

RADIATION SAFETY MANUAL



**GRAND VALLEY
STATE UNIVERSITY[®]**

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PURPOSE AND SCOPE

The purpose of this manual is to provide the necessary procedures, guidance and information for the safe use of radioactive materials and ionizing radiation-producing equipment at Grand Valley State University (GVSU). This manual contains only policies and procedures specific to the use of radiation at GVSU. Use of radioactivity is regulated by the United States Nuclear Regulatory Commission (NRC), Michigan Occupational Safety and Health Administration (MiOSHA), Michigan Department of Licensing and Regulatory Affairs (LARA) and Michigan Department of Environment, Great Lakes, and Energy (EGLE). Specific regulations may or may not be restated in this manual, yet all such regulations are applicable when working with or using radiation at GVSU. All other appropriate regulations and guidelines (biosafety, chemical, occupational safety, etc.) must also be followed.

This manual contains procedures for acquiring authorization to use, purchase, and possess radioactive material or radiation-producing equipment; procedures for procurement of materials and equipment; safety precautions to follow when working with radiation; emergency procedures for handling accidents involving radioactive materials; and procedures for requesting the disposal of radioactive materials. At no time are radioactive materials or radiation emitting equipment to be acquired, used, transferred, sold, purchased or disposed of, without prior written authorization from the GVSU Radiation Safety Officer. Failure to adhere to this regulation is in violation of the University's License. These regulations and procedures apply to all persons who receive, possess, use, dispose of radioactive materials or radiation emitting equipment at Grand Valley State University.

Applicable regulations and policy guidance for use of radioactivity at GVSU include, but are not limited to:

- U.S. Nuclear Regulatory Commission Materials License No. 21-32172
- U.S. Nuclear Regulatory Commission: 10 CFR Part 30, "Rules of General Applicability to Domestic Licensing of Byproduct Material
- U.S. Nuclear Regulatory Commission: 10 CFR Part 19, Notices, Instructions, and Reports to Workers: Inspections and Investigations
- U.S. Nuclear Regulatory Commission: 10 CFR PART 20, Standards for Protection against Radiation
- U.S. Nuclear Regulatory Commission: Consolidated Guidance About Materials Licenses - Program-Specific Guidance About Academic, Research and Development, and Other Licenses of Limited Scope. (NUREG 1556-Volume 7, Revision 1 (2018)
- Michigan Department of Licensing and Regulatory Affairs/MiOSHA/MiEGLE: Public Health Act 368 of 1978, Part 135 Radiation Control
 - Rule 325 – Michigan Dept. of Environment, Great Lakes and Energy Ionizing Materials Management Division, Ionizing Radiation Rules for Radioactive Material
 - Rule 333 – Michigan Dept. of Licensing and Regulatory Affairs Radiation Section, Rules Governing the use of Radiation Machines
- Michigan Department of Environment, Great Lakes, and Energy: Act 204 of 1987, Low Level Radioactive Waste Authority Act

ROLES AND RESPONSIBILITIES

This section identifies the roles and responsibilities for safe use of radioactivity and compliance with Nuclear Regulatory Commission and Michigan Occupational Safety and Health Administration. Those with defined roles include The Radiation Safety Committee, The Radiation Safety Officer, Authorized Users, and Radiation Workers.

GVSU Radiation Safety Committee (RSC)

a) Scope

The GVSU Radiation Safety Committee (RSC) is responsible for ensuring that radioactive materials and radiation-producing devices are used safely and in accordance with state and federal regulations as well as GVSU policies. The RSC establishes policies for the program and evaluates procedures, proposals and records. The policies and procedures established by the RSC are carried out by University's Radiation Safety Officer (RSO). The RSO is responsible for day to day operations and reports to the RSC at regular intervals. The RSC reports to the University Provost.

b) Membership

The Radiation Safety Committee shall consist of not less than 6 members, including the Radiation Safety Officer and five members appointed by the Provost. The RSC shall include faculty and/or staff members trained or experienced in the use of radioactive materials and radiation sources. Members shall be representative of the various users of radioactive materials and radiation emitting equipment across GVSU's academic programs. At least 1 member must be currently named on the University's NRC license and actively engaged in radiation related research. Committee members shall have an offset 3 year renewable term, except for the RSO. Activities of the RSC will be directed by its chair, who will be appointed by the University Research Integrity Officer upon consultation with the membership.

In addition to the RSC membership, advisors outside the committee may be asked to provide technical assistance for various issues that come before the committee.

c) Meetings

The Chair of the Committee shall convene the Committee as often as is necessary to consider all issues relevant to radiation safety, but not less than once each year. A quorum (simple majority) must be present for a meeting to be official. No quorum shall exist in the absence of the Radiation Safety Officer (RSO) or the RSO's designee. An action item shall pass or fail by the majority of those present (each member shall have one vote). Members shall not vote on issues in which they have personal involvement. The RSO (or RSO's designee) shall record the minutes of the meetings, and distribute these minutes to all members.

d) Responsibilities

The Committee shall evaluate and maintain surveillance over all uses of radioactive material and other sources of ionizing radiation at the University. The Committee shall be the organization at the University that ensures the use of radioactive materials and ionizing radiation meets or exceeds the safety requirements contained in the GVSU Radioactive Materials License and the provisions of State and Federal regulations. This responsibility

includes the authority to suspend or revoke permission to use radioactive materials or ionizing radiation at the University.

Specific duties of the RSC include the following:

1. Review and either approve or disapprove, on the basis of radiological safety or factors related to radiological health, all applications to use radioactive materials or acquire radiation emitting devices.
2. Review the training and experience of the proposed authorized users and the Radiation Safety Officer (RSO) to ensure they are qualified to perform their duties safely and in accordance with the regulations and the license.
3. Advise the RSO on technical matters and approve radiation safety procedures and program changes recommended by the RSO.
4. Review occupational radiation exposure records of all personnel.
5. Review at least every twelve months the entire radiation safety program to determine that all activities are being conducted safely. The review must include summaries of the types, amounts and purposes of radioactive materials used; occupational dose reports; and qualifications of all personnel who work with or in the vicinity of radioactive material;
6. Approve written minutes of all committee meetings.
7. Recommend corrective procedures when deficiencies in the radiation safety program or individual approvals are noted, which may include additional training and/or instructions, designated or limited areas of use, disposal methods, etc.
8. Review all reports that are submitted to the Committee by the Radiation Safety Officer.

The Radiation Safety Officer (RSO)

The person responsible for implementing the radiation protection program is the University Radiation Safety Officer, or RSO. The University RSO is appointed by the Research Integrity Officer and must be approved by the Nuclear Regulatory Commission (NRC) and listed on the facility license. In addition to the University RSO, an "Area RSO" may be designated by the committee and delegated with specific responsibilities. The RSO has independent authority to stop operations that he or she considers unsafe. He or she must have sufficient time and commitment from administration to fulfill certain duties and responsibilities to ensure that radioactive materials are used in a safe manner.

The radiation safety officer's (RSO's) duties and responsibilities include ensuring radiological safety, security, and compliance with both U.S. Nuclear Regulatory Commission and U.S. Department of Transportation (DOT) regulations and the conditions of the license. The University RSO shall have the following responsibilities:

1. Ensure that licensed material at GVSU is consistent with the NRC license.
2. Ensure security of radioactive material.
3. Ensure that licensed material is transported in accordance with applicable NRC and Department of Transportation (DOT) requirements.
4. Ensure that radiation exposures are "ALARA" (As Low As Reasonably Achievable).
5. Review all plans for the proposed use of radioisotopes with applicants from the standpoint of radiation safety, then present the proposal and make recommendations to the RSC.
6. Oversee all activities involving radioactive material, including monitoring and surveying of all areas in which radioactive material is used and records are kept.
7. Act as liaison with NRC and other regulatory authorities.

8. Oversee proper delivery, receipt, and conduct of radiation surveys for all shipments of radioactive material arriving at or leaving from the institution, as well as packaging and labeling all radioactive material leaving the institution.
9. Coordinate personnel monitoring, distribute and collect personnel radiation monitoring devices, notify individuals and their supervisors of radiation exposures and maintain documentation that demonstrates that the dose to individuals is within acceptable limits.
10. Conduct training programs and otherwise instruct personnel of the proper procedures for handling radioactive material prior to use, at periodic intervals (refresher training).
11. Supervise and coordinate the radioactive waste disposal program, including recordkeeping on waste storage and disposal records.
12. Ensure completion of leak tests on sealed sources and calibration of radiation survey equipment.
13. Maintain inventories of all radioisotopes possessed under the license and limit the quantity to the amounts authorized by the license, radiation emitting devices, and sealed sources.
14. Immediately terminate any unsafe condition or activity that is found to be a threat to public health and safety or property.
15. Supervise decontamination and recovery operations.
16. Hold periodic meetings with, and provide reports to, the Radiation Safety Committee.
17. Perform periodic audits of the radiation safety program, Authorized Users and controlled areas to ensure compliance with all applicable NRC regulations and the terms and conditions of the license, provide results of the audits to licensees and the RSC, and maintain records for at least 3 years.
18. Ensure that all incidents, accidents, and personnel exposure to radiation in excess of ALARA or regulatory limits are investigated and reported to NRC and other appropriate authorities.
19. Maintain understanding of and up-to-date copies of NRC regulations, the license, revised licensee procedures, and ensure that the license is amended whenever there are changes in licensed activities, responsible individuals, or information or commitments provided to NRC during the licensing process.
20. Maintain written minutes of Radiation Safety Committee meetings.

Authorized Users

An Authorized User is a person whose training and experience have been reviewed and approved by the RSC and uses or directly supervises the use of licensed material or radiation-producing equipment. Authorized Users using federally regulated radioactive materials must also be listed as an "Authorized User" on the facility NRC materials license. The Authorized User's primary responsibility is to ensure that radioactive materials or equipment used in the areas under his or her control are used safely and according to regulatory requirements. The Authorized User is also responsible to ensure that procedures and engineering controls are used to keep occupational doses and doses to members of the public ALARA.

Authorized Users must have adequate and appropriate training to provide reasonable assurance that they will use licensed material safely, including maintaining security of, and access to, licensed material, and respond appropriately to events or accidents involving licensed material to prevent the spread of contamination. In addition they must procure and maintain adequate funding for appropriate radiation safety supplies and lab termination. Standard costs for radioactive waste disposal will be paid by the RSO, however those costs must be estimated and approved as part of the initial proposal.

The RSC will review and approve all proposals to conduct research with radioactive materials and/or acquire radiation emitting equipment. Upon RSC approval an applicant approved to use radioactive material or equipment may then be required to be approved by NRC and added to the facility license,

or apply to Michigan Department of Licensing and Regulatory Affairs (LARA) for equipment registration. RSC approval is not a guarantee of regulatory agency approval, or vice versa.

Upon approval, the Authorized User shall have the following responsibilities:

1. Establish and maintain an awareness of the need for radiation safety in the workplace including control of radiation exposure to the lowest reasonable level (ALARA).
2. Ensure that operations involving radioactive materials or radiation-producing machines are performed only by personnel who have been properly instructed and authorized for such work.
3. Ensure that appropriate precautions are taken for radiation workers under their supervision including appropriate personnel dosimetry, survey instrumentation, and personal protective equipment.
4. Follow proper procedures for procurement of radioactive materials and radiation producing devices and provide security of materials and equipment.
5. Provide correct and current posting and labeling of laboratory areas, radioactive material containers and radiation-producing equipment.
6. Ensure an accurate and current inventory records for all radioactive materials and radiation producing equipment under his or her responsibility.
7. Perform radiation and contamination monitoring as required by applicable regulations, procedures in this manual, and as required by the Radiation Safety Committee and maintain accurate records of such monitoring results.
8. Follow established procedures for radioactive wastes.
9. Report immediately to the Radiation Safety Division any potentially hazardous spills, suspected radiation overexposures, loss or theft of radioactive materials, or other incidents having possible radiation safety implications.
10. Provide adequate use-specific safety training for all radiation workers under their supervision.
11. Notify RSO of changes in the use, location or quantities of radioactive materials
12. Arrange for disposal or transfer of all radioactive materials promptly upon termination of the authorized use or application.
13. Attend radiation safety meetings, assist with periodic safety audits, and submit quarterly reports as required by the RSO.
14. Maintain each controlled area in a way that is both considerate of other users and eliminates risks to maintenance, janitorial, and security personnel if they are required to enter an unoccupied space.
15. Ensure proper operation, maintenance, testing, regulatory compliance and recordkeeping of radiation-producing equipment.

Radiation Workers

Radiation Workers are personnel who will be working with radioactive materials or radiation emitting equipment under the direct supervision of an Authorized User. Direct supervision means that the Authorized User must work closely with the individual, physically demonstrate the procedures and give instruction on the hazards of the experiment. The supervisor should be physically present, unless convinced that the worker understands the procedures and can safely perform the assigned duties. The supervisor should be readily available for the worker to contact. The names of all workers must be provided or otherwise available to the RSO prior to working with radioactive material or equipment.

Sufficient training must be completed prior to working with radioactive material or radiation emitting equipment. This includes both classroom and on-the-job training with the Authorized User. See sections below on training requirements.

Radiation Worker responsibilities are as follows:

1. Follow policies and procedures in this Manual and issued by the RSC and RSO.
2. Be familiar with and use established emergency procedures.
3. Report suspected radiation overexposures to the RSO
4. Independently use radiation sources after completing and passing radiation safety and source specific operational training.
5. Routinely wear issued dosimeters as required.

Special Instructions for Maintenance, Security, Janitorial and Other Workers

No employees or members of the general public may enter a controlled area without prior authorization and/or training from the RSO. Maintenance, janitorial, and security personnel who are required to work in spaces where possible radiation hazards exist, must be informed of those hazards and be supervised when necessary. The Radiation Safety Officer should be notified by Physical Plant before maintenance or janitorial personnel start work on such projects, so that proper safety will be provided when necessary. Building security should also be informed of hazards in the event of an emergency response situation.

The following examples are types of projects that should be reported to the Radiation Safety Officer before work is begun:

1. Changing filters in hoods or glove boxes in which radioactive materials have been used.
2. Working on drains of sinks that are used for the disposal of radioactive materials.
3. Altering hoods, glove boxes or duct work where radioactive contamination is likely to be present.
4. Working on equipment that is likely to be contaminated with radioactive material.

RESEARCH PROTOCOL APPROVAL PROCEDURES

Radioactive Materials

All research and coursework at GVSU using radioactive materials in any amount, sealed or not, are subject to review and approval by the Radiation Safety Committee. In addition, the US Nuclear Regulatory Commission (NRC) regulates the use of most radioactive materials. Any faculty/staff wishing to use radioactive materials in research or academic activity must notify the RSO in advance of the proposed use. RSC approval and NRC license modifications may take as long as 6 months. In the case of very low energy materials, sealed sources, or other low risk materials not requiring NRC licensing, approvals are likely to be obtained much faster. A written proposal for the use of the material must be submitted to the RSO and approved by the RSC prior to procuring and using the radioactive material.

Individuals wishing to use radioactive materials must complete the following:

1. Read, be familiar with, and follow the procedures outlined in this manual. In addition, all users of isotopes should be familiar with the following:
 - a. NRC: Standards for Protection Against Radiation
 - b. NRC: Notices, Instructions, and Reports to Workers
 - c. NRC: Consolidated Guidance About Materials Licenses, NUREG Vol. 7, Rev. 1 (2018)
 - d. GVSU's NRC Materials License.
2. Submit a "Proposal for Use of Radioactive Materials" (see Appendix for form) which must be approved by the Radiation Safety Committee. All proposals must be signed by the applicant, who will become the "Authorized User" upon approval. The Radiation Safety Officer will assist in the completion of the form and will present the proposal to members of the Radiation Safety Committee on behalf of the applicant.
3. Indicate on the proposal additional users of the radioactive materials and describe their experience, training, and capabilities to safely conduct experiments using radioactive materials. If significant assistance is necessary from other GVSU staff not involved in the research, but necessary for support of the research, such as lab supervisors, they must be listed as well.
4. Submit to the Radiation Safety Officer a current curriculum vitae. The curriculum vitae should include practical experience in physically working with radioactive materials.

The Committee will approve proposals only if convincing evidence is provided that the user is competent in performing all applicable phases of the proposed experiments. If, after reviewing the proposal and supporting information, the Committee members have questions or concerns about the safety of the proposed use, they may require conditional approval, a personal interview with the applicant, or ask that the applicant first make trial runs of the experiment using nonradioactive materials. All inquiries and conditions of approval will be documented in the meeting minutes.

A proposal is initially approved for a period not to exceed one year, at which time the proposal may be resubmitted for an extension by the Committee. Upon request by an Authorized User, an extension may be granted for a period of 1 to 3 years. Extensions will be documented as part of the minutes of the meeting, unless certain conditions or modifications were made as part of the approval of the extension, in which case written notification will be provided to the Authorized User.

Upon approval by the RSC, the Authorized User may be required to assist the RSO with the license modification application to the NRC. Upon approval of the application by NRC, the Authorized User may order radioactive material and the research will continue to be bound by the terms of the approval by the RSC, the NRC license, State and Federal Regulations and the Radiation Safety Manual.

The Authorized User must submit an amendment to the proposal before substantially deviating from the kinds of radioisotopes, the maximum activities, the areas of use, or the experiments described on the proposal. Approval of the RSC and possibly NRC license modifications will be necessary. Minor changes in the proposal, including the addition of up to one millicurie in the amount of activity authorized, must be approved by the Radiation Safety Officer.

Radiation Emitting Devices

The RSC will review and approve the purchase and use of any electronic device regulated by Michigan Department of Community Health **Act 368, Part 135, RADIATION CONTROL**. This includes X-ray producing machines, such as radiographic and fluoroscopic X-ray units, CT scanners, X-ray diffractometers, cabinet irradiators, mobile bone densitometers, some scanning electron microscopes, or any device that emits a dose equivalent rate averaged over an area of 10 square centimeters above 0.5 mrem per hour at 5 cm from any accessible surface.

The individual requesting the equipment will be identified as the "Authorized User" upon approval. The Authorized User must be familiar with the policies and procedures outlined in this manual, understand regulatory compliance requirements and submit a written request for purchase. The request should include the following:

1. Equipment description and specifications
2. Proposed use and location
3. A description of the Authorized User's qualifications and/or training on the specific device

Upon approval by the RSC, the Authorized User must work with the RSO to properly register the equipment with the Michigan Department of Community Health.

Sealed Sources

Individuals wishing to purchase sealed sources of radioactivity must notify the RSO in writing in advance of purchase. The RSO will approve the purchase and designate an "Authorized User" with responsibility for safe use, leak testing, training, reporting and recordkeeping.

PREPARING FOR WORK WITH RADIOACTIVITY

Training

Before beginning work with radioactive material or radiation emitting equipment, Authorized Users and Radiation Workers must receive radiation safety training commensurate with their assigned duties and specific to GVSU's Radiation Safety Program. Each individual should also receive annual refresher training. Students enrolled in classes involving radiation may participate only if radiation safety instruction is provided as part of the coursework, clearly identified in the syllabus and is given by an Authorized User, the RSO, or an individual approved by the RSC.

a) Initial Training

Regardless of any radiation safety training prior to the approved use at GVSU, all Authorized Users and Radiation Workers must complete an initial training session. This will consist of general safety principles of either laboratory research with radioactive materials or radiation producing equipment safety. In addition, training will include policies and procedures specific to GVSU's radiation safety program. The training will be conducted on Blackboard and will require the completion of an examination to successfully complete the training.

b) Annual Refresher

Each year of authorized use the Authorized User and Radiation Worker must demonstrate completion of appropriate continuing education in the area of radiation safety. This may be in various forms including participation on the RSC, attendance at a RSO radiation safety meeting or audit, completion of a refresher training course on Blackboard, active participation in regional or national radiation safety organizations or conferences, or other substantial work in the field of radiation safety. Documentation of such work must be provided to the RSO on an annual basis and maintained on Blackboard. The RSC may choose to evaluate the merits of the training received and require additional training if annual refreshers are determined to be insufficient.

c) Training for Radiation Room Access

Any individual who enters or has access to enter an area controlled for radiation work must be authorized to do so by the RSO and must complete appropriate training. Training will either be in-person with the RSO or Authorized User, or online and must be documented on Blackboard. Individuals in need of limited access, such as maintenance contractors or housekeeping staff, may be granted access following orientation with the RSO or designated individual.

Controlled Areas

Storage and use of radioactive materials and radiation-producing equipment must be conducted only in "controlled areas" that have been appropriately designed and approved for use by the Radiation Safety Committee. A controlled area is a restricted access area and acts as a buffer between public areas and areas where higher levels of radiation may be present. Approved controlled areas at GVSU are as follows:

Facilities approved for use of for Licensed Materials:

1. Annis Water Resources Institute, Lake Michigan Center Room 229, Muskegon, MI

- Brass Key secured access (issued only to Authorized User and building supervisor)
 - Beckman LS6500 Liquid Scintillation Counter, annual service contract
 - Ludlum Model 3 survey meter with pancake probe
 - Emergency telephone and spill kit
 - Fume hood
 - Refrigerator
 - Acrylic containers and benchtop shielding
 - Designated “hot sink” for approved sewer disposal
 - Dedicated containment area for materials storage, lab equipment and waste
2. Padnos Hall of Science, Room 265, Allendale, MI
 - Keycard secured access
 - Packard 1900CA Liquid Scintillation Counter, serviced as necessary
 - Two WB Johnson Survey Meters with pancake probe
 - Ludlum Model 9-3 Ion Chamber
 - Emergency telephone and spill kit
 - Fume hood with HEPA filtration
 - Refrigerator
 - Acrylic containers and benchtop shielding, lead brick shielding
 - Designated “hot sink” for approved sewer disposal
 - Dedicated containment area for materials storage, lab equipment and waste
 3. Padnos Hall of Science, Room 00K, Allendale, MI
 - Keycard secured access
 - Ventilation system with HEPA filter rack and emergency shut-off damper with strobe
 - Emergency telephone
 - Lead for shielding
 - Ludlum Model 3 survey meter with pancake probe
 4. Cook-Devos Center for Health Sciences, Room 565b, Grand Rapids, MI
 - Keycard secured access
 - Beckman LS6500 Liquid Scintillation Counter, annual service contract
 - Johnson GSM-110 survey meter with pancake probe and scintillation probe
 - Emergency telephone and spill kit
 - Fume hood with HEPA filtration
 - Refrigerator
 - Acrylic containers and benchtop shielding
 - Designated “hot sink” for approved sewer disposal
 - Dedicated containment area for materials storage, lab equipment and waste

Facilities approved for radiation emitting devices

1. Padnos Hall of Science, Room 182, Allendale, MI (Scanning Electron Microscope (X-Ray Diffractometer))
2. Cook-Devos Center for Health Sciences, Room 415d, Grand Rapids, MI (X-ray medical imaging)
3. Raleigh Finklestein Hall, Room 011, Grand Rapids, MI (C-Arm Fluoroscopy Machine)

Signage

Certain signage and labeling must be provided prior to use of controlled areas including:

1. Applicable “Notice to Employees” from The Nuclear Regulatory Commission, MI Department Licensing and Regulatory Affairs, or Michigan Department of Environment, Great Lakes, and Energy. Links to each is provided under Radiation Safety Training in GVSU’s “Blackboard” learning management system

2. Each access point to a controlled area shall be posted in such a way that it is clear to all who wish to enter that it is a restricted area with radiological hazards. At a minimum these must include the radiation symbol (trefoil) and be of sufficient size, color and language to clearly communicate the hazards and restrictions of the area.
3. Each item or container of radioactive material shall bear a durable, clearly visible label bearing the standard radiation warning trefoil and the words "Caution, Radioactive Material" or "Danger, Radioactive Material."
4. All portable equipment intended for use within the controlled area that may become contaminated with radioactive material must be labeled as radioactive material to avoid removal of potentially contaminated items from the lab.

Procurement and Delivery of Radioactive Materials

Upon approval of a protocol for use of radioactive material by the RSC, the Authorized User must submit a "Material Request and Receipt Form" (see appendix) to the RSO at least one week prior the desired order date. Requisitions for radioactive materials shall not be submitted if such materials and quantities, plus the materials and quantities on hand, exceed those listed on the Authorized User's proposal as approved by the RSC and the University's NRC License.

All incoming packages of radioactive materials shall first be met in the building's loading dock and visually inspected for any signs of damage, then transferred directly to the controlled area for survey and un-packaging (within 3 hrs of delivery). The RSO, or a designated trained individual, will visually inspect the package, and survey it with a survey meter, beginning with the external packing, and ending with the final container. The packing slip and internal label will be checked for agreement and the product will be placed in the appropriate storage location.

Specific Procedures for receiving and opening packages are as follows:

1. Check the packing slip and label to ensure contents match the order.
2. Inspect all packages known to contain radioactive material for radioactive contamination and radiation levels if there is evidence of degradation of package integrity, such as packages that are crushed, wet, or damaged.
3. Monitor the external surfaces of the labeled package for radioactive contamination with a properly calibrated survey meter or wipe test. Surface contamination must not exceed limits outlined in 10 CFR Part 71 – Packaging and Transportation of Radioactive Material
 - a. Immediately notify the delivery carrier and the NRC Operations Center (301-816-5100), by telephone, when removable radioactive surface contamination exceeds the regulatory limits.
4. In the radiation lab, wear appropriate personal protective equipment (lab coat, gloves, eye protection), open the package and visually inspect for any sign of damage (e.g. crushed items, broken seals or vials, wet or stained packaging). Examine the material to confirm it is the material that was ordered.
5. Survey the stock vial and packaging material for contamination.
 - a. For packages containing soft beta emitters (e.g. H-3, C-14, S-35, Ca-45, P-33) wipe tests must be conducted using a liquid scintillation counter (LSC).
 - b. Packages containing isotopes with beta radiation of higher energy (e.g. P-32, Na-22, Cl-36, Ru-86, I-131) and most gamma emitters (e.g. Cs-137, Cr-51, Fe-59, Co-60) may be surveyed with a calibrated GM survey meter instead of wipe testing
 - c. If contamination is found, stop and notify the RSO.

- Record the findings of the package survey on the Radioactive Request and Receipt Form (Appendix K) and provide a copy to the RSO. Packaging that is not contaminated, may be discarded as regular trash after removing radiation warning labels.

PERSONAL PROTECTION

Personnel Monitoring

All persons will be monitored for radiation exposure if it is expected that a person will receive a dose in excess of 10% of the annual occupational dose limits for an adult radiation worker, given in Table 1, or when the RSO or RSC determine that it is necessary. In order to measure occupational exposure, GVSU utilizes different forms of personnel monitoring. Monitoring is most often done by using a dosimeter badge which contains either film or a thermoluminescent material sensitive to radiation.

Table 1: Allowable Annual Occupational Dose Limits

| Description | Dose Limit (Rem) |
|----------------------|------------------|
| Whole Body | 5 |
| Skin and Extremities | 50 |
| Lens of eye | 15 |
| Minors | 10% of above |
| Pregnant workers | 0.5 |

a) Dosimetry

Any individual who is occupationally exposed to ionizing radiation and is likely to receive a dose in excess of 10 percent of the applicable annual allowable limit will be issued a radiation monitoring device (radiation dosimeter). Monitoring will not be used on persons who are exposed only to low energy beta radiation such as ^3H , ^{14}C , ^{35}S , ^{45}Ca , and ^{63}Ni . The Radiation Safety Committee may require monitoring to be conducted on other individuals at their discretion. GVSU will manage its dosimetry program as follows.

- Personal dosimeters are supplied to Authorized Users on a monthly or quarterly basis and must be used at all times when working with ionizing radiation.
- Individuals are responsible for keeping track of their own dosimeters and returning them at the end of the monitoring period.
- It is typically the responsibility of the RSO to cover costs associated with monitoring of NRC Licensed user. Dosimetry for X-ray medical devices will be managed by the academic department utilizing the equipment.
- Personal dosimeters are assigned to one individual and are not to be used by any other individual during the monitoring period. Authorized users are responsible for ensuring dosimeters are used by the appropriate individual and are worn properly.
- A badge will be issued if it is likely that the body may be exposed fairly uniformly. Badges should be worn on chest, collar, or belt so as to indicate "whole body" exposure. If a lead apron is worn the badge should be worn at collar level outside the apron so that exposure to the head is monitored.

6. Ring badges should be issued in non-uniform radiation fields where an extremity may receive a significant exposure. They should be worn on the palm side of the hand to best monitor the exposure received from handling radionuclides. If wearing gloves to prevent contamination to the hands, the ring badge should be worn under the gloves.
7. Control badges are used to determine the background radiation levels which is subtracted from the individual's exposure to determine the occupational dose received. The control badge must not be exposed to any source of radiation.
8. If a dosimeter is lost or damaged, the RSO should be notified immediately so that a temporary replacement dosimeter can be issued.
9. Records will be received, reviewed and maintained by the RSO or other departmental authorized individuals. Unless posting of results is required, results will be available electronically and provided upon request of individuals tested. Each monitored individual should maintain records from their own entire occupational history of exposure to ionizing radiation. Monitoring records will be kept by GVSU indefinitely.

b) Bioassays

Bioassay is the determination of kinds, quantities or concentrations, and, in some cases, the locations of radioactive material in the human body. Bioassays may be conducted by direct measurement (in vivo counting such as Thyroid) or by analysis and evaluations of materials excreted or removed from the human body (such as urine). Bioassays are required when individuals use certain radioisotopes at specified quantities and/or within certain time periods. With the possible exception of emergency response, there are no situations currently approved for use at GVSU that require bioassays.

Shielding and Personal Protective Equipment

Each Authorized User shall develop written procedures for the use of personal protective equipment and shielding in their area. These should be included in the research protocols reviewed by the RSC. The minimum personal protective equipment for handling radioactive material includes lab coat, closed-toed footwear, safety glasses and disposable gloves. Protective equipment must not be worn outside the laboratory unless it has been monitored and found to be free of contamination. Gloves, while providing protection to the user, can spread contamination if worn outside the laboratory.

USING RADIOACTIVE MATERIALS

Standard Radiation Lab Safety Procedures

In addition to procedures outlined in other sections of this manual, the following safety procedures must be followed when working with radioactive materials:

1. Minimize external radiation exposure to workers by controlling the distance from the source, the exposure time, and shielding. Increasing the distance from the source is frequently the most effective and economical means to reduce radiation exposure from penetrating forms of radiation.
2. Store and transport containers of radioactive liquids in secondary containers that will hold the contents of the primary container in the event of breakage.
3. Clearly label all containers of radioactive material with an indication of the radionuclide, the quantity of radioactive material, the date of the assay and a standard radiation warning label.
4. Only Authorized Users or Radiation Workers may remove isotopes from storage and only designated cabinets, freezers, and refrigerators may be used for storing isotopes. All rooms where isotopes are stored must remain locked when not in use.
5. Eating, drinking, food preparation, food storage, and application of cosmetics are not permitted in laboratories where radioactive materials are stored or used.
6. A trial run without radioactive material must be conducted for all new procedures. Radioactive material may be used only after the safety of the procedures has been assured.
7. The laboratory should be kept clean and organized so that contaminated items are clearly identified and confined to a local area. A sign clearly identifying the area(s) where radioactive materials are stored and used must be posted.
8. Any work performed with volatile material or operations that have a potential for personnel exposure or contamination must be performed in an appropriate hood or glove box. New procedures involving these types of materials must be approved by the Radiation Safety Committee prior to initiation.
9. All work surfaces must be covered with absorbent paper that is changed on a regular basis. Procedures with large volumes of material and/or material with high spill possibility must be done in an appropriate spill tray.
10. After each experiment, clean up the work area and place disposable materials (Pasteur pipettes, kimwipes, etc.) in a plastic bag for disposal before removing gloves.

Surveys

Specific procedures for conducting radiation surveys should be part of the approved protocol for using radioactive materials. General policies for conducting radiation surveys are as follows:

1. Authorized users are responsible for periodically surveying all areas where radioactive materials are used and stored using appropriate instruments and methods. Surveys should be performed and recorded after each day's use of radioactivity. However, the Radiation Safety Committee may approve less frequent surveys and/or documentation. In no case will any Authorized User with radioactive material in inventory survey all areas of radioactive material use and storage (e.g., fume hoods, work benches, floor around work areas, storage areas, door handles) at a frequency less than quarterly, even if the lab is shared with others who have conducted surveys.
2. No person or object subject to radioactive contamination is to leave a laboratory without being monitored for radioactivity. Suitable monitoring techniques are using a thin end-window Gieger-Müller (GM) survey meter or conducting wipe tests. Specific techniques for lab surveys must be part of the protocols submitted for approval.

3. Documentation of surveys must be provided to the RSO on a quarterly basis using the Survey Log Form and must include:
 - a. A diagram of the area surveyed (See Figure Q.1)
 - b. A list of items and equipment surveyed
 - c. Specific locations on the survey diagram where wipe tests and/or survey meter readings were taken along with their radiation levels.
 - d. Ambient/background radiation levels with appropriate units
 - e. Survey results with noted contamination levels and appropriate units
 - f. Make and model number of instruments used
 - g. Name of the person making the evaluation and recording the results and date
4. The surveys must be done using wipe methods and portable survey instruments. (Wipe methods alone are sufficient for laboratories using only 3H.). Each lab must be equipped with the proper survey instruments kept in working order and calibrated according to the manufacturers specifications. Proper survey equipment and parties responsible for purchase and maintenance will be identified as part of the proposal.
5. A surface will be considered to be contaminated if levels are identified greater than two times background

a) Laboratory Wipe Criteria and Techniques

Wipe tests are performed to check surfaces such as bench tops, floors, hands, etc. for contamination. Disposable gloves shall be worn by any person taking wipes. Wipe tests should be performed in the work area after each experiment. Wipes should be taken from the areas of the lab where work has been performed. In addition, areas that are not supposed to contain radiation, the door knob, desks, "cold" centrifuges and incubators, etc. will also be wipe tested.

To properly carry out a wipe survey the following steps should be done.

1. Be familiar with the operation of the scintillation counter. A reference sample of known radioactivity should be counted in addition to wipes to check that the counter is responding correctly.
2. The wipe medium should consist of an absorbent paper measuring approximately 2.5 x 3.0 cm.
3. All wipe papers should be moistened with ethanol just prior to being used.
4. Each wipe should represent a surface area as close to 100 cm² as possible, but a typical wipe should be made in a random pattern over the general area of interest.
5. Wipes shall promptly be placed in a vial for assay and counted in the scintillation counter.
6. If the counts are more than twice background, the area must be decontaminated before proceeding.
7. Results of the wipe tests must be recorded on the survey log form for each room in which isotopes are used.

b) Laboratory Survey Meter Criteria and Techniques

To begin the survey, if the isotope is detectable with a survey meter, check the areas of the lab where work has been performed and where isotopes are stored. In addition, check areas that are not supposed to contain radiation, the door knob, desks, "cold" centrifuges and incubators, etc.

It is very important to use the survey meter appropriate for the isotope used. The action level for dose rate surveys is 2 mrem/hr over background in unrestricted areas, on personal clothing and on skin while the action level for restricted areas and protective clothing used only in restricted areas is 10 mrem/hr over background. This means that if the survey yields levels above the action level, decontaminate or shield the area and notify radiation safety.

When preparing to use a GM there are four things which need to be checked:

1. Calibration - Before performing the survey, check that the meter is in calibration. Survey meters used in typical laboratory operations must be calibrated every 5 years, unless dropped or otherwise damaged. A sticker on the side of the meter shows the date of calibration and the date that the meter is due for calibration. If the meter is out of calibration, contact the Radiation Safety Officer to have it calibrated. If possible, the RSO will provide a "loaner" meter while the other is being calibrated. After calibration, the meter is returned with a certificate of calibration.
2. Battery - A battery check should be performed. Most of the meters have a scale labeled "BAT." By scaling the meter to this setting, the needle should move to the corresponding area on the meter face. Never use an instrument with low battery power since this may result in erroneous readings. The batteries can be changed in the instrument when necessary without disturbing the calibration.
3. Test - Check that the meter is responding to radiation is necessary. By placing the probe next to a known radiation source such as a stock vial, the meter can be checked for response. If the meter is not responding to radiation, contact the Radiation Safety Officer for repair.
4. Scale setting - Most instruments have three or more scales which represent multipliers to use with the instrument scale. The most common are X0.1, X1, X10 and X100. The instrument can be set initially at either the highest or lowest setting and then moved as necessary to enable reading. In most cases in the lab, the X0.1 or X1 will be the most appropriate scale. Read the result from the meter and then multiply by the scale that the meter is set at.

It is also a good practice to keep the audio on when the survey meter is in use. The audio responds to radiation in the same manner without regard to the scale.

To properly carry out a GM survey the following steps should be done.

1. A drawing of the room or area to be surveyed shall be on hand and the survey results promptly recorded thereon.
2. Survey areas that may be occupied by personnel where the radioactive materials are stored and/or used.
3. When surveying surfaces, a close distance must be maintained between the probe and the surface being surveyed - about one centimeter - while avoiding touching the surface with the probe.
4. During the survey, the probe must be moved slowly so that the instrument will have time to respond to a "hot spot".
5. During the survey, if any elevated radiation levels are found that are not considered normal, resolve the matter before leaving the laboratory. Notify the RSO if levels cannot be brought to within 2x background levels.
6. After the survey, the instrument should be turned off, including the "audible" switch, if independently powered.

7. Radiation Safety personnel will provide technical assistance, as needed.

Inventory of Radioactive Materials

Each Authorized User is required to maintain a "Radioactive Material Utilization and Disposal Record" (see appendix) and submit it to the Radiation Safety Officer quarterly. The inventory forms are for reporting the amounts of each isotope received, transferred and disposed of during the reporting period, plus the amount of each isotope "on hand" at the end of the reporting period, corrected for decay.

WASTE

General Procedures

Procedures for radioactive waste disposal must be included in the research protocols for review and approval by the Radiation Safety Committee. Specific rules, regulations, and guidelines must be followed for the disposal of radioactive waste. General procedures are provided below:

1. Minimize quantities of waste and segregate non-radioactive waste from radioactive waste
2. Waste must be stored in secure restricted access areas and containers must be clearly labeled with the appropriate warning sign.
3. Segregate waste according to isotope, half-life, chemical form, physical form, or combinations thereof.
4. All radioactive waste disposals must be entered on the inventory form.
5. All off-site disposal of radioactive material will be coordinated through the RSO.
6. Waste should be stored in suitable well-marked containers, and the containers should provide adequate shielding

Decay-in-Storage

Solid radioactive waste with half-lives less than or equal to 120 days can be disposed as ordinary trash under the following conditions:

1. The waste must be held in storage until the radiation exposure rate cannot be distinguished from background radiation levels.
2. The waste must be monitored at the container's surface and with no interposed shielding.
3. The waste must be monitored with an appropriate radiation detection instrument set at its most sensitive scale.
4. The licensee must obliterate or remove all radiation labels.
5. The Record of Disposal form must be complete and maintained at least 3 years.

As a general rule, the contents of the container should be allowed to decay for at least 10 half-lives of the longest-lived radioisotope in the container. The container should be sealed, properly shielded, and labeled with the date sealed, isotopes present, the date when 10 half-lives have transpired, and the individual who sealed the container.

Sewer Disposal

Very limited amounts of aqueous liquid waste in microcurie amounts, including biodegradable scintillation cocktails may be discarded down designated sink drains. Sink disposal must be approved in advance by the RSC. Guidelines for disposal are provided below:

1. Liquid radioactive waste must be soluble and readily dispersible in water.
2. Identify all other constituents such as flammable solvents, heavy metals or biohazards in the solution that may be restricted from sewer discharge.
3. Sewer disposal concentrations must be within regulatory limits. First, calculate the amount of each isotope that can be discharged, then make sure that the amount does not exceed the university's monthly discharge limit. Waste limits are discussed in 10 CFR 20.2003(a)(4) which states:

“The total quantity of licensed and other radioactive material that the licensee releases into the sanitary sewerage system in a year does not exceed 5 curies (185 GBq) of

hydrogen-3, 1 curie (37 GBq) of carbon-14, and 1 curie (37 GBq) of all other radioactive materials combined.”

Table 3 of 10 CFR 20 provides the monthly average concentrations for release to sanitary sewers. Some common radionuclides and their limits are provided below:

| Radionuclide | Concentration (uCi/ml) |
|--------------|------------------------|
| H-3 | 1×10^{-2} |
| C-14 | 3×10^{-4} |
| P-32 | 9×10^{-5} |
| P-33 | 8×10^{-4} |
| S-35 | 1×10^{-3} |
| Na-22 | 6×10^{-5} |

4. Discharge the liquid into a designated and labeled sink with water running from the faucet. Survey the sink and surrounding surfaces following disposal
5. Record the date, isotope, activity, location, and the person discharging waste.
6. Scintillation waste – Most biodegradable scintillation fluids meet the sink disposal criteria. Traditional flammable organic solvents such as toluene or xylene must be disposed as hazardous waste, regardless of radioactivity. Organic liquid waste shall be segregated by isotope in safety containers provided by the RSO. All containers must be labeled as to which specific isotopes should be discarded therein; strict compliance with these labels is essential. Contact the RSO for Off-site disposal.

Transfer Off-Site

Solid radioactive waste that is ineligible for decay-in-storage, liquid waste that does not meet the sewer disposal limits, and waste containing other regulated material such as hazardous or biohazardous waste and sharps must be transferred offsite to an authorized recipient. The waste must be packaged in proper shipping containers and labeled prior to shipment. The Authorized User must notify the RSO when a shipment is ready to be removed from a regulated area and complete the disposal record form. The shipment must include the NRC manifest form, which will also be returned and signed upon disposal. The RSO will be responsible for disposal records of all off-site shipments.

USING RADIATION EMITTING DEVICES

General Guidelines

X-ray or gamma-emitting equipment must comply with Michigan Department of Community Health regulations and must meet the following guidelines for use:

1. Acquisition of radiation-emitting equipment requires authorization by the RSC.
2. If applicable, radiation-emitting equipment shall be registered with the Michigan Department of Community Health before being put into use.
3. Radiation-emitting equipment shall be inspected by the RSO after acquisition, relocation, modification, or repair. The equipment shall not be put into use until found to comply with all applicable State and University regulations.
4. Each approved operator and each person working with or near radiation-emitting equipment shall be given radiation safety training commensurate with the degree of hazard involved. Documentation shall be maintained by the Authorized User and copies sent to the RSO.
5. Radiation-emitting equipment shall be adequately secured against unauthorized use or relocation.

Leak Tests for Sealed Sources

1. Leak tests must be performed on each sealed source at a frequency not to exceed six months, or if there has been maintenance or damage to the equipment that could affect the integrity of the device. The Authorized User for the device will conduct the test and submit results to the RSO, who will maintain records for not less than 3 years. If the leak test reveals the presence of 0.005 millicuries (185 Bq) or more of removable contamination the source must be removed from use.
2. Sealed sources require leak testing if they meet the following criteria:
 - a. Half-life greater than 30 days
 - b. Nongaseous form
 - c. Activity greater than 0.100 mCi (3.7 MBq) for a beta or gamma emitter, or 0.010 mCi (370 kBq) for an alpha emitter
 - d. Not required for tritium
3. Sources obtained as sealed sources shall not be opened. The safety and handling precautions furnished by the manufacturer shall be maintained in a location that is readily available to all workers and followed.

Stationary Analytical Devices

Analytical x-ray devices utilize x- or gamma radiation to determine the elemental composition or examine the microstructure of materials using diffraction or fluorescence analysis. This includes the diffractometer and scanning electron microscope. Guidelines for use are as follows:

1. Each x-ray unit must have a safety device (interlock) that prevents the entry of any portion of an individual's body into the path of the active primary x-ray beam.
2. The x-ray unit must have an indication of x-ray tube on/off status; shutter open/closed status; and a warning light labeled with the words "**X-RAY ON**", or similar words.
3. All analytical x-ray equipment shall be labeled near any switch that energizes an x-ray tube with a readily discernible sign bearing the radiation symbol and the words: "**Caution Radiation - This equipment produces radiation when energized.**"

4. Each source housing shall be equipped with an interlock that shuts off the tube if it is removed from the radiation source housing, or if the housing is disassembled.
5. Each radiation source housing or port cover should be constructed so that, with all shutters closed, the radiation dose measured at a distance of 5 cm from its surface is not in excess of 2.5 mrem in one hour.
6. Each x-ray generator shall be supplied with a protective generator cabinet that limits leakage radiation measured at a distance of 5 cm from its surface such that it is not capable of producing a dose in excess of 0.25 mrem in one hour.

a) Operating Requirements

1. Operating procedures shall be written and available to all analytical x-ray equipment workers. No individual shall be permitted to operate analytical x-ray equipment in any manner other than that specified in the procedures unless such individual has obtained the written approval of the RSO.
2. No individual shall bypass a safety device or interlock, unless such individual has obtained the written approval of the RSO. Such approval shall be for a specified period of time. When a safety device or interlock has been bypassed, a readily discernible sign bearing the words “**Safety Device Not Working**”, or similar words, shall be placed on the radiation source housing.
3. Except as described in the previous paragraph, no operation involving removal of covers, shielding materials, or tube housings, or modifications to shutters, collimators, or beam stops shall be performed without ascertaining that the tube is off and will remain off until safe conditions have been restored. The main switch, rather than interlocks, shall be used for routine shutdown in preparation for repairs.
4. If the x-ray device contains a radioactive source, replacement, leak testing, or other maintenance or repair procedures shall be conducted only by the Authorized User.

b) Personnel Requirements

Personnel dosimeters are required for:

1. Operators of analytical x-ray equipment having an open-beam configuration and not equipped with a safety device
2. Personnel maintaining analytical x-ray equipment if the maintenance procedures require the presence of a primary x-ray beam when any local component in the analytical x-ray system is disassembled or removed.

X-ray Medical Radiation Devices

GVSU's Radiological Imaging staff is responsible for developing and implementing policies and procedures for use of medical radiation devices.

REPORTING AND RECORDKEEPING

Compliance Documentation

The RSO will collect and maintain all records necessary to document compliance with this policy and state and federal regulations. Records will be available electronically through secure access to the University's Blackboard system. Authorized users are responsible for ensuring that accurate and up-to-date records in Blackboard. All records that are part of a report to the RSO will be uploaded by the RSO and need not be duplicated. A summary of records are provided below:

| Item | Responsible Party | Retention Period |
|------------------------------------------------------------------------------------------------------------|---------------------|--------------------------|
| NRC License and Correspondence | RSO | Lifetime of License |
| MI Dept. of Community Health device licenses | Authorized User | Lifetime of License |
| Radiation Safety Committee Proceedings | RSO | Lifetime of License |
| Approvals/extensions for use of rad. materials and/or devices | Authorized User/RSO | Lifetime of License |
| Training records | RSO | 30 years post separation |
| Personnel monitoring records | RSO | 30 yrs post separation |
| Specifications, instruction manuals and preventative maintenance schedules for devices and sealed sources. | Authorized User | Lifetime of Device |
| Procurement and receipt documents | Authorized User/RSO | 3.5 Years |
| Leak Test Results | Authorized User | 3.5 Years |
| Survey meter and LSC calibration and maintenance records | RSO | 3.5 Years |
| Radioactive Material Utilization and Disposal Record | Authorized User | 3.5 Years |
| Radioactive Material Survey Log Form | Authorized User | 3.5 Years |
| Radioactive Material Accident/Spill Form | Authorized User | 3.5 Years |
| Records of off-site disposal | RSO | 3.5 Years |

Reports

The following reports are required to be submitted to the RSO.

1. Radioactive Material Quarterly Reports – At the end of each quarter each authorized user of radioactive material with any quantity of radioactive material on-hand radioactive material must submit the following information to the RSO regardless of whether or not radioactive material was used in the preceding quarter:
 - a. Radioactive Material Survey Log form, including instrument readings and a map of survey locations.
 - b. Radioactive Material Utilization and Disposal Form
 - c. Radioactive Material Accident/Spill Form (if needed)
 - d. 4th Quarter only – a short narrative of the year's activities

2. Radiation Emitting Devices/Sealed Source Annual Report – At the end of the calendar year each authorized user of a device or sealed source must provide a written report to the RSO including:
 - a. An inventory equipment and its current disposition (in use, idle, storage, broken, etc.).

- b. Records of repairs, preventative maintenance, leak tests and disposal or sale from the preceding year.
- c. Copies of any correspondence with regulatory agencies.
- d. A narrative of the past years activities including any significant malfunctions or other safety concerns with the equipment and any likely modifications for use in the upcoming year.

RADIOLOGICAL EMERGENCY PROCEDURES

Serious Incident

In case of serious accident and/or injury involving radiation or radioactive materials call the Radiation Safety Officer, and dial 911. Tell the dispatcher your name, the building and location, and the seriousness of injury, if any. Phone numbers are posted in the Radiation Laboratory.

Stay on the line until all necessary information is furnished to the dispatcher. The dispatcher will notify the appropriate emergency response agencies. If the Radiation Safety Officer cannot be reached, a member of the Radiation Safety Committee must be notified. Other emergency personnel may also be notified. A current list of names and phone numbers of response personnel are posed in the Radiation Laboratory and with the GSVU Physical Plant. If no serious injury is involved, call the Radiation Safety Officer.

a) Care of Injured

1. Apply first aid, if necessary, using caution not to further aggravate the injury while disregarding the possibility of radioactive contamination, which can be dealt with at a later time.
2. Stay with the victim until emergency team members arrive and advise on the extent of the incident, the victim's condition, and the extent of contamination, if known.
3. Accompany the accident victim to the hospital, if possible, and take along a GM survey meter, if available, whenever radioactive contamination is suspected.
4. Care of a Contaminated/Exposed Person -- The Radiation Safety Officer will evaluate the extent of the exposed person's dose. If necessary, arrangements will be made for the exposed person to go to the hospital for examination to determine the extent of radiation damage and/or treatment.

b) Nonvolatile Liquid Spill

When liquid radioactive material is spilled in a laboratory, specific action must be taken. Listed below, in order of priority, are steps to be taken in handling a typical spill; such as spills of millicurie amounts of a radioisotope.

1. Request help from lab workers, if present.
2. Make a quick evaluation of the extent of the hazard. If there is an airborne problem, shut off the air handling system, leave the immediate area, but keep involved personnel in the general area; prevent the entry of non-essential personnel; and contact emergency personnel. If there is no airborne problem, proceed to monitor personnel and the area to establish the extent of contamination. If the radiation levels exceed two millirem per hour, shield the source or leave the area. Be careful to not track contamination away from the spillage area.
3. Control the area. To protect people against radiation exposure and to avoid the spread of contamination, rope off the area and post signs warning of the radiation incident. If shoes are contaminated and you must leave the area, go to the outer perimeter of the contaminated area and remove shoes. Try not to leave the area unattended.
4. Notify the Radiation Safety Officer of the spill. Provide details and the location of the incident. Maintain control of the area until safety personnel arrive.
5. Decontaminate the workers involved, their clothing and the area, under the supervision of safety personnel. Decontamination supplies and waste containers will be provided. Skin should be decontaminated immediately. Contaminated clothing should be promptly removed. Skin and clothing shall be reported to the Radiation Safety Officer.

6. The decontamination procedure for a spill is to start at the perimeter (the least concentrated area), absorbing the radioactive liquid while working toward the center of the spill area (the most concentrated area). After the major portion of the liquid is absorbed, further decontaminate using a decontamination agent, as instructed. Repeat the decontamination procedure until the wipe tests (performed by Radiation Safety Officer) reveal that the activity is within the permissible limits.
7. Assist in preparing the final report by giving detailed information of the incident to the Radiation Safety Officer.

c) Powdered, Volatile Liquid or Gaseous Activity Spill

1. Evacuate personnel immediately and turn off any laboratory apparatus that needs constant attention.
2. Turn off re-circulating air handling equipment, if possible.
3. Assemble personnel immediately outside the room and instruct them to stay in one location, to prevent the spread of contamination.
4. Close and lock the room doors to prevent reentry. If the hood fans are off, try to seal accessible openings into the laboratory to prevent further escape of airborne activity into the corridor.

Minor Incidents

Spills of a few microcuries of radioactive materials with no personnel contamination or damaged equipment are not required to be reported.

a) Small volume spills

1. Notify others in the vicinity that a spill has occurred.
2. Wear rubber gloves. Recover as much liquid as possible by pipetting with a pipette control device.
3. Blot up the remaining liquid with paper towels, using as few towels as possible. Do not spread the contamination further by adding water.
4. Once the spill is absorbed, the area should be cleansed with a decontaminant until a wipe test shows only background activity.
5. Check your shoes, hands and clothing for contamination.
6. All disposable materials, such as towels, used in the process should be placed in a plastic bag in the appropriate radioactive waste container.
7. No further work is permitted until all of the contamination has been removed.
8. Notify your supervisor that a spill occurred and assist her/him in completing a spill report.

b) Large volume spills

1. In the event of a large volume spill, use towels or spill containment pillows to keep the spill from spreading. The area of the spill and the isotope should be clearly marked.
2. Do not attempt to clean the spill by yourself. Notify your supervisor immediately. Keep other persons from entering the area by locking the door, or physically blocking the area if in a hallway.
3. Your supervisor will oversee cleaning the spill with absorbent pillows, cleansing the area with decontaminant, and surveying for contamination.

Assist your supervisor in preparing a spill report.

c) Skin contact

1. Rinse the area immediately with water, followed by thorough cleansing with soap and water. Then use a decontaminant cleanser made especially for skin.
2. Repeat until a survey shows only background levels of radioactivity.
3. Notify your supervisor of the accident, and assist him/her in preparing a report.

APPENDIX

Appendix A: Primer on Radiation and Radiation Safety

Introduction

Isotopes are variants of elements that differ in the number of neutrons. The properties of an element are defined by the number of protons (the atomic number, Z) and the atomic mass (or weight) which is the sum of the number of protons and neutrons. For example, most carbon atoms have a nucleus composed of 6 neutrons and 6 protons (^{12}C). However, other forms of carbon have seven (^{13}C) or eight (^{14}C) neutrons. The ^{14}C form of carbon is unstable and breaks down (decays) by emitting energy in the form of a beta particle (an electron) formed by a neutron splitting into a proton and an electron. The gain of a proton converts ^{14}C (six protons and eight neutrons) to the most common isotope of nitrogen, ^{14}N (seven protons and seven neutrons). This accompanying release of energy (radiation) can be detected by a variety of methods and takes place at a constant rate. The time it takes for one half of the isotope to decay is called the radiological half-life. Each of these radioactive isotopes has specific characteristics (see Table 1). Radioactive isotopes can be characterized in terms of their half-lives, the activity (measured in Curies or Becquerels), or the type of decay (alpha, beta, or gamma).

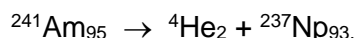
The use of radioactive isotopes as tracers in biology is common as the energy released by decay allows precise localization and quantities of very small amounts of biological molecules. Typically the molecule to be followed is labeled with a radioactive isotope in one of the atoms normally found in the molecule. Commonly used isotopes in biology are carbon-14 (^{14}C), tritium (^3H), phosphorous-32 (^{32}P), sulfur-35 (^{35}S), and iodine-125 (^{125}I). DNA is commonly labeled with ^{32}P or ^{35}S (replacing phosphorous in the structure) for applications like DNA sequencing, Southern Blotting, etc.

Use of radioactive materials poses several potential risks both to the user and to others who might be exposed. This section will include a review of the nature of radioactivity, how radioactivity interacts with biological material, and the potential risks of radiation exposure.

Types of Radiation

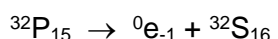
There are three basic types of radiation released by radioactive decay: alpha particles, beta particles, and gamma or X-rays. Radioactive isotopes can release energy in more than one form, and the decay products formed by decay may also be radioactive.

Alpha particles are charged helium nuclei consisting of two protons and two neutrons. They are produced during radioactive decay of high atomic number materials in which the ratio of neutrons to protons in the nucleus is too low. For example, ^{241}Am decays to ^{237}Np by alpha emission:



Alpha particles are released from the nucleus and are very large particles and, therefore, have a very short range in air and very little penetrating power through material. They can be easily shielded by a sheet of paper or by the outer layer of skin. The exposure hazard consequently, is not external to the body but rather internal to target organs. If ingested or inhaled they will produce a great amount of damage in a small area. Alpha emitters are not commonly used in biological applications.

Beta particles are ordinary electrons and can be positively or negatively charged. They are emitted from the nucleus of an atom in which the neutron to proton ratio is too high. For example, ^{32}P decays to ^{32}S by beta emission:



The most common beta emitters encountered in biological applications are ^3H , ^{14}C , ^{35}S and ^{32}P . The penetrating power of the beta particle depends on its energy. The betas emitted by ^3H , ^{14}C , and ^{35}S

are all low energy betas and are therefore not an external exposure hazard. In fact, the low energy betas will not cause the film on a dosimeter badge to be exposed. Also the ^3H beta cannot be detected with the survey meter, and a very sensitive probe is necessary to detect the ^{14}C and ^{35}S . However, these materials are capable of causing internal damage like alpha particles. Protective clothing should be worn when handling these materials, but no additional shielding is necessary. If there is a possibility of volatility, the materials should be used in the fume hood.

The high energy betas such as those emitted by ^{32}P are more penetrating and therefore present an external exposure hazard, especially to the skin. Shielding is necessary when working with these high energy betas. A low Z, i.e. less dense material such as Plexiglas or Lucite, is preferred. When a beta particle strikes a high Z material such as lead, the beta particle interacts with the orbital electrons and slows down emitting characteristic x-rays known as *bremsstrahlung*. The less dense material does not have the abundance of orbital electrons and therefore the *bremsstrahlung* is not as prominent. Many commercial shields made from Plexiglas are available for bench work, test tubes and solid and liquid waste containers. Donning two pair of gloves for manual procedures will provide additional protection to the hands and fingers when working with concentrated stock solutions. If there is a possibility of volatility, the materials should be used in the fume hood.

Gamma radiation is a high energy form of electromagnetic radiation similar to visible light, ultraviolet rays and radio waves. Gamma rays have no mass and no charge and are, therefore, very penetrating and can travel long distances in air and other materials. Common gamma emitters encountered in biological applications include ^{125}I . The proper shielding for gamma or x-rays is lead. If there is a possibility of volatility, the materials should be used in the fume hood.

Radioactive Decay and Units

When the neutrons and protons are in the right proportion, the nucleus is considered stable. For light nuclei ($1 < Z < 20$) there is an equal number of protons and neutrons. For heavier nuclei ($Z > 20$) more neutrons must be added for each added proton and therefore heavier nuclei are more likely to be unstable. All elements with very high atomic numbers (Z greater than 81) are naturally unstable.

In order to become stable, the nuclei emit radiation. This is known as radioactive decay. The radiation which is emitted is in the form of alpha particles, beta particles and/or gamma rays. The nuclei may change only one time and become stable or many times before becoming stable. However, each time it changes, some type of radiation is emitted. The activity of the radioactive material refers to the rate of its transformation or its decay. The activity is dependent on the number of disintegrations and not the number of emissions. For example, each transformation of ^{60}Co results in the emission two gamma rays. Different isotopes are transformed at different rates, and each has a characteristic transformation rate. No operation, either chemical or physical, can alter the transformation rate of the isotope. This transformation rate is known as the half-life, the time in which half the atoms of a radioisotope are transformed through radioactive decay. Half-lives of some common isotopes used in biology are shown in Table One.

Table 1. Characteristics of Isotopes Commonly Used in Biology

| Isotope | Half-life | Decay Process | Radiation Emitted | Energies MeV (max) |
|------------------|-------------|---------------------------------------|-------------------|--------------------|
| ^{14}C | 5730 years | Beta to ^{14}N | Beta | 0.156 |
| ^3H | 12.33 years | Beta to ^3He | Beta | 0.019 |
| ^{32}P | 14.26 days | Beta to ^{32}S | Beta | 1.711 |
| ^{35}S | 87.51 days | Beta to ^{35}Cl | Beta | 0.167 |
| ^{125}I | 59.41 days | Electron capture to ^{125}Te | Gamma | 0.035 |

The SI unit for measuring activity is the Becquerel (Bq) which is one transformation (disintegration) per second (1 dps). However, in the United States, the common unit of activity is the Curie (Ci) and is

defined as 3.7×10^{10} dps. One curie is equal to 3.7×10^{10} Becquerels. The Curie is a very large unit, so we commonly use the millicurie (10^{-3} Ci) and the microcurie (10^{-6} Ci) which are abbreviated mCi and uCi respectively.

In order to calculate the amount of the radioactive material after decay, it is necessary to know the half-life of the isotope, the original amount and the elapsed time. The mathematical equation for the amount of radioactivity is: $N = N_0 e^{(-0.69315(t/t_{1/2}))}$. N_0 is the original amount, t is the elapsed time, and $t_{1/2}$ is the half-life. If N_0 is one, then the formula is simplified to $N = e^{(-0.69315(t/t_{1/2}))}$.

For example, a shipment of ^{32}P contains 1000 uCi. How much remains after 7 days? In this case, $N = 1000e^{(-0.69315(7/14.26))} = 1000e^{-0.33233} = 717.3$ uCi. For commonly used isotopes, the decay fractions have been calculated and tabulated to make decay calculations easier.

Exposure from Background Radiation

Everyone is exposed to radiation from the environment. Background radiation is from three sources: cosmic rays and high-energy particles from the sun and outer space; radioactive elements in the earth, air, and water; and manufactured sources of radiation from medical testing, nuclear testing, and consumer goods. For most people, background radiation is the largest source of exposure. Table 2 summarizes the average background radiation exposure received by individuals in the United States. Variation in this average dose can occur due to a number of reasons.

Table 2. Background Radiation Sources

| Source | Exposure (mrem/yr) |
|---------------------------|--------------------|
| Radon | 198 |
| Internal | 40 |
| Cosmic sources | 29 |
| Terrestrial (rocks, soil) | 29 |
| Medical X-rays | 40 |
| Nuclear Medicine | 14 |
| Consumer Products | 10 |
| Other | 3 |
| Total | 363 |

Average natural background in the United States about 363 mrem/yr with the majority, around 200 mrem/yr, due to radon gas, a daughter product of uranium decay. However, many places on earth receive more than 1000 mrem/yr from radon. The amount of radon in the air depends on the uranium content of the soil in the area, weather and other atmospheric conditions. Also, concentrations will be higher indoors than outdoors due to a lack of ventilation and the uranium content of construction materials. Radon decays to form other radioactive isotopes which, when inhaled, can lodge in the lung and irradiate tissues.

Radioactive isotopes such as ^3H , ^{14}C , ^{40}K , and ^{87}Rb are naturally present within the body. Certain foods, for example shellfish and Brazil nuts, concentrate radioactive materials so that consumption of large amounts can increase the radiation dose received. ^{40}K is the main source of internal radiation contributing, on average, about 19 mrem/yr to soft tissue and 15 mrem/yr to bone marrow. ^{40}K occurs to an extent of 0.01% in natural potassium and the amount in the body varies with the amount of muscle. A person who weighs 70 kg contains about 140 g of potassium. It follows that the ^{40}K content of the body is of the order of 0.1 uCi.

External gamma or X-ray radiation exposure due to cosmic and terrestrial radiation sources will average about 55 mrem/yr in the United States. The cosmic radiation sources are galactic cosmic rays, geomagnetically trapped particles, and solar cosmic rays. The amount of cosmic radiation

varies with atmospheric thickness, i.e. by altitude and latitude. The atmosphere provides an effective shield for cosmic radiation. In Guangdong Province China, the average is between 300 and 400 mrem/yr, in Kerala India 380 mrem/yr and in Guarapari Brazil it averages greater than 600 mrem/yr. In the United States, this varies from an average of 25 to 75 mrem/yr.

Terrestrial radiation from the soil is due to uranium and thorium decay chains producing gamma and X-ray radiation and naturally occurring ^{40}K and varies with geographical location. In the United States, this varies from an average of 20 to 90 mrem/yr with the Colorado Plateau area having the highest exposure.

Radiation is used in medicine for diagnostic purposes such as X-rays for imaging and injection as dyes, ingestion, or inhalation of gamma ray emitting radioactive materials (nuclear medicine). Additionally, radiation is used to treat cancer using high energy X-rays or gamma rays or by injection of radioactive materials targeted to kill cancer cells. X-rays and nuclear medicine contribute about 52 mrem/yr.

Consumer products also cause some exposure. Products such as tobacco products which contain ^{210}Po ; domestic water containing ^{226}Ra and ^{220}Rn ; combustible fuels; ophthalmic glass containing thorium for rose tinting; luminous dials and signs containing ^3H ; and ^{147}Pm and smoke detectors containing ^{241}Am contribute about 10 mrem/yr.

Other sources of radiation such as nuclear power plants, etc. contribute relatively minor amounts of exposure. Travel in airplanes can increase exposure, with a coast-to-coast trip exposure of about 5 mrem. Nuclear weapons testing has resulted in a residual background exposure estimated to be about 4.6 mrem/yr in 1990 and 4.9 mrem/yr in the year 2000.

Biological Effects of Radiation

Radiation biology is the study of the effects of exposure to radiation and their relationship to dose. These effects can be divided into those caused from chronic vs. acute exposure and the effects that occur early and those that are delayed. The process by which radiation interacts with biological molecules can be divided into a number of steps. First, radiation interacts with target molecules producing ions, free radicals and chemically active species. Second, chemical reactions caused by these products change biologically significant molecules or structures. Third, the nature of these altered products cause specific short and long term effects.

Most of the reactive ions and chemical species have no effect. Most of the chemical reactions produce nonfunctional molecules that are either replaced or repaired by the cell. However, in some cases the reactions are so extensive as to impair normal functioning, or the damage occurs to critical biological molecules such as DNA causing long term effects.

The expression of the effects depends on the amount of time exposed to a radiation source as well as the type of radiation. An acute exposure refers to an exposure time that is very short or a one-time exposure to a specific amount of radiation. A chronic exposure refers to an exposure over a longer period of time such as one extended over hours or days or a perpetual exposure.

Acute exposures can cause prompt somatic effects where the functions of cells are impaired. Table 3 shows the effects of different levels of whole body acute exposure.

Table 3. Effects of Whole Body Exposure.

| Dose (mrem) | Effect of Total Body Exposure in 24 hours |
|-----------------|-------------------------------------------|
| 25,000 | No Detectable Effects |
| 50,000 | Slight Temporary Blood Change |
| 100,000 | Nausea, fatigue |
| 200,000-500,000 | Death with no medical treatment |
| 500,000 | Half of exposed individuals die |

In addition to these prompt effects, delayed effects such as cancer may occur as late as 30 years following exposure. Teratogenic (developmental) effects resulting from the exposure to an embryo or fetus can also occur.

Long term effects are primarily due to mutation in the DNA. Mutations to DNA can cause cancer in the exposed individual. Mutations in egg or sperm and cause abnormalities that occur in the future children of exposed individuals and in subsequent generations. The amount of radiation necessary to double the spontaneous mutation rate in humans has been estimated to be from 170,000 to 200,000 mrem for acute exposures and between 340,000 to 450,000 mrem for chronic exposures. There appears to be no threshold level for radiation exposure, however, so the goal of radiation safety is to minimize any additional radiation exposure. Exposure to 200 mrem/yr will result in a 30 year exposure of 6000 mrem. If 200,000 mrem is the doubling dose, this exposure will result in a 3% (6000/200000) increase in mutation beyond the spontaneous mutation rate. A low estimate of detectable spontaneous mutations per million births is about 2000 mutations. A 3% increase would result in about 60 new mutations.

To better put into perspective the types of risk one is taking by being occupationally exposed to radiation, a number of risk comparisons are shown in Tables 4, 5, and 6. These data is taken from the NRC Draft guide DG-8012 and were adapted from B.L. Cohen and I.S. Lee, "Catalogue of Risks Extended and Updates", Health Physics, Vol. 61, Sept 1991 (Table 4); DOE Radiation Worker Training (Table 5); and Radiobiology for the Radiologist, Fourth Edition, Eric Hall, 1994, J. B. Lippincott Company (Table 6).

A 300 mrem/yr exposure would result in an estimated loss of 15 days of life expectancy. A 300 mrem exposure would result in a 30 in a million chance of dying from cancer, be equivalent to about 94 chest X-rays, 844 cigarettes smoked, and driving 2,156 miles on the highway. Exposures at GVSU are designed to be well below 300 mrem/yr.

Table 4. Loss of Life Expectancies Due to Various Activities

| Activity | Life Expectancy Lost |
|-----------------------------------|----------------------|
| Smoking 20 cigarettes per day | 6 years |
| 15 % Overweight | 2 years |
| Average U.S. Alcohol Consumption | 1 year |
| All Accidents | 207 days |
| All Natural Hazards | 7 days |
| Occupational dose of 300 mrem/yr | 15 days |
| Occupational dose of 1000 mrem/yr | 51 days |

Table 5. Activity Rates to Cause a One in a Million Chance of Dying

| Activity | Exposure to cause 1 in a million chance of dying | Cause of Death |
|-----------------|--------------------------------------------------|----------------------|
| Smoking | 1.4 cigarettes per day | Lung Cancer |
| Eating | 40 tablespoons of peanut butter | Heart Disease |
| Living | 2 days in New York City | Air pollution |
| Driving | 40 miles | Accident |
| Flying in a jet | 2500 miles | Accident |
| Canoeing | 6 minutes | Accident |
| Radiation | 10 mrem | Cancer from mutation |

Table 6. Risk Equivalencies Between Medical Procedures, Smoking, and Driving

| Procedure | Effective Dose (mrem) | Risk of Fatal Cancer | Equivalent Number of Cigarettes Smoked | Equivalent Number of Highway Miles Driven |
|--------------|-----------------------|----------------------|----------------------------------------|-------------------------------------------|
| Chest X-ray | 3.2 | 1.3×10^{-6} | 9 | 23 |
| Skull X-ray | 15 | 6×10^{-6} | 44 | 104 |
| Barium Enema | 54 | 2×10^{-5} | 148 | 357 |
| Bone Scan | 440 | 1.8×10^{-4} | 1300 | 3200 |

Occupational Exposure and Dose Units

A variety of different units are used to quantify occupational exposure. The rad is the unit of absorbed dose. It is a measure of radiation energy absorbed in any type of material: steel, wood, human tissue, etc. The rad is a large unit therefore, the more common unit is the mrad (10^{-3} rad). The rad has a corresponding SI unit, the gray (Gy). The conversion factor is $1 \text{ Gy} = 100 \text{ rads}$.

The rem (Roentgen Equivalent Man) is the unit of dose equivalence. Dose equivalence accounts for the effect on tissue of the various types of radiation. A dose of x-rays, gamma rays or electrons produces a smaller amount of injury than an equal dose of alpha radiation, therefore, the use of a quality factor (QF) accounts for the difference in dose. Table 7 shows various radiation types and their corresponding quality factors. Dose equivalencies are calculated by the formula: Absorbed dose (rad) * QF = Dose Equivalent (rem). An absorbed dose of 30 mrad of gamma radiation is equal to a dose equivalence of 300 mrem, while an absorbed dose of 30 mrad of alpha radiation is equal to a dose equivalence of 6000 mrem. Since most of the radiation used at GVSU produces high energy beta radiation, 1 rad is essentially equal to 1 rem. The corresponding SI unit of dose equivalence is the sievert (Sv). The conversion factor is $1 \text{ Sv} = 100 \text{ rem}$.

Table 7. Quality Factor for Calculating Dose Equivalence

| Radiation Type | QF |
|---------------------------------------|-----|
| Gamma Rays | 1 |
| X-rays | 1 |
| Beta emission and electrons >0.03 MeV | 1 |
| Beta emission and electrons <0.03 MeV | 1.7 |
| Alpha Particle | 20 |

From a radiation protection standpoint, the most important concern is the potential damage from radiation exposure and not necessarily the amount of energy absorbed. For this reason, all personnel monitoring is determined in units of dose equivalence and be reported in mrem.

Personnel Monitoring

In order to measure occupational exposure, it is recommended to utilize different forms of personal monitoring. Monitoring is most often done by using a dosimeter badge which contains either photographic film or a thermoluminescent material sensitive to radiation. Different types of badges are used to detect different levels of radioactivity.

All persons working with radioactivity should be monitored, and the monitoring devices will be provided upon request. Individuals actively using radioactive materials will be issued a dosimeter badge which will be processed by a NAVLAP approved company on a monthly or quarterly basis. The badge monitors exposure to gammas, x-rays and high energy betas but will not detect low energy betas of ^3H and ^{14}C . The RSO will determine the type of badge(s) needed for each individual. The RSO is responsible for issuing and collecting dosimeter badges.

The monitoring device should be worn while in the lab and should not be removed from the laboratory area since the purpose of the monitoring device is to measure exposure to radiation by the user. The device should be stored with the control so as to correctly account for background. Also, great care should be taken with the film badge to ensure that it is not accidentally washed in the washing machine or left on the dashboard of a car. These practices could lead to false readings. The badge should be worn where it will receive the greatest exposure. If work is performed in the hood, the badge should be worn on the chest but if the work is done on a low bench, the badge should be worn at the waist. Ring badges should be worn with the label facing in and on the inside of the glove so as to guard against contaminating the ring.

The second form of personnel monitoring is through bioassay. However, bioassays are not routinely conducted for ³²P, ³³P, and ³⁵S because of the very short half-lives of the isotopes.

Personnel monitoring reports are reviewed monthly and quarterly by the RSO. The RSO will also distribute cumulative exposure histories to all badge recipients yearly. The RSO reviews exposure histories to see if they exceed recommended dose limits recommended by the National Council on Radiation Protection (NCRP) and adopted by the Nuclear Regulatory Commission (NRC) and Agreement States. These limits are shown in Table 8.

These limits should be viewed as maximum limits. Of particular concern is exposure to children, fetuses, and embryos. The sensitivity of cells to radiation damage is related to their reproductive activity and inversely related to their degree of differentiation. It follows that children could be expected to be more radiosensitive than adults, fetuses more radiosensitive than children and embryos even more radiosensitive. For this reason, different limits exist for minors than on adult workers. Specifically, it limits anyone under the age of 18 to exposure not exceeding 10% of the limit for adult workers.

Since studies indicate that the embryo or fetus is more radiosensitive than an adult, particularly during the first three months after conception when a woman may not be aware that she is pregnant, the NCRP recommends that special precautions be taken to limit exposure when an occupationally exposed woman could be pregnant. The NCRP has recommended that during the entire gestation period, the maximum permissible dose equivalent to the fetus from occupational exposure of the expectant mother should not exceed 500 mrem. The level of exposure of laboratory workers rarely approach this limit and in most occupational exposures, the dose to the fetus is less than the dose to the mother.

Table 8. Occupational Limits for Radiation Exposure

| Occupational Dose Limits (mrem/yr) | | Monthly Investigational Limits (mrem) | | Quarterly Investigational Limits (mrem) | | |
|------------------------------------|-------|---------------------------------------|---------|-----------------------------------------|---------|----------|
| Site | | Badge | Level I | Badge | Level I | Level II |
| Whole Body | 5000 | Trunk of Body | 400 | Trunk of Body | 125 | 375 |
| Lens of Eye (1) | 5000 | | | Extremities | 1250 | 3750 |
| Extremities/Skin | 50000 | | | Collar | 400 | 1200 |
| Pregnant, Fetal (mrem/term) | 500 | | | | | |

Monthly Exposure

< Level I - No action

> Level I - RSO notifies employee in writing, discuss preventive measures

Quarterly Exposure

Exposure < Level I - No Action

Exposure between Level I and Level II - Reported to RC&PC

Exposure > Level II - Reported to RC&PC and employee and investigated by RSO

Radiation Protection

A. External Exposure

In addition to properly wearing monitoring devices, it is also the responsibility of the radiation worker to control their external exposure to radiation sources. This can be accomplished by following the three principles of radiation protection: time, distance, and shielding.

By minimizing the amount of time spent around a radiation source, exposures can be minimized. Prior planning is the key to minimizing time spent around radiation. Preplanning the procedure, practicing the technique without the radiation source and preparing the tools, equipment and chemicals prior to working all will markedly reduce exposure time.

Radiation drops off with increased distance. The relationship between radiation and distance is an inverse square relationship. If the distance from a point source of radiation is doubled, the exposure is only 1/4 of that at the original distance. Exposure can be minimized by taking this into consideration when choosing work spaces and how radioactive materials will be handled.

The final principle of radiation protection is shielding. Radiation interacts with the material which it passes through so by properly choosing material placed between the radiation worker and the radiation, the amount of radiation can be reduced. In choosing shielding, one should consider the type of radiation and the energy of the radiation. Lead is a very dense material and provides efficient shielding for X-rays and gamma radiation. High energy beta particles such as those found in ^{32}P should be shielded with a less dense material such as Plexiglas. This is because very dense (high Z) materials such as lead interact with high energy beta particles to produce *Bremsstrahlung* or X-ray radiation due to the absorption of energy by the shielding materials. Plexiglas provides shielding for beta particles without producing *Bremsstrahlung*.

B. Internal Exposure

In addition to shielding to protect from external radiation, it is also important for radiation workers to protect against internal exposure. Internal exposure occurs when radioactive material enters the body by ingestion, inhalation or absorption through the skin. Special precautions can be taken to greatly reduce the possibility of internalizing radioactive material.

To prevent ingestion of radioactive material no eating, drinking, smoking or application of cosmetics is allowed in areas where radioactive materials are used. No food can be stored in refrigerators where radioactive material is also stored. Also, pipetting by mouth is prohibited. Some radioactive material such as unbound ^{125}I , ^{131}I and some ^{35}S compounds are volatile; therefore, to prevent inhalation, these should be used under the hood.

To prevent against absorption of radioactive material, proper use of protective clothing is necessary. Lab coats, disposable gloves and protective eyewear should be worn at all times while working with radioactive material. Protective clothing should be removed and hands should be washed carefully before leaving the laboratory.

Laboratory Surveys and Instrumentation

One of the best methods for protection against internal and external exposure is the lab survey. If performed correctly, the survey can detect areas of contamination which could be sources of exposure. For example, if the phone is accidentally contaminated by someone who answers it wearing contaminated gloves, the lab survey will find the contamination before it becomes a problem. Every time radioactive material is used in the laboratory, it is good practice to survey the area where the material was used as well as survey the person who used it. This is easily accomplished if the radioactive material is a high energy beta emitter such as ^{32}P .

The survey meter that is best known is the Geiger Counter or Geiger-Müller (GM) Survey Meter. It is simple in principle, easy to operate, relatively inexpensive, sensitive, reliable and versatile. It is particularly suited to radiation safety surveys. The GM can detect gamma or X-ray radiation (^{125}I and ^{51}Cr) and high energy betas (^{32}P , ^{90}Sr). The GM will not detect the ^3H betas and a sensitive probe such as the pancake is necessary to detect ^{35}S and ^{14}C .

The GM tube consists of a cylinder with a conductive shell filled with an inert gas at low pressure (1/8 atmosphere). It has a central wire with a positive charge. Anytime an ionization occurs, it initiates a chain reaction in which there is a succession of ionizations that cause the control wire to collect a multitude of electrons. Multiplication of charge produces a signal of around one volt which is used to activate the counting circuit. Detector probes used with survey meters vary with the type of work being done and the isotopes in use. The best probe for radiation safety surveys is the pancake probe. This probe enables one to detect ^{14}C and ^{35}S which is very difficult if not impossible with other probes.

An additional and more sensitive method of surveying is by scintillation counting of wipe samples. Several materials scintillate, that is they produce light when struck by charged particles or gamma radiation. Such light can be detected by a variety of methods, including a photomultiplier tube. Wipe tests involve using a moistened wipe swabbed over a specific area which is then placed in a tube into the scintillation counter. In many cases a liquid scintillation fluid is used. Scintillation counting is more sensitive in detecting radiation than a survey meter.

These surveys do not have to be documented each time it is done. The Radiation Safety Officer will help determine the frequency of these surveys but currently they are required on a quarterly basis with the results submitted to the RSO and a copy placed in the local Radiation Safety Manual. Survey forms are available from the RSO and are included as an appendix to the Radiation Safety Manual included in the local manual. The survey consists of a dose rate survey and a wipe test survey. The record must include the date, area surveyed, equipment used, name and signature of the person conducting the survey, a diagram of the areas surveyed and measurements. Unless the areas where radioactive materials are handled significantly change within the lab, the areas surveyed should remain the same so as to track the effectiveness of the controls used to prevent contamination. Further details on survey procedures are found in the following pages.

Summary

Radiation is a normal part of everyday life and humans are adapted to the naturally occurring background levels of radiation that exist. Within the last century, humans have been able to produce concentrated sources of radioactive materials for a variety of purposes. The use of radiation in science has brought tremendous benefits to society. Proper use of radioactive materials limits the potential risks of using these materials while maximizing the benefits. Understanding the nature of radioactivity, how exposure occurs, the effects of exposure, and how protection can be achieved, is the first step in the safe use of radioactive materials.

Appendix B: Handling Radioactive Incidents

Incidents may occur during the use of radioactive materials, such as spills, accidental releases into the air, contamination of the worker or the work area, and numerous other possible problems. When an incident occurs, the worker must first make a judgment as to whether the incident is a minor incident, major incident or emergency. Subsequent actions are based on this decision.

A minor incident with radioactive materials is an unplanned occurrence involving low amounts of radioactive materials (a few micro curies), where the worker handling the spill knows how to clean it up, has the decontamination materials on hand, and can respond without incurring risk of exposure or spreading within a reasonably short time.

A major incident is an unplanned occurrence involving high amounts of radioactive materials, high risk nuclides, large areas being contaminated, contamination of the skin, airborne radioactivity, or any situation where contamination may have been spread outside the authorized area. Major spills must be reported to the RSO or his/her designee immediately, as required by federal law. Call 911 during working hours; dial 911 during non-working hours.

An *emergency* is an incident which involves serious injury or death, fire, explosion, or significant release of a health or life threatening material, which is or may be coupled with a minor or major radiological incident. DIAL 911 IMMEDIATELY IF AN EMERGENCY HAS OCCURRED!!

In the event of a **MINOR** incident, these procedures should be followed:

1. Notify the principal investigator and persons in the area that an incident has occurred.
2. Contain the spill. Cover with absorbent paper or dike with absorbent.
3. Isolate the area to prevent unnecessary spread and personnel exposures.
4. Survey using the appropriate monitoring equipment in order to evaluate the presence of contamination on an individual's skin and clothing and on lab equipment. If skin or clothing contamination is present, a major spill has occurred. Contact the RSO or local Lab Supervisor immediately.
5. Using disposable gloves, carefully fold up the absorbent paper and pad and deposit in an appropriate radioactive waste container.
6. Survey the area of the spill to determine the extent.
7. Decontaminate the spill using decontaminant detergent, and resurvey.
8. Continue step 7 until the area is decontaminated completely.
9. Document spill in radiation survey log book.

In the event of a **MAJOR** incident, the following procedure should be instituted:

1. Notify all persons in the area that a major spill or incident has occurred and evacuate unnecessary personnel. Notify the principal investigator.

2. If possible, prevent the spreading of the radioactive material by using absorbent paper. Do not attempt to clean it up. Confine all potentially contaminated individuals in order to prevent the further spread of contamination.
3. Leave the affected room and lock the doors in order to prevent entry. Attempt to prevent further contamination or spreading to unrestricted areas. (Hallways, non-radiation laboratories, etc., are unrestricted areas.)
4. Contact the RSO or local Lab Supervisor if the spill occurs during normal work hours. Call the Department of Public Safety, 911, after normal working hours.
5. Remove all contaminated clothing and await instructions concerning cleanup from the RSO.
6. If skin contamination has occurred, measure levels of contamination with a survey meter, record, and begin decontamination by gentle washing with warm water and soap, washing downwards towards extremities, not upwards.

In the event of an **EMERGENCY** in which radioactive materials are involved, the following procedure should be instituted:

1. Notify all persons in the area that an EMERGENCY has occurred and evacuate the area if a risk to persons present exists.
2. Dial 911 and NOTIFY of the nature emergency, using the reporting guidelines previously listed in this section.
3. AWAIT THE EMERGENCY RESPONDERS who will assist and provide direction, as well as contact any other necessary responders.

All incidents involving radioactive materials must be reported as soon as possible to the principal investigator. If the principal investigator is not available, notify the RSO, who will advise and assist with the problem.

Appendix C: Transportation Information

Requirements for the transportation of radioactive material on campus and to other institutions must comply with both the NRC and DOT regulations. Transporting may involve walking or driving radioactive material across campus, or shipping off campus. The RSO must be notified at least 2 weeks before any transfers to insure that proper procedures are followed and movement of radioactive material is tracked. Any transfers of radioactive material (possession transferred from one principal investigator to another) must to be pre-authorized by the RSO.

Package Preparation

All packages used to transport radioactive material must be strong, tight containers that will not leak under normal transportation conditions (such as dropping, jarring or temperature extremes). If liquid is shipped, use at least twice the amount of absorbent needed to contain the entire volume, in case the container should break or leak. If you are not sure whether the container you plan to use is adequate, contact the RSO.

Transportation on Campus

Whenever radioactive material is transported from one building to another, the RSO must be notified of the following information:

- When the material will need to be moved
- The names of the person sending and receiving the material (if different)
- The sending and receiving locations
- The nuclide(s) being moved
- The chemical form of the isotope
- The total activity in mCi
- Number of containers
- Phone numbers of responsible persons
- Any special conditions

Walking to another building

Use an appropriate container and label with a radiation symbol, the isotope, activity in DPM, uCi or mCi and date. Clearly identify the principal investigator and one other contact in case of an accident or loss of the package. The package must be tested for removable contamination before it leaves its place of origin and after it reaches its destination. Contact the RSO if any removable contamination is detected.

Driving to another building

The transportation of radioactive material is regulated by the Nuclear Regulatory Commission (NRC) and the Department of Transportation (DOT). **You must not move any radioactive material on a**

public road without prior authorization by the RSO. The sender's responsibility is to contact the RSO in advance, and properly package the radioactive material.

Prepare to move your material using an appropriate container and labeling. Do not seal the package. The condition of the package must be checked and a leak test performed by the RSO or designated Lab Supervisor. A radiation worker must be present at the receiving location to take possession of the material at the arranged time.

Shipping Radioactive Material

When preparing to ship radioactive material, whether it is radioactive samples or a piece of equipment being returned for repairs, the RSO must be informed in advance. **Do not expect to send shipments out immediately.** Federal regulations must be followed regardless of the quantity being sent.

Shipments can only be made to institutions that are licensed to possess radioactive material. When shipping to another licensee, it is required that prior authorization be obtained from the Radiation Safety Office at that location, preferably the Radiation Safety Officer. License information must be on record or obtained before the shipment can be sent. To initiate this process, the person sending the material must have the following information:

- The name of the person sending the material, facility name and address
- The name of the person receiving the material
- The Radiation Safety Officer's (or other staff member) name and phone number
- The nuclide(s) being sent
- The chemical form of each isotope
- The total activity in mCi for each isotope
- Number of containers in the shipment
- Any special conditions.

Prepare to ship your material using an appropriate container and labels. Do not seal the package, as the condition of the package must be checked and a leak test performed by the RSO or designated Lab Supervisor. Labels will be placed on the package, if required. When the package and paperwork are in order, the package can be transported to the GVSU mail room. Copies of the shipping papers, material return form, and any other paperwork will be made and maintained for review by the RSO. Radioactive material is sent from this university through the GVSU mail room

Appendix D: Radiation Worker Training Checklist

The following is a list of information which should be reviewed by the Principal Investigator with all individuals frequenting any work area where there are radioactive materials.

| | | | |
|----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|--------|
| Trainee Name: | | GVSU email | |
| Authorized User Name | | | Y/N/NA |
| 1. | General Lab Safety Training has been completed. | | |
| 2. | Laboratory Radiation Safety online training and quizzes completed. | | |
| 3. | Radiation Safety Manual and GVSU policies reviewed with RSO. | | |
| 4. | Other required training has been completed (Animal Care, Biosafety, Blood-borne Pathogen, etc.). | | |
| 5. | The exposure limits for radiation have been reviewed with the worker. | | |
| 6. | ALARA and Time, Distance & Shielding procedures have been reviewed. | | |
| 7. | Radiation warning symbols and their meanings have been reviewed. | | |
| 8. | The locations of radioactive materials, hazardous chemicals and biohazardous agents present in the laboratory have been pointed out to the worker. | | |
| 9. | The relative risks of being near to or using the hazardous agents present in the laboratory have been reviewed with the worker. | | |
| 10. | The location and types of wastes, containers, and disposal procedures for the wastes have been identified with the worker. | | |
| 11. | The proper procedures for emergencies which may arise in the laboratory have been reviewed with the worker. This information includes the location of emergency spill kits, emergency response telephone numbers and immediate persons to contact in the laboratory if an emergency arises. | | |
| 12. | Security requirements for radioactive material have been reviewed. | | |
| 13. | The worker can locate: <ul style="list-style-type: none"> - SDS Database & Chemical Hygiene Plan at www.gvsu.edu/labsafety - Radiation Safety Manual at www.gvsu.edu/radsafety - GVUS's NRC Materials License, NRC Notice to Employees, and the Authorized User's approved protocol and records in Blackboard. | | |

I certify that I have been provided with and understand the information indicated above. I understand that this is a certification of principal investigator training and informed consent, and does not constitute a waiver of my rights. I understand that I am responsible for adhering to all safety practices, laws, rules and guidelines.

| | | |
|----------------------------|----------------|------|
| Radiation Worker Signature | Title/Function | Date |
|----------------------------|----------------|------|

I certify that the above information was reviewed with or provided to the above certified worker.

| | |
|---------------------------|------|
| Authorized User Signature | Date |
|---------------------------|------|

INSTRUCTIONS FOR RADIATION SAFETY TRAINING

1. Individuals frequenting an area where radioactive materials are used, stored or disposed should receive Radiation Safety Training. This training may be documented with this checklist.
2. Training is function specific and site specific, meaning the content and depth of training is related to the duties of the person and the scope of the hazards present in the work area.
3. Exposure limits must be explained to workers. For persons who are not identified as radiation workers, the exposure limits are General Public, or 100 mrem per year. For radiation workers, the limits are the occupational limits set forth in the 10 CFR 20 laws, or 5 rem per year (whole body), 50 rem per year to an organ, 15 rem per year to the lens of the eye, 50 rem per year for the skin of the whole body and/or extremities. Radiation workers must have received introductory safety training and must attend annual refreshers for radiation and hazardous waste.
4. Copies of the training records may be kept in the safety notebook.
5. Security and control of radioactive materials must be provided at all times, either with persons present or locking or securing to prevent tampering or unauthorized use or removal. Persons who are not radiation workers may provide this control if they are appropriately trained by the PI and/or the RSO safety training class.

This document serves as informed consent of the worker.

Appendix E: Radiation Safety Inspections

The RSO frequently inspects all areas where radioactive materials are used or stored to ensure that safety requirements are being met, that the posting of signs and the labeling of containers is proper, that exposure levels are not exceeding prescribed limits and that radioactive material is being used in accordance with the license and/or directive of the GVSU Radiation Safety Committee. The radioisotope laboratory will be surveyed by the RSO or local laboratory supervisor on a monthly basis when actively engaged in the use of radioactive material, and wipe tested in places where contamination may be suspected. The completed survey forms shall be maintained in the local radiation safety manual. On a quarterly basis, a copy of the completed survey form will be sent to the RSO who maintains the master radiation safety manual. More frequent wipes and/or surveys will be performed when directed by the GVSU Radiation Safety Committee or the RSO.

Except for hoods, glove boxes and other enclosed areas not susceptible to the transfer or removable activity, the RSO will take action to have laboratory areas decontaminated if a wipe test exceeds the 100 disintegrations per minute beta-gamma or 10dpm alpha per 100 cm² over background.

Any contamination exceeding these limits will be highlighted on the lab map and delivered to the Principal Investigator as soon as practicable. Lab wipes that indicate levels of contamination 10 times the limits stated above are immediately made known to the Principal Investigator and the areas are re-wiped by the RSO within seven working days. The RSO will investigate the situation and make the determinations as to who was at fault, if anyone was contaminated and what further corrective actions should be taken. The RSO will provide technical assistance during any laboratory or personnel decontamination procedure, as necessary.

During laboratory surveys conducted by the RSO, any elevated radiation levels found that are not considered as low as reasonably achievable, will be discussed with laboratory personnel and an attempt will be made to resolve the matter before leaving the laboratory.

Appendix F: Isotope Data

HYDROGEN-3 [³H]

PHYSICAL DATA

- Beta Energy:
18.6 keV (maximum)
5.7 keV (average) (100% abundance)
- Physical Half-Life:
12.3 years
- Biological Half-Life:
10-12 days
- Effective Half-Life:
10-12 days *

*Forcing liquids to tolerance (3-4 liters/day) will reduce the effective half-life of ³H by a factor of 2 or 3. (Relatively easy to flush out of system with fluids.)

- Specific Activity:
9640 Ci/gram
- Maximum Beta Range in Air:
6 mm = 0.6 cm = 1/4"
- Maximum Beta Range in Water:
0.006 mm = 0.0006 cm = 3/10,000"
- Penetrability in Matter or Tissue:
Insignificant*

*[0% of beta particle energy transmitted through dead layer of skin]

RADIOLOGICAL DATA

- Least radiotoxic of all radionuclides.
- Critical Organ: Body Water or Tissue
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption
- External exposure from weak ³H beta energy - not a radiological concern
- Internal exposure & contamination are primary radiological concerns
- Committed Dose Equivalent (CDE):
 - o 64 mrem/mCi (ingested)
 - o 64 mrem/mCi (inhaled)
 - o 64 mrem/mCi (puncture)
- Committed Effective Dose Equivalent:
 - o 90 mrem/mCi (ingested)
 - o 63 mrem/mCi (inhaled)
- Annual Limit on Intake (ALI)*:
 - o 80 mCi (ingestion or inhalation) [³H₂O]
 - o *[1.0 ALI = 80 mCi (³H) = 5,000 mrem CEDE]
- Skin Contamination Exposure Rate:

- 57,900 mrad/hr/mCi (contact)*
 - * Exposure rate to dead layer of skin only.
 - * Skin contamination of 1.0 uCi/cm² = 0 mrad/hr dose rate to basal cells
- Rule of Thumb:
 - 0.001 uCi/ml of ³H in urine sample is indicative of a total integrated whole body dose of approximately 10 mrem (average person) if no treatment is instituted (i.e., flush with fluids); [NCRP-65, 1980]

SHIELDING

- None required

SURVEY INSTRUMENTATION

- CANNOT detect ³H using a G-M or NaI survey meter
- Liquid scintillation counter (indirect) is the only monitoring method

RADIATION MONITORING DOSIMETERS

- Whole Body Badge or Finger Rings: Not Needed (beta energy too low)

RADIOACTIVE WASTE

- Solid, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

- Derived Air Concentration (DAC):
 - 2.0E-5 uCi/cc (occupational)
- Airborne Effluent Release Limit:
 - 1.0E-7 uCi/cc*
 - * [Applicable to the assessment & control of dose to the public (10 CFR 20.1302). If this concentration was inhaled continuously for over one year the resulting TEDE would be 50 mrem.]
- Controlled Area Removable Contamination Limit:
 - 2,200 dpm/100 cm²
- Urinalysis (Byproduct License):
 - required when handling greater than or equal to 100 mCi ³H

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Inherent Volatility (at STP): **Substantial**
- Experimental uses include: total body water measurements & in-vivo labeling of proliferatory cells by injection of tritium-labeled compounds (i.e., thymidine). Tritium labeling is also used in a variety of metabolic studies.
- Oxidation of ³H gas in air is usually slow (< 1% per day)
- Absorption of ³H inhaled in air is much less when it is present as elemental ³H than as tritiated water (HTO).
- Tritium penetrates the skin, lungs, and GI tract either as tritiated water or in the gaseous form.

- As gaseous hydrogen, ^3H entering the lung or GI tract is completely absorbed and rapidly dispersed within the body.
- Some ^3H is incorporated into cellular components and has a long turnover rate.
- Forcing fluids reduces integrated internal exposures from ^3H .
- Monitor for ^3H contamination using only wipe-testing (bench tops, floors, refrigerator/freezer handles, phone, etc.)
- Always wear a lab coat & disposable gloves when handling ^3H .
- Skin contamination, inhalation, ingestion, or absorption through the skin is assumed to be completely and instantaneously absorbed and rapidly mixed with total body water.
- The volume of total body water (standard man) is 42,000 ml.
- The concentration of ^3H in urine assumed to be the same as in total body water.
- Detection limit of ^3H in urine: 1.08E^{-5} uCi/ml (approximately)
- For a continuous inhalation exposure at a rate of 1/365 of an ALI per day, the equilibrium concentration of ^3H in urine is 0.073 uCi/ml. [NOTE : 1/365 of 80 mCi (ALI) = 219 uCi]
- The predicted concentration activity normalized to unit intake from inhalation is 2.204E^{-5} uCi/ml/uCi of ^3H
- Beta dose rates from 1.0 mCi ^3H point source:

| <u>Distance</u> | <u>Rad/hr</u> |
|-----------------|---------------|
| 0.25 cm | 10,293.00 |
| 0.50 cm | 28.12 |
| 0.56 cm | 1.12 |

CARBON-14 [¹⁴C]

PHYSICAL DATA

- Beta Energy:
 - o 156 keV (maximum)
 - o 49 keV (average) (100% abundance)
- Physical Half-Life:
 - o 5730 years
- Biological Half-Life:
 - o 12 days
- Effective Half-Life:
 - o 12 days (Bound)
- Effective Half-Life:
 - o 40 days (Unbound)
- Specific Activity:
 - o 4460 mCi/gram
- Maximum Beta Range in Air:
 - o 24.00 cm = 10 inches
- Maximum Beta Range in Water/Tissue:
 - o *0.28 mm = 0.012 inches
- Maximum Range in Plexiglas/Lucite/Plastic:
 - o 0.25 mm = 0.010 inches

*Fraction of ¹⁴C beta particles transmitted through dead layer of skin: At 0.007 cm depth = 1%

RADIOLOGICAL DATA

- Critical Organ:
 - o Fat Tissue
- Routes of Intake:
 - o Ingestion, Inhalation, Skin Contact
- External exposure
 - o Deep dose from weak ¹⁴C beta particles is not a radiological concern
- Internal exposure & contamination:
 - o primary radiological concerns
- Committed Dose Equivalent (CDE): (Fat Tissue)
 - o 2.08 mrem/uCi (ingested)
 - o 2.07 mrem/uCi (puncture)
 - o 2.09 mrem uCi (inhalation)
- Committed Effective Dose Equivalent (CEDE):
 - o 1.54 mrem/uCi (ingested)
- Annual Limit on Intake (ALI)*:
 - o 2 mCi (ingestion of labeled organic compound)
 - o 2000 mCi (inhalation of carbon monoxide)
 - o 200 mCi (inhalation of carbon dioxide)

*[1.0 ALI = 2 mCi (ingested C-14 organic compound) = 5,000 mrem CEDE]
- Skin Contamination Dose Rate:

- 1090-1180 mrem per 1.0 uCi/cm² (7 mg/cm² depth)
- Dose Rate to Basal Cells from Skin Contamination:
 - 1.0 uCi/cm² = 1400 mrad/hour.
- Immersion in ¹⁴C Contaminated Air = 2.183E⁷ mrem/year per uCi/cm³ at 70 um depth of tissue and 4.07E⁶ mrem/year per uCi/cm³ value averaged over dermis.

SHIELDING

- None required (≤ 3 mm Plexiglas)

SURVEY INSTRUMENTATION

- Can detect ¹⁴C using a thin-window G-M survey meter; survey meter probe must be at close range (1 cm.)
- G-M survey meters have very low counting efficiency for ¹⁴C (5%)
- Liquid scintillation counter (indirect counting) may be used to detect removable ¹⁴C on wipes

RADIATION MONITORING DOSIMETERS

- Not Needed (beta energy too low)
- ¹⁴C Beta Dose Rate:
 - 6.32 rad/hr at 1.0 in air per 1.0 mCi ¹⁴C
- Skin Contamination Dose Rate:
 - 13.33 mrad/hr per uCi on skin
- Dose Rate from a 1 mCi isotropic point source of ¹⁴C:

| <u>Distance</u> | <u>Rad/Hr</u> |
|-----------------|---------------|
| 1.0 cm | 1241.4 |
| 2.0 cm | 250.4 |
| 15.2 cm | 0.126 |
| 20.0 cm | 0.0046 |

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Urinalysis: Not Required; however, prudent after a ¹⁴C radioactive spill or suspected intake.
- Inherent volatility (at STP): Not Significant.
- Possibility of organic ¹⁴C compounds being absorbed through gloves.
- Care should be taken **NOT** to generate ¹⁴CO₂ gas which could be inhaled.
- Internal Dose is the concern: Skin contamination, ingestion, inhalation, and puncture
- Always wear a lab coat and disposable gloves when working with ¹⁴C.
- The concentration of carbon in adipose tissue, including the yellow marrow, is about 3 times the average whole body concentration. No other organ or tissue of the body concentrates stable carbon to any significant extent.
- The fractional absorption of dietary carbon (uptake to blood) is usually in excess of 0.90.

- Three main classes of carbon compounds may be inhaled: organic compounds, gases (CO or CO₂), and aerosols of carbon containing compounds such as carbonates and carbides.

Organic Compounds - most organic compounds are NOT very volatile under normal circumstances; the probability of these being inhaled as vapors is therefore small. In circumstances where such substances are inhaled, it would be prudent to assume that once they enter the respiratory system they are instantaneously and completely translocated to the systemic circulation without changing their chemical form.

Gases - the inhalation of CO and its retention in body tissues has been studied extensively. Since gas has a relatively low solubility in tissue water, doses due to absorbed gas in tissues are insignificant in comparison with doses due to the retention of CO bound to hemoglobin. CO₂ in the blood exists mainly as a bicarbonate.

Carbonates & Carbides - It is assumed that inhaled or ingested ¹⁴C labeled compounds are instantaneously and uniformly distributed throughout all organs & tissues of the body where they are retained with a biological half-life of 12-40 days.

PHOSPHORUS-32 [³²P]

PHYSICAL DATA

- Beta energy:
 - o 1.709 MeV (maximum)
 - o 0.690 MeV (average, 100% abundance)
- Physical half-life:
 - o 14.3 days
- Biological half-life:
 - o 1155 days
- Effective half-life:
 - o 14.1 days (bone) /13.5 days (whole body)
- Specific activity:
 - o 285,000 Ci/gm
- Maximum range in air:
 - o 610 cm = 240 inches = 20 feet
- Maximum range in water/tissue:
 - o 0.76 cm = 1/3 inch
- Maximum range in Plexiglas/Lucite/plastic:
 - o 0.61 cm = 3/8 inch
- Half-Value Layer (HVL):
 - o 2.00 mm (water/tissue)

RADIOLOGICAL DATA

- Critical organ (biological destination) (soluble forms):
 - o Bone
- Critical organs (insoluble forms or non-transportable ³²P compounds):
 - o Lung (inhalation)
 - o G.I. tract/lower large intestine (ingestion)
- Routes of intake:
 - o Ingestion, inhalation, puncture, wound, skin contamination (absorption)
- Committed Dose Equivalent (CDE) (Organ Doses):
 - o 32 mrem/mCi (ingested)
 - o 37 mrem/mCi (puncture)
 - o 96 mrem/mCi (inhaled/Class W/lungs)
 - o 22 mrem/mCi (inhaled/Class D/bone marrow)
- Committed Effective Dose Equivalent (CEDE):
 - o 7.50 mrem/mCi (ingested/WB)
 - o 5.55 mrem/mCi (inhale/Class D)
 - o 13.22 mrem/mCi (inhale/Class W)
- Skin contamination dose rate:
 - o 8700-9170 mrem/mCi/cm² (7 mg/cm² or 0.007 cm depth in tissue)
- Dose rate to basal cells from skin contamination of 1.0 mCi/cm² (localized dose):
 - o 9200 mrad/hr
- Bone receives approximately 20% of the dose ingested or inhaled for soluble ³²P compounds.
- Tissues with rapid cellular turnover rates show higher retention due to concentration of phosphorous in the nucleoproteins.
- ³²P is eliminated from the body primarily via urine.
- Phosphorus metabolism; see ³³P Fact Sheet.

SHIELDING

- $\leq 3/8$ inch thick Plexiglas/acrylic/Lucite/plastic/wood
- Do not use lead foil or sheets! Penetrating Bremsstrahlung x-ray will be produced!
- Use lead sheets or foil to shield Bremsstrahlung x-rays only **after** low density Plexiglas/acrylic/Lucite/wood shielding.

SURVEY INSTRUMENTATION

- GM survey meter and a pancake probe.
- Low-energy NaI probe is used **only to detect Bremsstrahlung x-rays**.
- Liquid scintillation counter (indirect counting) may be used to detect removable surface contamination of ^{32}P on smears or wipes.

DOSE RATES

(from unshielded 1.0 mCi isotropic point source)

| <u>Distance</u> | <u>Rads/hr</u> |
|-----------------|----------------|
| 1.00 cm | 348 |
| 15.24 cm | 1.49 |
| 10.00 ft. | 0.0015 |

- 780,000 mrad/hr at surface of 1.0 mCi ^{32}P in 1 ml liquid.
- 26,000 mrad/hr at mouth of open vial containing 1.0 ml ^{32}P in 1.0 ml liquid.

GENERAL PRECAUTIONS

- Because it is a bone seeker, special precautions must be taken to minimize any chance of introducing into the body.
- Airborne contamination can be generated through drying (dust), rapid boiling, or expelling solutions through syringe needles and pipette tips, due to aerosols.
- Personnel radiation monitors (whole body and finger rings) are **required** when handling greater than 1.0 mCi of ^{32}P at any time.
- Never work directly over an open container; avoid direct eye exposure from penetrating ^{32}P beta particles.
- Always wear a lab coat and disposable gloves when handling ^{32}P .
- Monitor personnel work areas and floors using a GM survey meter equipped with a pancake (beta) probe, for surface contamination.
- Monitor for removable surface contamination by smearing, or wiping where ^{32}P is used.
- Use low-density (low atomic number) shielding material to shield ^{32}P and reduce the generation of Bremsstrahlung x-rays. The following materials are low atomic number materials: Plexiglas, acrylic, Lucite, plastic, wood, or water.
- Do NOT use lead foil, lead sheets, or other high density materials (metals) to shield ^{32}P directly. Materials with atomic number higher than that of aluminum ($Z = 13$) should NOT be used. Penetrating Bremsstrahlung x-rays will be generated in lead and other high density shielding material.
- Safety glasses or goggles are recommended when working with ^{32}P .
- Typical GM survey meter with pancake probe efficiency is greater than or equal to 45%. Typical liquid scintillation counter counting efficiency for ^{32}P (full window/maximum) greater than or equal to 85%.
- Typical detection limit of ^{32}P in urine specimens using a liquid scintillation counter:

- $1.1 \times 10^{-7} \text{uCi/ml}$.

PHOSPHORUS-33 [³³P]

PHYSICAL DATA

- Beta energy:
 - o 0.249 MeV (maximum, 100% abundance)
 - o 0.085 MeV (average)
- Physical half-life:
 - o 25.4 days
- Biological half-life:
 - o 19 days (40% of intake; 30% rapidly eliminated from body, remaining 30% decays)
- Effective half-life:
 - o 24.9 days (bone)
- Specific activity:
 - o 1,000 - 3,000 Ci/millimole
- Maximum beta range in air:
 - o 89 cm = 35 inches = 3 feet
- Maximum range in water/tissue:
 - o 0.11 cm = 0.04 inch
- Maximum range in Plexiglas/Lucite/plastic:
 - o 0.089 cm = 0.035 inch
- Half-Value Layer (HVL):
 - o 0.30 mm (water/tissue)

RADIOLOGICAL DATA

- Critical organ (biological destination) (soluble forms): Bone marrow
- Critical organs (insoluble forms or non-transportable ³³P compounds): Lung (inhalation) and G.I. tract/lower large intestine (ingestion)
- Routes of intake: Ingestion, inhalation, puncture, wound, skin contamination (absorption)
- Internal exposure and contamination are the primary radiological concerns
- Committed Dose Equivalent (CDE): 0.5 mrem/mCi (inhalation)
- Skin contamination dose rate: 2,910 mrem/hr/uCi/cm² (7 mg/cm² or 0.007 cm depth in tissue)
- Fraction of ³³P beta particles transmitted through the dead skin layer is about 14%.
- Tissues with rapid cellular turnover rates show higher retention due to concentration of phosphorus in the nucleoproteins.
- ³³P is eliminated from the body primarily via urine.
- Phosphorus metabolism:
 - o 30% is rapidly eliminated from body
 - o 40% has a 19-day biological half-life
 - o 60% of ³³P (ingested) is excreted from body in first 24 hrs.

SHIELDING

- Not required; however low density material is recommended, e.g., 3/8 inch thick Plexiglas, acrylic, Lucite, plastic or plywood

SURVEY INSTRUMENTATION

- GM survey meter with a pancake probe.
- Liquid scintillation counting of wipes may be used to detect removable surface contamination.

PERSONNEL DOSIMETERS

- Are not required, since they do not detect this low energy nuclide.

GENERAL PRECAUTIONS

- Inherent volatility (STP): Insignificant
- Skin dose and contamination are the primary concerns.
- Drying can form airborne ³³P contamination.
- Monitor work areas for contamination, using smears or wipes to check for removable contamination.

SULFUR-35 [³⁵S]

PHYSICAL DATA

- Beta energy:
 - o 167 keV (maximum)
 - o 53 keV (average) (100% abundance)
- Physical Half Life:
 - o 87.4 days
- Biological Half Life:
 - o 623 days (unbound ³⁵S)
- Effective Half Life:
 - o 44-76 days (unbound ³⁵S)
- Specific Activity:
 - o 42,400 Ci/g
- Maximum Beta Range in Air:
 - o 26.00 cm. = 10.2 in.
- Maximum Beta Range in Water or Tissue:
 - o 0.32 mm. = 0.015 in.
- Maximum Beta Range in Plexiglas or Lucite:
 - o 0.25 mm. = 0.01 in.
- Fraction of ³⁵S betas transmitted through dead layer of skin = 12%

RADIOLOGICAL DATA

- Critical organ: Testis
- Routes of Intake: Ingestion, inhalation, puncture, wound, skin contamination (absorption)
- External exposure (deep dose) from weak ³⁵S beta particles is not a radiological concern.
- Internal exposure and contamination are the primary radiological concerns.
- Committed dose equivalent (CDE):
 - o 10.00 mrem/uCi (ingested)
 - o 0.352 millirem/uCi (puncture)
- Committed Effective Dose Equivalent (CEDE):
 - o 2.6 mrem l/uCi (ingested)*
 - *(Assumes a 90 day biological half-life)
- Annual Limit on Intake (ALI)*:
 - o 10 mCi (ingestion of inorganic ³⁵S compounds)
 - o 6 mCi (Ingestion of elemental ³⁵S)
 - o 8 mCi (ingestion of sulfides or sulfates/LLI)**
 - o 10 mCi (inhalation of ³⁵S vapors)
 - o 20 mCi (inhalation of sulfides or sulfates)
 - o 2 mCi (inhalation of elemental ³⁵S)
 - *1.0 ALI = 10 mCi (inhaled ³⁵S vapors) = 5,000 mrem CEDE
 - **1.0 ALI = 8 mCi (ingestion sulfides/sulfates LLI) = 50,000 mrem CDE
- Skin Contamination Dose Rate:
 - o 1,170 - 1,260 mrem/1.0 uCi/cm² (7.0 mg/cm² depth)
- Beta Dose Rates for ³⁵S:
 - o 14.94 rad/h (contact) in air per 1.0 mCi
 - o 0.20 rad/h (6 inches) in air per 1.0 mCi

SHIELDING

- None required ($\frac{3}{4}$ 3 mm Plexiglas shields; shielding optional)

SURVEY INSTRUMENTATION

- Can detect using a thin window G-M survey meter (pancake), however, probe **MUST** be at close range, recommend 1 cm distance.
- G-M survey meter has low efficiency, usually 4 - 6%.
- Liquid scintillation counter (wipes, smears) may be used for secondary, **but will NOT detect non removable contamination!**

RADIATION MONITORING DEVICES

- (Badges): Not needed: ^{35}S beta energy is too low, and is not an external radiation hazard
- Dose Rate from a 1 millicurie unshielded isotropic point source of ^{35}S :

| <u>Distance</u> | <u>Rad/Hr</u> |
|-----------------|---------------|
| 1.0 cm | 1173.6 |
| 2.5 cm | 93.7 |
| 15.24 cm | 0.2 |
| 20.00 cm | 0.01 |

GENERAL RADIATION SAFETY INFORMATION

- Urinalysis: Not required, but may be requested by Health Physics staff after a spill or personnel contamination involving ^{35}S
- Inherent volatility (STP): **SIGNIFICANT** for ^{35}S methionine and cysteine.
- Radiolysis of ^{35}S amino acids (cysteine and methionine) during storage and use may lead to the release of volatile impurities. Volatile impurities are small ($\frac{3}{4}$ 0.05%)
- Metabolic behavior of organic compounds of sulfur (cysteine and methionine) differs considerably from the metabolic behavior of inorganic compounds.
- Organic compounds of sulfur (cysteine and methionine) become incorporated into various metabolites. Thus, sulfur entering the body as an organic compound is often tenaciously retained.
- The fractional absorption of sulfur from the gastrointestinal tract is typically > 60% for organic compounds of sulfur. Elemental sulfur is less well absorbed from the GI tract than are inorganic compounds of the element (80% for all inorganic compounds and 10% for sulfur in its elemental form). Elemental sulfur is an NRC inhalation Class W (meaning it is retained for weeks in the body).
- Inhalation of the gases SO_2 , COS , H_2S , and CS_2 must be considered. Sulfur entering the lungs in these forms is completely and instantaneously translocated to the transfer compartment; from there, its metabolism is the same as that of sulfur entering the transfer compartment following ingestion or inhalation of any other organic compound of sulfur.
- Contamination of internal surfaces of storage and reaction vessels may occur (rubber stoppers, gaskets or o rings).
- Vials of ^{35}S labeled cysteine and methionine should be opened and used in ventilated enclosures (exhaust hoods).
- The volatile components of ^{35}S labeled amino acids should be opened and used in ventilated enclosures (exhaust hoods).
- The volatile components of ^{35}S labeled cysteine and methionine are presumed to be hydrogen sulfide (H_2S) and methyl mercaptan (CH_3SH), respectively.

- ^{35}S vapors may be released when opening vials containing labeled amino acids, during any incubating of culture or cells containing ^{35}S , and the storage of ^{35}S contaminated wastes.
- Excessive contamination can be found on the inside surfaces and in water reservoirs of incubators used for ^{35}S work. Most notable surface contamination can be found on rubber seals of incubators and centrifuges.
- Radiolytic breakdown may occur during freezing processes, releasing as much as 1.0 μCi of ^{35}S per 8.0 mCi vial of ^{35}S amino acid during the thawing process.
- ^{35}S labeled amino acids work should be conducted in an exhaust hood designated for radiolytic work..
- Vent ^{35}S amino acid stock vials with an open-ended charcoal-filled disposable syringe. Activated charcoal has a high affinity for ^{35}S vapors.

Place an activated carbon or charcoal canister, absorbent sheet, or tray (50-100 grams of granules evenly distributed in a tray or dish) into an incubator to passively absorb ^{35}S vapors. Discard absorbers which exhibit survey meter readings above normal area background levels in the solid radioactive waste

Appendix G: Flow Chart for Procedures for Using Radioactive Materials

| Step | Form | Reference |
|-------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|
| Application Submitted to Radiation Safety Committee | Procedure for Applying for Approval to Use Radioactive Materials (User) | Appendix - Forms |
| ↓ | | |
| Radiation Safety Committee approves application | None; Chair of Committee signs application, minutes of meeting record action | Radiation Manual |
| ↓ | | |
| Training supervised by RSO | None; RSO certifies training on approved application | Radiation Manual |
| ↓ | | |
| Order Placed with RSO | Radioactive materials Order and Receipt Form | Appendix Forms |
| ↓ | | |
| RSO receives material | Radioactive materials Order and Receipt Form | Appendix Forms |
| ↓ | | |
| Approved user maintains use and waste records | Radioactive Material Utilization and Disposal Record (User) Radioactive Materials Survey Log Form (User and RSO) Radioactive Materials Accident/Spill Report Form (User and RSO) | Appendix Forms Appendix Forms Appendix Forms |
| ↓ | | |
| RSO maintains records | Quarterly and Yearly Report Checklist (RSO) Disposal Records | Radiation Manual |
| ↓ | | |
| Radiation Safety Committee and Radiation Safety Officer conduct yearly review | None; Minutes of meeting record actions | Radiation Manual |

Appendix H: Application for the Use of Radioactive Materials

A. Applicant Information ("Authorized User")

| | | | |
|-------------------------------|------------|----------------|---------------|
| Name | Department | G-Number | Date of Birth |
| | | | |
| Office Location | Telephone | E-mail Address | |
| | | | |
| Application Type (check one): | Initial | Renewal | Modification |

B. Radioactive Material Types and Quantities

| Isotope | Max. Quantity On-Hand | Chemical Form | Annual Usage |
|---------|-----------------------|---------------|--------------|
| | | | |
| | | | |
| | | | |

C. Time Period/Radiation Workers

| | | | | | | |
|------------|----------|---------------|---------------|----------------------------|--|--------------------------------------|
| Beginning: | | Ending: | | Additional Staff (yes/no): | | (If yes, complete the section below) |
| Name | G Number | Date of Birth | Email address | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

D. Project Description and Health and Safety Considerations

| |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>On a separate sheet provide the following information about the project with a Curriculum Vita:</p> <ul style="list-style-type: none"> - Description of proposed use and research objectives - Health and safety hazards associated with exposure - Description of procedures to maintain use/storage exposure to radiation ALARA - Personal protection requirements – dosimetry, protective equipment, etc. - Waste streams and disposal procedures - Exposure and spill response procedures - Employee training and hazard communication procedures - General lab rules beyond those in the Chemical, Biosafety, and Radiation Manuals |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

E. Space & Equipment Requirements

| Isotope(s) | Building, Room Number | Monitoring & Safety Equipment (survey meters, probes, scintillation, hoods, etc.) |
|------------|-----------------------|-----------------------------------------------------------------------------------|
| | | |
| | | |
| | | |

Applicant Signature: _____ Date: _____

RSC Approval Date: _____ Approval Expiration Date: _____

Appendix I: Radioactive Material Utilization and Disposal Record

Use this form to track radioactive material inventory. Beginning with the first use of a new shipment, track use, disposal and decay of the material.

Authorized User: _____ Date Received: _____ P.O.: _____
 Isotope & Chemical Form: _____ Amount (μCi): _____ Specific Activity ($\mu\text{Ci}/\mu\text{L}$): _____

| Date | User Name | Amount Used (μL or μCi) | Amount Remaining | Quantity of Waste | | Quantity for Disposal | | | Natural Decay |
|------|-----------|-------------------------------------------------|------------------|-------------------|-------|-----------------------|--------|---------|---------------|
| | | | | Liquid | Solid | Sink | D.I.P. | Offsite | |
| | | | | | | | | | |
| | | | | | | | | | |
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| | | | | | | | | | |

Final Disposal:

| Date | Lab Waste | Licensed Facility | Accumulation time | | Total Activity | Disposed by | Manifest # | Comments |
|------|--------------------------|--------------------------|-------------------|----|----------------|-------------|------------|----------|
| | | | From | To | | | | |
| | <input type="checkbox"/> | <input type="checkbox"/> | | | | | | |
| | <input type="checkbox"/> | <input type="checkbox"/> | | | | | | |

Appendix J: Radioactive Materials Survey Log Form

Periodic monitoring by both Approved Users and the RSO of areas where radioactive materials are used or stored is required by NRC and GVSU's Radiation Safety Manual. This form will be used by Approved Users and the RSO to record the results of contamination surveys. If contamination is detected a Radioactive Materials Accident/Spill Report may have to be filed (see Radiation Manual).

| Date | Time | Person | Location | Survey Method | Activity Detected | Notes |
|------|------|--------|----------|---------------|-------------------|-------|
| | | | | | | |
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Location: Room and area within room (i.e. "Hot sink in PAD 235")
 Survey Method: Geiger Counter, Wipe in Scintillation Counter, etc.
 Activity Detected: Recorded in units (i.e. 300 cpm/min., 4000 cpm, etc.)

Appendix K: Radioactive Materials Order Form

VENDOR INFORMATION

Delivery Date:

| | |
|-----------------|----------------------------------------------------------------------------------------------------------------------|
| Vendor Address: | Shipping Instructions: Normal <input type="checkbox"/> Next Day <input type="checkbox"/> Special Instructions: |
|-----------------|----------------------------------------------------------------------------------------------------------------------|

AUTHORIZED USER INFORMATION

| | | |
|------|---------|----------------------------------|
| Name | Phone # | Delivery Location (bldg. & room) |
|------|---------|----------------------------------|

ISOTOPE ORDER INFORMATION

| | | | | |
|----------------------------|--------|--------------------|--------|-------------|
| Order Date | | Purchase Order # | | Quote # |
| Catalogue# | #Units | Isotope name | Amount | Description |
| | | | | |
| | | | | |
| RSO Approval: _____ | | Date: _____ | | |

 This portion is to be filled out by the RSO or other authorized person to check that the material has arrived in a safe manner.

RECIEPT

| | |
|----------------------------------------|----------------------|
| Date Received: | Inspected by: |
| Condition of Outer Package | |
| Survey Results of Outer Package | |
| Condition of Inner Package | |
| Survey Results of Inner Package | |
| Storage Location | |

(Note: Record survey meters in mrem/hr, wipe tests must be DPM, with results attached. No survey required for DOT Class 7 (radioactive) with "empty" label. Attach shipping documents to this form.)

Comments: _____

Appendix L: Radioactive Materials Accident/Spill Report Form

| | | | | | |
|------|--|------|--|----------|--|
| Date | | Time | | Location | |
|------|--|------|--|----------|--|

| Personnel Present | Personnel Contamination Survey Results |
|-------------------|----------------------------------------|
| | |
| | |
| | |
| | |

Personnel Contamination checked using

Isotope(s) present or suspected in spill.

| | | | | |
|--|-----------------------------------|--|----------------|--|
| | microcuries (μCi) of | | in the form of | |
| | microcuries (μCi) of | | in the form of | |
| | microcuries (μCi) of | | in the form of | |

Give a brief description of the accident and include suggestion for preventing a future recurrence.

On the reverse side diagram the location(s) of the spill, and include the results of an area survey after decontamination for each location.

| | | | |
|-----------------|--|--|--|
| Authorized User | | | |
|-----------------|--|--|--|

Name

Signature

Date

| | | | |
|-----------------|--|--|--|
| Reviewed by RSO | | | |
|-----------------|--|--|--|

Name

Signature

Date

Appendix M: Radioactive Materials Sink Disposal Form

Year: _____
 Institution: _____
 Building: _____
 Lab #: _____
 Sink #: _____

Monthly Sink Disposal Limits (μCi)

| | |
|-------------------------|-------------------------|
| ¹⁴ C: 11,300 | ³² P: 3,400 |
| ³ H: 330,000 | ³³ P: 30,200 |
| ²² Na: 2,200 | ³⁵ S: 37,800 |

*****IMPORTANT!!! PLEASE EXPRESS AMOUNT ONLY IN μCi *****

| |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Discharge Requirements |
| 1. Liquid radioactive waste must be soluble and readily disburseable in water. |
| 2. Identify all other constituents such as flammable solvents, heavy metals or biohazards in the solution that may be restricted from sewer discharge. |
| 3. Sewer disposal concentrations must be within regulatory limits. First, calculate the amount of each isotope that can be discharged, then make sure that the amount does not exceed the university's monthly discharge limit at the top of this form. |
| 4. Discharge the liquid into a designated and labeled sink with water running from the faucet. Survey the sink and surrounding surfaces following disposal. |
| 5. Record the date, isotope, activity, location, and the person discharging waste. |
| 6. Scintillation waste – Most biodegradable scintillation fluids meet the sink disposal criteria. Flammable organic scintillation fluids such as toluene or xylene must be disposed as hazardous waste, regardless of radioactivity. |

| Date (M/D/Y) | Authorized User Name | ³² P | ³⁵ S | ³ H | ¹⁴ C | ³³ P | Other | |
|------------------------|----------------------|-----------------|-----------------|----------------|-----------------|-----------------|---------|----------|
| | | | | | | | Isotope | Activity |
| <i>January 1, 2000</i> | <i>John Doe, PhD</i> | | | <i>20 uci</i> | | | | |
| | | | | | | | | |
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**** PLEASE WRITE LEGIBLY. DISPOSAL RECORDS WILL BE ENTERED INTO DATABASE. ****