). Alpha decay results from the emission of an $\alpha$ particle, which is the nucleus of a helium atom (2 protons and 2 neutrons). This mode is found in heavier nuclides.

Beta decay results from the emission of an electron, a negatively charged particle, from the nucleus. This electron is produced from the transformation of the neutron into a proton, an electron, and energy in the form of a photon.

Gamma decay results from the emission of a photon from the nucleus due to a nucleon falling to its ground energy state.

3. **Radioactivity Units:**

Until recently, the units of radioactivity have been the curie (Ci), defined as $3.7 \times 10^{10}$ dis/s. A disintegration constitutes the emission of a particle or a photon. For convenience, the curie is used with the multiplying prefixes micro- ($\mu$Ci) ($1 \times 10^{-6}$Ci) and milli- (mCi) ($1 \times 10^{-3}$Ci). The SI unit of radioactivity is the Becquerel (Bq), defined as 1 dis/s. For convenience the Bq is used with the multiplying prefixes mega- (MBq) $1 \times 10^{6}$ Bq) and tera- (TBq) ($1 \times 10^{12}$ Bq).

4. **Interaction of Radiation with Matter:**

There are two ways in which radiation interacts with matter. The first requires actual contact with the nucleus of atoms in a material, through which the radiation passes and relates only to particle radiation (e.g., $\alpha$ or $\beta$). The second, requires indirect interaction between the radiation and the nucleus of the atoms in the material and relates to photon radiation (e.g., $\gamma$).

5. **Radiation Units:**

When discussing radiation units, it is important to understand that the different units represent different perspectives of the interaction of radiation. These perspectives are exposure, the extent to which ionization occurs; absorbed dose, the extent to which the absorption of the radiation’s energy occurs; and equivalent dose, equilibration of the biological effects of the different types of radiation.
The roentgen (R) expresses the extent to which radiation exposure causes ionizations in air and 1 R causes 1.61 \times 10^{15} ion pairs to be formed per kg of air. The energy needed to produce these ionizations is 8.69 \times 10^{-3} Joules (J). Since the roentgen applies only to production of ion pairs in air from x-ray and \( \gamma \) radiation, it has limited use.

Absorption of ionizing radiation’s energy into a material uses the unit rad (radiation absorbed dose), which is defined as an energy deposition of 0.01 J/kg. The material that absorbs the radiation is always specified, however, for our use we will be concerned with human tissue.

The SI system of units uses the gray (Gy), which is defined: 1 Gy = J/kg = 100 rad = 104.2 R (in tissue).

(Since the rad is a large dose milliard (mrad) is used.) However, absorbed dose only equates biological damage for \( \gamma \), X-ray, and \( B \) radiation. The other types of radiation must be adjusted in order to standardize the biological effect.

The rem (rad equivalent man) expresses a standardized unit on how the types of radiation are equilibrated. A quality factor (QF) is used as multiplier to equate the absorbed dose, expressed in rads, to a biological effect. This factor relates the ability of the different types of radiation to cause damage. If \( \gamma \) radiation is being used 1 rem = 1 rad, since the QF=1.

The QF for some of the types of radiation are:

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The SI system uses the sievert (Sv), which is equivalent to 1 Gy or 100 rem. (Again, since the rem is such a large dose millirem (mrem) is used.)

The term “dose” has been commonly used for all three expressions, however, to be technically correct it should be used to refer to dose equivalent. Amount of exposure and absorbed dose are use to indicate the other two perspectives.

### B. BIOLOGICAL EFFECTS:

Radiation, from unstable elements, is different from heat or light, since it contains sufficient energy to produce ionizations. The ionizations, in the aqueous environment of a biological cell, can lead to molecular changes which can be damaging to the DNA
material. The damage caused can lead to changes in the makeup and/or function of the cell.

Studies on the damage done in response to radiation, have shown that as the dose rate is reduced, the effects from the radiation exposure are reduced. However, these studies have only been done using dose rates that are significantly above what is normally experienced. Extrapolating from the data obtained in these studies, it can be predicted that a low dose rate will result in a small amount of damage. This process using the “straight-line” theory, assumes that the dose/damage relationship is linear. A second theory that has been proposed, states that since the body has an automatic self-repair system, a certain dose rate level must be achieved before lasting damage occurs. This is called the “threshold” theory.

The damage can be classified into: acute effects (immediately), chronic effects (over long-term), heredity effects (shows up in offspring), and embryological effects (damage done to a fetus).

1. **Acute Effects:**

Acute effects occur when a person is exposed to high doses of radiation. (This level, >25 rem, should not occur in laboratory experiments at FAMU.) The LD50-30 (the lethal dose at which 50% of the people exposed will die in 30 days) is 500 rem, with instantaneous death occurring at ~ 100,000 rem. Sings and symptoms from these large doses range from nausea, weakness and blood cell changes to a depressed immune system and, of course, death.

2. **Chronic Effects:**

Chronic effects occur after exposure to low levels of radiation over a period of time. It has been observed that radiologists and their patients, both of whom have been exposed to a significant amount of radiation, have a higher rate of cancer as compared to the normal population. Cancer is an over-proliferation of cells of an organ, which is thought to be due to damage to the control system that controls cell growth.

3. **Heredity Effects:**

Heredity effects, from radiation exposure, occur when the reproductive cells are damaged. This damage takes place in the form of alterations of the DNA in the
cells of the reproductive organs. As with acute and chronic effects, there is evidence that there is risk. However, these effects are documented from radiation levels above what a person is normally exposed to in a laboratory experiment. The risks involved at low exposure levels can only be postulated based on the established theories.

4. **Embryological Effects:**

   The fetus, as it is developing in the uterus, is very sensitive, and even the mother who is under stress can cause changes in its development. Exposure to radiation during pregnancy, especially the first trimester may be harmful. Again as discussed earlier, this effect has been observed when the fetus is subjected to relatively doses of radiation. See the section on “Notice to Female Radiation Workers”.

C. **NOTICE TO FEMALE RADIATION WORKERS:**

   The U.S. Nuclear Regulatory Commission and the Florida Department of Health require that all females using radioactive materials be instructed concerning the hazards of radiation exposure to unborn children. The following facts are brought to the attention of female radiation workers:

   1. The fetus is much more susceptible to radiation damage than an adult.

   2. One study indicates that the incidence of leukemia among children, from birth to 10 years, could rise from 3.7 cases per 10,000 children to 5.6 cases per 10,000 if the children were exposed to 1.0 rem of radiation before birth. Although this estimate may be high, all women should be aware of possible risk.

   3. The National Council on Radiation Protection and Measurements recommends vigorous efforts to keep prenatal exposure as low as practical and exposure should not exceed 500 mrem during the nine-month gestation period, nor exceed 50 mrem in any one month.

   4. Any woman, who is pregnant and who feels that she might receive enough radiation to be hazardous to her unborn child should consider alternatives.
Any necessary steps should be taken without delay since the first 3 months of pregnancy are the most vulnerable.

5. Any pregnant employee wishing to declare status as a Declared Pregnant Worker, or to revoke this status (if previously declared) should complete the “Declared Pregnant Worker” Form in Appendix B and submit it to her superior and a copy to the Radiation Safety Officer.

D. **LIMITS:**

Limits have been established by the Nuclear Regulatory Commission, and adopted by the Department of Health, for the exposure for personnel to radiation. The lifetime limit for all persons is based on the following equation:

\[ \text{Limited limit (in rem)} = (n-18)^5 \]

Where \( n \) is the age of the person in years.

The federal and state regulations address guidelines: for exceptions to this limit; for exposure to those individuals under the age of 18; and for those who are pregnant (see Section C., Notice to Female radiation Workers).

It is recommended that exposure of individuals always be as low as reasonably allowable and not exceed the following dose rates:

a. 2 mrems in any one hour to whole body, head and trunk, blood forming organs, lens of eyes or gonads.
b. 10 mrems in any one hour to skin of whole body.
c. 20 mrems in any one hour to hands and forearms, feet and ankles.

If one must exceed the dose rates indicated above, the RSO must be consulted before the work is begun. Personnel shall not exceed the following doses:

a. 1.25 rems per calendar quarter to whole body, head and trunk, blood forming organs, lens of eyes, or gonads.
b. 7.50 rems per calendar quarter to skin of whole body.
c. 18.75 rems per calendar quarter to hands and forearms, feet and ankles.

Any incident resulting in: a total effective dose equivalent of 25 rem or more; eye dose equivalent of 75 rem or more; or a shallow dose equivalent to the skin or extremities or a total organ dose equivalent of 250 rad or more, shall be immediately reported to the RSO (campus extension 3442) and to Florida Department of Health. (850-245-4545).

Any incident resulting in the following doses must be reported to the RSO and the Florida Department of Health within 24 hours of discovery: total effective dose
equivalent exceeding 5 rem; an eye dose equivalent exceeding 15 rem; or a shallow dose equivalent to the skin or extremities or a total organ dose equivalent exceeding 50 rem.

APPENDIX E

RADIATION PROTECTION
RADIATION PROTECTION

A. **EXTERNAL PROTECTION:**

The external radiation hazard arises from sources of radiation outside of the body. α radiation is not an external hazard as it cannot penetrate the outer layers of the skin, while β and γ radiation are external hazards, since they do penetrate the skin. In order to deal with external radiation protection, an introduction to what is occurring must be accomplished.

A radiation source, no matter how large or how small, gives off radiation at a certain dose rate (DR), usually expressed in mrem/hr. There are three methods that can be utilized to reduce the radiation levels that are present.

1. **Time:**
If less time \((t)\) is spent in a radiation area, the resultant dose is reduced. This is because the dose accumulated is directly proportional to the time spent in the area.

2. **Distance:**

   It can be proven that as distance \((r)\) from a radioactive source increases, the measured dose rate at that point decreases in response to the “inverse square law.”

   The inverse square law states that when the distance doubles, the dose rate is reduced by a factor of four. Therefore, a work area farther from a radiation source results in a smaller accumulated dose.

   An extension of this method is the practice of only using the amount of radioactive material that is needed at the time. By doing this the radiation levels are reduced, therefore lowering the accumulated dose.

3. **Shielding:**

   A third method uses shielding techniques to decrease the radiation levels, which effectively does the same thing as increasing the distance from the radiation source. The material used to shield the radiation does so by absorbing the radiation. It decelerates the radiation as it passes through, which lowers the radiation levels.

   An important problem of shielding high energy \(B\) radiation is the production of secondary x-rays from the deceleration of the \(B\) particle, known as bremsstrahlung. To minimize this, the use of aluminum, Lucite, or plexiglass is suggested.

   By following these methods the goal of minimizing radiation exposure will be realized. One or more of these methods should be used in all activities using radioactive materials.

**B. INTERNAL PROTECTION:**

Radioactive material can normally enter body via absorption through the skin, inhalation or ingestion. When radioactive material gains access to the inside of the body, the skin, the body’s main defense mechanism, is by passed and an increased likelihood of damage occurs. Once the contamination is in the body, it can accumulate in different parts of the body and act as a radiation source without the benefit of the shielding of the skin. This material can then irradiate organs directly, causing damage. The internal contamination will be removed from the body, but only after a significant period of time. Internal
radiation hazards can result from the use of radioactive isotopes in volatile liquids and loose radioactive contamination becoming airborne. Contamination is loose radioactive material where it is not desired. In order to prevent internal contamination, a few methods can be utilized.

1. Isolate the contamination at the source. (Seal samples, use fume hoods, etc.)

2. Establish and maintain the contamination control zone. (Leave your coffee cup on your desk, etc.)

3. Follow established lab procedures.

As stated in the discussion of external hazards, if these techniques are used, the exposure to and thus the damage from radioactive materials is minimized.

APPENDIX F

RADIATION SURVEY AND DETECTION INSTRUMENTS
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1. GENERAL PRINCIPLES:

The human body is unable to sense ionizing radiation, therefore, reliance must be placed on instrumentation to warn of its presence. Instrumentation detection of radiation is based on either the ionization or the excitation of a material. This chapter will discuss the basic radiation survey and detection instruments. Survey instruments are designed to measure dose rate, while personnel monitoring devices measure dose.
1. **Survey Instruments:**

Survey instruments can be either portable or fixed. Portable survey instruments sense and measure radiation based on the ionizations that occur. The ion pairs produced in the instrument are collected to form an electrical signal. This signal is used to drive a miter to register the presence and amount of radiation. The most common type of radiation survey instrument is the Geiger Counter, also known as the Geiger-Muller (G-M) counter. Since the detector has to be calibrated for each energy level of radiation to provide an accurate reading, the GM counter is primarily used to detect the presence of radioactive material.

The fixed survey instrument utilizes scintillation counting, which is the most common technique for measurement of low energy β emitters. These isotopes are difficult to detect with portable instruments since the low energy β cannot penetrate the window of the detector. In β scintillation counting, the sample is dissolved in a certain solvent. The energy of the low energy β excites the solvent, known as a scintillator. When the scintillator returns to its ground energy state, a flash of light, or scintillation occurs. The number of scintillations that occur is proportional to the energy of the β particle. Low energy γ radiation can also be measured using this method. Measurement of higher energy γ can be accomplished through use of a scintillation crystal instead of a scintillation solution.

2. **Personnel Monitoring:**

Personnel monitoring uses two different techniques. This first, is Thermoluminescence detection or TLD. This technique uses the electron trapping process. A material is selected so that electrons are trapped as a result of exposure to ionizing radiation. To read the dose the material is heated, which causes the release of the trapped electrons in the form of energy. The energy released is directly proportional to the dose that the material and the individual wearing it was exposed to by ionizing radiation. The second method of personnel monitoring is through the use of the photographic effect. Ionizing radiation affects photographic film in the same way as visible light. After it is developed, the exposed film can then be read by passing a beam of light and measuring it’s optical density. This technique has an advantage in that the film can be stored and reread at a later date, while with the TLD method once the electrons are released the reading cannot be rechecked; however, the TLD can be reused.
APPENDIX G

REFERENCES
REFERENCES

1. **Basic Radiation Study Guide.** Radiation Control Department, Environmental Health and Safety Division, University of Florida.


4. **Radiation Safety Procedures**, Environmental Safety Services Department, Public Safety Division, University of Georgia: 1981


