RADIATION SAFETY MANUAL

Central Michigan University

TABLE OF CONTENTS

Section 1: Introduction

The purpose of this Radiation Safety Manual is to offer guidance on maintaining a safe and compliant radiation program at Central Michigan University (CMU). This plan has been developed to comply with 10 CFR Parts 19, 20, and 30, and Michigan's Radiation Safety Rules . A copy of applicable standards can be found in Appendix A.

Section 2: The Central Michigan University (CMU) Nuclear Regulatory Commission (NRC) License

Central Michigan University (CMU) operates under the U.S. Nuclear Regulatory Commission (NRC) License Number 21-01432-02. The license confers authority upon the University to approve, manage and control the receipt, use and disposal of radioactive materials.

There is only one license for the entire university, and any individual or action which jeopardizes the license endangers the permission of all researchers to utilize radioactive material at CMU. If, for any reason, the license is suspended or terminated, no individual or principal investigator may use licensed radioactive materials until the license is reinstated. Therefore, this license places significant responsibility on each individual who uses radioactive materials to conform to safe work practices, and to conduct and complete all required compliance duties, however large or small they may be.

Section 3: Duties/Responsibilities of the Radiation Safety Officer (RSO)

The Radiation Safety Officer's (RSO) duties and responsibilities include ensuring radiological safety and compliance with federal and state regulations and the conditions of the license. These duties and responsibilities include the following:

1. Ensure that licensed material possessed by the licensee is limited to the types and quantities of byproduct material listed on the license.
2. Maintain documentation that demonstrates that the dose to individual members of the public does not exceed the limit specified in 10 CFR 20.1301 "Dose Limits for Individual Members of the Public".
3. Ensure security of radioactive material.
4. Posting of documents as required by 10 CFR Parts 19.11 "Posting of Notices to Workers" and 21.6 "Posting Requirements".
5. Ensure that licensed material is transported in accordance with applicable NRC and DOT requirements.
6. Ensure that radiation exposures are As Low As Reasonably Achievable (ALARA).

7. Oversee all activities involving radioactive material, including monitoring and surveys of all areas in which radioactive material is used.
8. Act as liaison with NRC and other regulatory authorities.
9. Provide necessary information on all aspects of radiation protection to personnel at all levels of responsibility, pursuant to 10 CFR Parts 19 “Notices, Instructions and Reports to Workers: Inspection and Investigations” and 20 “Standards for Protection Against Radiation”, and any other applicable regulations.
10. 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.
11. Determine the need for personnel monitoring, distribute and collect personnel radiation monitoring devices, evaluate bioassays, monitor personnel radiation exposure and bioassay records for trends and high exposures, notify individuals and their supervisors of radiation exposures approaching the limits, and recommend appropriate remedial action.
12. Conduct training programs and otherwise instruct personnel in the proper procedures for handling radioactive material prior to use, at periodic intervals (refresher training), and as required by changes in procedures, equipment, regulations, etc.
13. Supervise and coordinate the radioactive waste disposal program, including effluent monitoring and recordkeeping on waste storage and disposal records.
14. Oversee the storage of radioactive material not in current use, including waste.
15. Perform or arrange for leak tests on all sealed sources and calibration of radiation survey instruments.
16. Maintain an inventory of all radioisotopes possessed under the license and limit the quantity to the amounts authorized by the license.
17. Immediately terminate any unsafe condition or activity that is found to be a threat to public health and safety or property.
18. Supervise decontamination and recovery operations.
19. Maintain other records not specifically designated above, for example, records of receipts, transfers, and surveys as required by 10 CFR 30.51 “Records” and 10 CFR 20.2100, Subpart L, “Records.”
20. Hold periodic meetings with, and provide reports to, licensee management.
21. Ensure that all users are properly trained.
22. Perform periodic audits of the radiation safety program to ensure that the licensee is complying with all applicable NRC regulations and the terms and conditions of the license (e.g., leak tests, inventories, use limited to trained, approved users, etc.), the content and implementation of the radiation safety program to achieve occupational doses and doses to members of the public that are ALARA in accordance with 10 CFR 20.1101 “Radiation Protection Programs”, and required records are maintained.
23. Ensure that the results of audits, identification of deficiencies, and recommendations for change are documented (and maintained for at least 3 years)

and provided to management for review; ensure that prompt action is taken to correct deficiencies.

24. Ensure that the audit results and corrective actions are communicated to all personnel who use licensed material.
25. Ensure that all incidents, accidents, and personnel exposure to radiation in excess of ALARA or Part 20 “Standards for Protection Against Radiation” limits are investigated and reported to NRC and other appropriate authorities, if required, within the required time limits.
26. 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.

Section 4: Duties/Responsibilities of the Radiation Safety Committee (RSC)

The Central Michigan University (CMU) Radiation Safety Committee (RSC) is comprised of faculty and staff who have been delegated responsibility for radiological health, safety and compliance at the University. Approval for use of radioactive materials, reviewing policy and campus radiation safety, advising the university administration on radiation safety issues and programs, and auditing the operations and activities of the RSO are some of the functions performed by the RSC.

The RSC, along with all individuals who use radioisotopes, are responsible for safe use of nuclides. RSC member responsibilities include the following:

1. To provide input on radiation safety policy, forms, and procedures.
2. To provide input to and from the various departments.
3. To review protocol forms for the use of radioisotope material on the CMU campus.

Section 5: Approvals for Use of Radioactive Materials

Approval for the use of radioactive materials is given by the RSC and is reviewed periodically. Approval may be obtained by submitting an application describing the requested material and quantity to be used, the location, individuals who will handle the material, the training and experience of the applicant, the training of workers, the protective equipment to be used, monitoring equipment, a brief description of experimental procedures with emphasis on potential safety concerns, and waste disposal information. Applicants must be Authorized Users (see Section 6), have experience in the use of radioactive materials, and must be trained prior to approval. The application will be reviewed by RSC members, wherein approval may be granted.

The RSC may require additional conditions under which the use of the material must be conducted. The approved principal investigator may then order, receive and use the

requested materials, but must do so according to the statements and representations made in the application, and any conditions set forth by the safety committee and all applicable local, state and federal laws, regulations and license conditions. Violations or infractions of these conditions may be cause for suspension or termination of the approval to receive and use radioisotopes.

Applications for new Authorized Users must be approved directly by the RSC, regardless of previous approvals at other institutions.

New applications are required for the use of a new radionuclide, for a change in experimental procedures which have an impact on safety, a change in chemical or physical form of a material previously approved, and for substantial increases in the quantity. Amendments to current approvals are given for slight increases in quantity or moderate changes in chemical form and may be obtained by submitting an application for an amendment stating the desired change and the reason for the change, referencing to the original approved application to be amended. Applications need to be renewed every three years. New applications, amendments, and renewals should be directed to the RSO. Appendix B contains the application form to be submitted.

Section 6: Responsibilities of the Authorized User (AU)

An Authorized User (AU) is a person whose training and experience has been reviewed and approved by the NRC, who is named on the license, and who uses or directly supervises the use of licensed material. The AU is directly responsible for compliance with all regulations governing radiation safety in the laboratory, and for safe practices of individuals working under their supervision. To become an AU, an individual must first contact the RSO. The AU is obligated to:

1. Ensure that individuals working under their control are properly supervised and trained to enable safe working habits and prevent exposures to themselves and others and/or contamination of the work areas or environment.
2. Be aware of the potential radiation hazards inherent in a proposed activity; be responsible for instructing personnel in safe practices or directing personnel to sources of information concerning safe practices.
3. Maintain inventory and knowledge of the various forms (physical and chemical) and quantities of radiation which are present in their work areas.
4. Avoid any unnecessary exposure, either to themselves or to other workers.
5. Understand the risks associated with the possession, use and shipment of all radioactive materials. Federal and state regulations control the use and shipping of radioactive materials and certain other hazardous materials.
6. Keep current records of the receipt and the disposition of radioactive material in their possession including use in research, waste disposal, transfer, storage, etc., if applicable.

7. Maintain constant surveillance and immediate control of radioactive materials to prevent unauthorized removal or tampering, and/or assure that all workers occupying the area maintain security.
8. Post warnings and restrict entry to areas that contain potentially hazardous radioactivity or chemicals. Label radioactive use equipment and work areas.
9. Notify the RSO of any personnel changes, including addition or termination of employees, or changes of areas where radioactive materials may be used or stored.
10. Assure instruction of female radiation workers of the risks associated with working with radioactive materials during pregnancy. (NRC Regulatory Guide 8.13 "Instruction Concerning Prenatal Radiation Exposure").
11. Assure designation of a responsible individual to oversee radioisotope work during short absences, and of a stand-in AU with the required committee approvals during extended absences (greater than 60 days).
12. Ensure that radiation safety surveys and audits in the laboratory are conducted, and maintain records for review, if applicable.
13. Be aware of regulations and requirements pertaining to the use of radioactive materials; maintain compliance and a safe working area.
14. Use radioactive materials according to statements, representations and conditions set forth in the approved protocol application. Changes from the approved protocol must be approved by the RSC in an amendment or new application prior to the implementation of the change.
15. Maintain use logs for radioisotopes, if applicable.

Failure to comply with the rules and regulations set forth above and throughout this manual may lead to disciplinary actions and/or the cessation of radioisotope shipments and experiments. The RSO may terminate any radioisotope use and/or research if deemed necessary. Suspension or termination of approval to use radioactive materials may result from situations jeopardizing health and safety, the environment or the CMU license.

Section 7: Responsibilities of the Worker

Individuals who use radioactive materials assume certain responsibilities in their work. The individual worker is the "first line of defense" in protection of people and the environment against undue risks of radiation exposure and/or contamination. Since the workers, themselves, are the direct handlers of the radioactive material, the final responsibility lies with them for safety and compliance with laws and regulations. For this reason, it is critical that they be aware of the risks, safe practices and requirements for use of radioactive materials.

The term "worker" is used by the university to identify an individual who uses radioactive material in the course of his/her employment or study with the university. Workers may be Authorized Users, graduate students, undergraduate students,

technicians, post-doctorates, visitors, or any other individual who will handle radioactive material. The following items are to be adhered to at all times by radiation workers:

1. Each worker must complete appropriate training for their work area and isotope use.
2. Workers are responsible for adhering to all laws, rules, regulations, license conditions and guidelines pertaining to the use of radioactive materials.
3. Workers must wear their assigned radiation dosimeter during uses of radioactive materials, if applicable.
4. Workers must practice ALARA (As Low As Reasonably Achievable) in their work, and minimize the potential for exposures, contamination or release of radioactive materials.
5. Radiation work areas must be monitored by the user after each use of radioactive material, where applicable. If contamination is found, it must be cleaned up.
6. No changes in experimental procedures using radioactive materials are to occur without the approval of the AU. Do not take short cuts. Changes in experimental procedures impacting upon safety (higher quantities, higher risk, use in animals, etc.) must be approved by the RSC.
7. Any abnormal occurrence must be reported immediately to the AU, such as spills, significant contamination, equipment failure, loss of radiation dosimeters and unplanned release. If the AU cannot be reached, contact the RSO.
8. It is the responsibility of the worker to clean any contamination or spills that occur in their work area. DO NOT LEAVE IT FOR ANOTHER PERSON TO CLEAN UP. The AU and RSO will supervise/assist.
9. Workers are responsible for reporting any loss or contamination of the dosimeter to the RSO.
10. Workers are responsible for informing the RSO of any exposures which have occurred at a previous employer when beginning employment at CMU. They are also responsible for notifying the RSO of termination of employment and returning the radiation dosimeter at the end of their employment.
11. Workers are responsible for maintaining security of radioactive materials.

Section 8: Training

It is mandatory that all workers, including AU's, be trained prior to the use of radioactive materials or x-ray generating devices. The radioisotope use is variable at Central Michigan University. The training program considers teaching and research as separate types of radioisotope use.

The Physics Department uses radioisotopes to teach the various emission characteristics, properties of isotope decay and neutron activation. These laboratories typically use short-lived, low activity radionuclides that are used to show methods of monitoring and measuring radioisotope emission. An instructor will provide the basic principles and practices of radiation protection. The laboratory exercise will be supervised by a qualified faculty member. Students enrolled in courses will be limited to

working with license-exempt quantities in sealed sources, or with minute amounts of short-lived nuclides, under supervision of a faculty member.

Research use of radioisotopes is predominantly with ^{32}P, ^{14}C, ^{3}H, and ^{35}S. All personnel working with radioactive materials will be required to complete radiation safety training.

Individuals who may require awareness-level training include Facilities Management employees, CMU Police, Office of Information Technology employees, and Central Receiving employees, and workers who do not work with radioisotopes but who may need to enter the areas that use radioisotopes.

The RSO will determine the necessary training for the individuals based on their use of radioisotopes, use of x-ray generating devices, and potential for exposure. In some cases, a test may be used to assess the user's knowledge along with a visual assessment of the user's lab technique.

Frequency of Training

Training will be conducted as follows:
1. Before assuming duties with, or in the vicinity of, radioactive materials or x-ray generating devices (for users and awareness-level employees).
2. Whenever there is a significant change in duties, regulations, or the terms of the license (for users and awareness-level employees).
3. Periodic refresher training (for users). An appropriate time interval will be determined based on isotope use and type of x-ray generating device use.

Training Topics

Topics may include all or some of the following depending on the individual's use of radioisotopes and potential for exposure:

A. Radiation safety
    1. Radiation vs. contamination
    2. Internal vs. external exposure
    3. Biological effects of radiation
    4. ALARA concept
    5. Use of time, distance, and shielding to minimize exposure

B. Regulatory requirements
    1. RSO
    2. Material control and accountability

3. Personnel dosimetry
4. Radiation safety program audits
5. Transfer and disposal
6. Record keeping
7. Surveys
8. Postings
9. Labeling of containers
10. Handling and reporting of incidents or events
11. Licensing and inspection by NRC
12. Need for complete and accurate information
13. Employee protection
14. Deliberate misconduct

Additional licensee-specific program elements may need to be covered which may include all or some of the following:

A. Authorized users and supervised users. This includes control procedures for obtaining permission to use radioactive materials at the facility and limitations on quantity to be handled per user and allowed per experiment.
B. Ordering and receiving radioisotopes. This includes instructions concerning transfer of licensed materials between rooms, halls, or corridors, if applicable.
C. Applicable regulations and license conditions.
D. Areas where radioactive material is used or stored. This includes requirements of storage, labeling of containers, and identification of areas where licensed materials are used.
E. Potential hazards associated with radioactive material in each area where the individuals will work.
F. Appropriate radiation safety procedures. This includes reviewing necessary protective clothing and what laboratory apparel to wear and what equipment to use. This includes prohibition of pipetting by mouth, eating, smoking, and drinking in areas where licensed materials are used.
G. Protocol-specific safety measures.
H. Each individual's obligation to report unsafe conditions to the RSO.
I. Appropriate response to spills, emergencies or other unsafe conditions.
J. Worker's right to be informed of occupational radiation exposure and bioassay results, if applicable.
K. Locations where the licensee has posted or made available: notices, copies of pertinent regulations, and copies of pertinent license and license conditions (including applications and applicable correspondence), as required by 10 CFR Part 19 "Notices, Instructions and Reports to Workers: Inspection and Investigations".
L. Emergency procedures
    1. RSO name and telephone number
    2. Immediate steps to prevent or control spread of contamination
    3. Clean-up instructions, decontamination

M. Survey program
    1. Survey instrument accessibility
    2. Who is responsible
    3. Types, contamination and area
    4. Frequency
    5. Levels of contamination
    6. Personnel, hands, shoes
    7. Records
N. Waste
    1. Liquid
    2. Solid
    3. Sanitary sewer
    4. Burial (transfer to low level waste repository)
    5. Storage
    6. Decay-in-storage
    7. Waste storage surveys
    8. Records
O. Dosimetry
    1. Whole body
    2. Extremities
    3. Lost or replacement badges and dose assessment
    4. Bioassay procedures
    5. Records
P. Instrumentation
    1. Survey meters-use, calibration frequency, use of check sources
    2. Analytical instruments-liquid scintillation counters
Q. Procedures for receiving packages containing radioactive materials
    1. Normal
    2. Off-duty
    3. Notification of user and RSO
    4. Security
    5. Exposure levels
    6. Possession limit
    7. Receipt of damaged packages
R. Procedures for opening and examining packages
    1. Leakage and contamination
    2. Monitoring packages
    3. Monitoring packing materials
    4. Gloves
    5. Transferring material to users
S. Sealed sources
    1. Leak test requirements
    2. Inventory requirements
    3. Exempt quantities

4. Records

Training is provided for users of x-ray generating devices specific to the use of the bone densitometer, x-ray diffraction, and portable x-ray fluorescence.

Section 9: Laws and Regulations Concerning Radiation

The U.S. Nuclear Regulatory Commission (NRC) is the branch of the federal government which regulates the licensing, use and disposal of radioactive materials. A multitude of laws set forth by the NRC must be obeyed. The State of Michigan also has laws, guidelines and regulations. City of Mount Pleasant local regulations governing radioactive materials uses also exist, primarily with effluent discharges. Central Michigan University possesses a radioactive materials license which contains further conditions of operation. Appendix A contains the applicable NRC and State of Michigan regulations.

All of the above laws, guidelines and regulations must be obeyed. If any of the regulating agencies or authorities determine that the laws or conditions are not complied with during the periodic inspections which they conduct, violations will be cited, and penalties may be imposed. Penalties may include civil penalties (which may be fines or criminal prosecution in court), sanctions, suspension or termination of the license. For this reason, it is imperative that all Authorized Users, workers and support staff involved in the receipt, use, disposal or records of radioactive materials be aware of and comply with these laws.

The Code of Federal Regulations (CFR), Title 10, Parts 19 "Notices, Instructions and Reports to Workers: Inspection and Investigations" and 20 "Standards for Protection Against Radiation", are legal requirements set forth for all radioactive materials licensees. In particular, Part 20 contains the general practices, requirements and conditions by which all users of radioactive materials must abide.

Section 10: As Low As Reasonably Achievable (ALARA)

ALARA is an acronym meaning **A**s **L**ow **A**s **R**easonably **A**chievable. It is a requirement in the law, meaning all facilities possessing radioactive materials licenses must have a formal ALARA program. It may be defined as a professional standard of excellence, and is practiced by keeping all doses, releases, contamination and other risks as low as reasonably achievable. The regulatory guideline requires managing programs and procedures to achieve ≤ 10% of applicable legal limits, such as air and water release limits, exposure limits or contamination limits for radiation use facilities.

It is not a violation of the law to exceed an ALARA guideline; however, these occurrences alert the radiation safety officer and radioactive materials users to situations which need to be reviewed to determine whether the practices may be modified to better

reflect ALARA management practices. Practical measures to incorporate ALARA into work practices are included in this manual to assist radiation workers. Some simple concepts and easy precautions may prevent contamination, exposures and releases.

Section 11: Occupational Dose

Exposure standards have been established by the NRC and set at a level where apparent injury due to ionizing radiation during a normal lifetime is unlikely. (There are unique standards for minors (< 18 years of age) and pregnant workers. See sections 13 and 14 for more information.) However, personnel should not completely disregard exposures at or below these limits. It is the responsibility of each individual to keep his/her exposure to all radiation as low as is reasonable, and to avoid all exposures to radiation when such exposures are unnecessary.

The exposure limit for whole body exposures is lower than that for a single organ because all organs and tissues are exposed in a whole body exposure, while only a single organ is involved in the single organ exposure limits. The risk to the organ is incorporated in the exposure calculations, which must be done if organs or tissues are exposed. Occupational limits to external radiation for adult and minor radiation workers are given in the table below.

OCCUPATIONAL RADIATION EXPOSURE LIMITS

Part of Body	Adult Yearly (mrem)	Minors Yearly (< 18 yrs. age) (mrem)	Adult ALARA Yearly (mrem)
Whole Body, Head and Trunk, Active Blood Forming Organs **(TEDE)**	5,000	500	500
Lens of Eye **(LDE)**	15,000	1,500	1,500
Extremities **(SDE)** (Elbows, Forearms, Hands, Knees, Lower Legs, Feet)	50,000	5,000	5,000
Single Organ Dose **(TODE)**	50,000	5,000	5,000
Skin of Whole Body **(SDE)**	50,000	5,000	5,000

The following definitions describe the quantities. (Note: the types of doses are quantities; the units used for these quantities are the rem or the Sievert (Sv).)

DE: Dose Equivalent. The product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. The units of dose equivalent are the rem and Sievert.

CDE: Committed Dose Equivalent. Means the dose equivalent to organs or tissues of reference that will be received from an intake of radioactive materials by an individual during the 50 year period following the intake.

EDE: Effective Dose Equivalent. It is the sum of the products of the dose equivalent to the organ or tissue and the weighting factors applicable to each of the body organs or tissues that are irradiated.

CEDE: Committed Effective Dose Equivalent. It is the sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to these organs or tissues.

DDE: Deep Dose Equivalent. Applies to external whole-body exposure. It is the dose equivalent at a tissue depth of 1 centimeter (1000 mg/cm^2).

TODE: Total Organ Dose Equivalent. The sum of the CDE and DDE for the maximally exposed organ.

SDE: Shallow Dose Equivalent. Applies to the external exposure of the skin or an extremity, is taken as the dose equivalent at a tissue depth of 0.007 centimeter (7 mg/cm^2), averaged over an area of 1 square centimeter.

LDE: Lens of Eye Dose Equivalent. Applies to the external exposure of the lens of the eye and is taken as the dose equivalent at tissue depth of 0.3 centimeter (300 mg/cm^2).

TEDE: Total Effective Dose Equivalent. The sum of the deep dose equivalent (for external exposures) and the committed dose equivalent (for internal exposures).

Section 12: Personnel Monitoring

Radiation detection dosimeters (badges) must be worn routinely by personnel when exposure to penetrating radiation is possible. At Central Michigan University, this means that workers handling radiation that is energetic enough to penetrate and cause exposures need to wear a dosimeter. Some dosimeters are exchanged quarterly, and some are exchanged monthly.

The use of individual monitoring devices for external dose is required for:

- Adults who are likely to receive an annual dose in excess of any of the following (each evaluated separately):
  - 5 mSv (0.5 rem) deep-dose equivalent.
  - 15 mSv (1.5 rems) eye dose equivalent.
  - 50 mSv (5 rems) shallow-dose equivalent to the skin.
  - 50 mSv (5 rems) shallow-dose equivalent to any extremity.

- Minors who are likely to receive an annual dose in excess of any of the following (each evaluated separately):

- 0.5 mSv (0.05 rem) deep-dose equivalent.
- 1.5 mSv (0.15 rem) eye dose equivalent.
- 5 mSv (0.5 rem) shallow-dose equivalent to the skin.
- 5 mSv (0.5 rem) shallow-dose equivalent to any extremity.

- Declared pregnant women who are likely to receive an annual dose from occupational exposures in excess of 0.5 mSv (0.05 rem) deep-dose equivalent, although the dose limit applies to the entire gestation period.

- Individuals entering a high or very high radiation area.

According to 10 CFR 20.1502 "Conditions Requiring Individual Monitoring of External and Internal Occupational Dose", if an adult (individual) is likely to receive in 1 year a dose greater than 10% of any applicable limit, monitoring for occupational exposure is required. The RSO will perform an evaluation of the dose the individual is likely to receive prior to allowing the individual to receive the dose. This evaluation need not be made for every individual; evaluations can be made for employees with similar job functions or work areas.

These badges provide legal documentation of external radiation exposure received while working with radioactive materials. Each work area will have a designated area to store badges. The badges are not to leave your immediate work area; they are not to be taken home or to any other location, since non-occupational exposures may occur (e.g., a dentist's office or another laboratory). The exception is for badges worn during approved fieldwork activities using the portable XRF units. Some badges are heat and light sensitive, and if left in a car where the temperature may be high, a false exposure may be recorded. It will then become difficult to distinguish a true radiation dose from a dose caused by exposure to excessive heat or light.

Radiation detection dosimeters are not assigned for work with certain radionuclides, since the energies are beneath the detection limit of the badge. This is not a risk to the worker, however, because these kinds of radiation are not penetrating enough to cause a deep radiation dose. Examples of these radionuclides are ^{3}H, ^{14}C, ^{35}S, ^{45}Ca, ^{33}P and ^{63}Ni.

For those individuals who use X-ray equipment and/or high energy beta or gamma emitters, extremity (ring) badges should be used in conjunction with the whole body dosimeter. It is a legal requirement that workers handling greater than or equal to 1 mCi of ^{32}P must wear extremity badges. The whole body badge should be worn on the torso with the name tag facing the suspected source of radiation. With finger ring badges, the name tag must face the radiation source.

Care should be taken to make sure that badges do not become contaminated with radioactive materials. Lost or misplaced badges should be reported immediately to the RSO in order to receive a replacement. Under no circumstances should workers wear a

dosimeter belonging to another individual. It is a legal requirement that doses be tracked for the worker to whom the dosimeter is assigned.

When terminating employment with the university, badges must be returned to the RSO. If badges are not returned and proper notification of termination of employment/study has not occurred, it is noncompliance with regulatory requirements. A termination report will be supplied when a worker leaves, since the next place of employment must be supplied with this report before the individual will be allowed to work with radioactive materials.

At any time, individuals can contact the RSO for their dosimeter data. It typically takes 4 to 6 weeks to have the badges sent off and processed. The badge vendor will call the RSO to report any doses that are significantly higher than normal (i.e., greater than 200 mrem on a badge), and the worker will be notified. If you suspect that you have received a significant exposure, contact the RSO immediately. Potential exposure will be evaluated, and the badge may be sent immediately for an emergency reading. Another badge will be issued for the interim period. On an emergency basis, results can be obtained within a few days.

To apply for a radiation dosimeter, fill out the form in Appendix B. All new radiation workers (even those working with only tritium) must complete the dosimeter request form to ensure radiation exposure history is reported.

Section 13: Minors Working With Radioactive Materials

Radiation exposure limits exist for minors, (individuals under 18 years of age) who work with radioactive materials. These limits are 10% of all of the occupational limits for adult radiation workers. For these workers, safety training must be completed prior to work with radioactive materials as with other occupational workers. It is university policy that an informed parental consent form must be completed and kept on file for purposes of liability and risk management.

Due to university policy and legal requirements, Authorized Users must notify the RSO before allowing minors to handle radioactive materials. The RSO will assist with documentation.

Section 14: Pregnant Radiation Workers

A special situation arises when a radiation worker becomes pregnant. Under these conditions, radiation exposure could also involve exposure to the embryo or fetus. A number of studies have indicated that the embryo or fetus is more sensitive than the adult, particularly during the first four months of pregnancy. This can be a problem since many workers are unaware of their pregnancy during the first month or two of gestation. Hence, the NRC and the State of Michigan require that all occupationally exposed

workers be instructed concerning the potential health protection problems associated with prenatal radiation exposure.

The maximum permissible exposure for a declared pregnant worker during the gestation period is 500 mrem. There are relatively few research laboratories where radiation levels are high enough that a fetus would receive this dose before birth. If a radiation worker is pregnant, she may notify the RSO and then declare the pregnancy in writing in order for the prenatal exposure limits to take effect. The pregnant radiation worker will then meet with the RSO, and a complete assessment of her radiation exposure potential will be made. The written declaration is made by completing a Declaration of Pregnancy form (found in Appendix B), which is maintained in the records by the RSO.

If notification is not made in writing, the radiation exposure limits remain at the occupational level, that is, 5 rem per year. An individual may "un-declare" her pregnancy at any time, but this also should be documented.

Declared pregnant workers (DPW) will be assigned two badges, one for the whole body, normally worn on the torso and one for the fetus, normally worn on the abdomen. The badges will be exchanged on a monthly basis. Exposures must be maintained beneath a cap of 50 mrem per month in order to prevent exposure spikes.

Section 15: Exposure Limits for the General Public

Visitors to a radiation laboratory who are not classified as radiation workers by their employers, laboratory workers who are not trained in radiation safety, custodial staff, and any other non-radiation workers are all members of the general public under the law. They must not receive a radiation dose in excess of either:

1. Two mrem in any one hour.
2. 100 mrem in any one year.

To assure that no member of the public will have a potential to neither exceed 2 mrem in any one hour nor exceed 100 mrem in any one year, CMU has continuously monitored badges that are processed on a quarterly basis by a NVLAP certified company and wipe tests of the areas to assure no contamination. Since most radiation use facilities frequently have members of the general public visit their work areas, Central Michigan University has elected to maintain unrestricted area contamination limits as part of the ALARA program (see section 35).

Section 16: Area Restrictions

All rooms or areas in which licensed quantities of radioactive materials are used or stored must be posted with a "Caution Radioactive Material" sign, an "NRC Licensing

and Regulation Information Bulletin" sign, and a "Notice To Workers" sign. Door signs must include the Authorized User's name. Postings can be obtained from the RSO.

The following definitions are set forth in the federal law for area restrictions.

DEFINITIONS OF AREA RESTRICTIONS
10 CFR 20.1003 "Definitions"

Unrestricted Area
An area, access to which is neither controlled nor restricted by the licensee.

Restricted Area
An area, access to which is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials. A restricted area does not include areas used as residential quarters, but separate rooms in a residential building may be used as a restricted area.

Controlled Area
An area, outside of a restricted area but inside of the site boundary, access to which can be limited by the licensee for any reason.

Radiation Area
An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 5 mrem in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

High Radiation Area
An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 100 mrem in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

Very High Radiation Area
An area, accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads* in 1 hour at 1 meter from a radiation source or from any surface that the radiation penetrates.

*The exposure rates for Very High Radiation Areas are in rads, rather than rems, because potentially life threatening exposures could result in areas with these fluxes of radiation.

At Central Michigan University, most of the radiation use areas on campus are managed as restricted areas. Most radiation use areas are open to the public, and may have both radiation workers and other individuals present often or all of the time. Members of the public are permitted to be present, as long they are escorted by a trained worker while in the restricted area or have been trained in radiation safety to work

independently. Radiation Awareness training accomplishes training requirements for workers frequenting the laboratory but not handling radioactive materials.

Within the restricted area, it is imperative that strict surveillance be maintained to assure that significant exposure levels are not present, whether in the form of contamination, airborne levels of radiation or external exposure levels. For this reason, unrestricted area limits for contamination, exposures and/or releases are to be adhered to at all times, rather than restricted area limits (see section 35).

Another very important requirement for restricted areas is the security of radioactive materials. It is the responsibility of all workers frequenting a restricted area to maintain security. This is discussed in the section on security of radioactive materials.

Other radiation area restriction categories (radiation area) exist only in a few specific locations, which are typically not accessible to the general public. In the event of emergency or other unusual situations, any of the restricted areas may be restricted to a more secure level to protect against radiation or any other hazard which may be present. If this were to occur, the area(s) would be clearly marked and posted with warning signs or barriers.

Warning signs and labels are available from the RSO. Indiscriminate use of warning signs and/or labeling of non-radioactive materials with "Radioactive" stickers or labels is prohibited.

Section 17: Labeling Requirements

Work areas, trays, racks, stock solutions, tools, equipment, etc., which contain radioactive material or are contaminated must be labeled with radioactive materials tape. The label must contain the radioisotope present, date, and the total activity in disintegrations per minute (DPM) or microcuries. It is not reasonable to expect that each tube or vial be labeled, but the container, tray or rack that holds them must be labeled. (For example, scintillation vials do not need to be individually labeled, but the tray or box that they are stored in must have the above described label). The "rule of thumb" is that if there is radiation above the background in or on something, it must be labeled.

For contaminated equipment which is in frequent use, the isotope, date and maximum activity which may be present at any given time is to be written on the radioactive warning label. For equipment which is used for radioactive materials, but is not contaminated (equipment which the staff wishes to identify for radioactive use), a label with the radioactive materials warning, "Caution, Radioactive Materials", may be used. Labels are not required if the equipment is not contaminated.

All radioactive waste must be similarly labeled with the above described information. Bench top waste containers are to be labeled in the same method as for radioactive

materials in use or storage. As soon as radioactive waste is placed in the radioactive waste container, all information on the waste tag must be filled out.

Work areas must be labeled with the "Caution Radioactive Materials" sign, or marked off with the radioactive warning label tape. If the area is seldom used for radioactive materials, the area may be labeled only for the duration of the use, providing that it is surveyed for contamination and is free of contamination before the labels are removed. If the work area is frequently used, it is best to label the area permanently. For work areas frequently used for radioactive materials work, and which may contain contaminated equipment, the area may be labeled with a maximum reasonable amount of activity, the radioisotope, the date and the "Caution Radioactive Materials" warning.

Each room in which licensed quantities of radioactive materials are used must bear a label on doors to the room. These labels must have the radioactive warning symbol, and the name of the Authorized User and one other person who is knowledgeable about the radioactive materials uses in the room(s). These labels are for emergency response purposes.. These labels must not be disposed in the regular trash unless they are cut up or blacked out.

Section 18: Bioassays

The NRC regulations require CMU to monitor the occupational intakes of workers who are likely to exceed the applicable annual limit on intake or committed effective dose equivalents thresholds specified in the regulation. If a research protocol creates circumstances in which intakes above 10% of the annual limit on intake are likely to occur, then CMU must establish a threshold for monitoring workers for intakes based on the quantity of material handled by a worker in a year. Monitoring will include suitable and timely measurements of concentrations of radioactive materials in air in work areas, or quantities of radionuclides in the body, or quantities of radionuclides excreted from the body, or combinations of these measurements.

Presently, there is no research being done at CMU that requires bioassay.

Section 19: Ordering Radioactive Materials

All orders require prior approval of the RSO before being processed by Purchasing. Protocols must be filed with the RSO before purchase of radioisotopes. Standing purchase orders are available, but the Authorized User must inform the RSO several days prior to the shipping date. All orders come to the RSO or a trained delegate. The Authorized User must inform the RSO when to expect an incoming shipment of radioactive material.

Authorization is based on prior protocol approval by the RSC as described earlier. See Appendix B for a purchase authorization form. Every shipment of radioactive

material received must be tracked in the inventory database and summed with the campus totals. This is to prevent an individual Authorized User or the campus from exceeding individual approval or CMU license possession limits.

Electron capture detectors used in some gas chromatographs contain ^{63}Ni. It is critical that the RSO approves the purchase of these detectors to maintain compliance with the license and regulations, and to make sure the detectors are leak tested every 6 months.

Gifts containing a radioactive source or radioactive material must also be approved by the RSO for the same reasons listed above.

Section 20: Receiving and Monitoring Radioisotope Shipments

The RSO must approve all orders for radioactive material and ensure that the requested material, quantities, manufacturer, and model are authorized by the license and that the possession limits are not exceeded.

Shipments are delivered to Central Receiving, located in the Combined Services Building. Radioactive material is not stored or used at this location. When the shipment arrives, Central Receiving notifies the RSO or a designated, trained radiation worker who picks up the package, transports the package to the radiation safety lab, follows the safe opening procedures and guidelines in Appendix D, and delivers the package to the AU.

Section 21: Transfer of Radioactive Materials

Transfer of radioactive material between investigators of different projects must be approved by the RSO. These transfers must be between “committee approved” Authorized Users, and within the limits of the approved quantities. The transfer should not take place until the authorization to do so has been given by the RSO. All transfers must be done in a way that minimizes the probability of spillage or breakage. Double containers must be used, including suitable shielding, for such transfers.

Licensed material shall not be transferred or shipped from one institution to another without the approval of the RSO.

Section 22: Food and Drink Policy

There shall be no food, drink, smoking or applying cosmetics in the laboratories which have licensable radioactive materials, biohazardous materials or hazardous chemicals present. There shall be no storage, use or disposal of any "consumable" items in laboratories (including refrigerators within laboratories). Rooms which are adjacent, but are separated by floor to ceiling walls, and do not have any chemical, radioactive or

biohazardous agents present, might be used for food consumption or preparation at the discretion of the Office of Laboratory and Field Safety..

It is important to be aware that even the presence of empty food and drink containers in the normal trash may cause a violation, since it is construed as "evidence of consumption" by regulators and the burden of proof to the contrary then lies with the licensee. Please also note that gum and tobacco chewing are prohibited in laboratories.

Floor to ceiling enclosures must separate food areas from hazardous materials areas, due to the potential for release of a hazardous material into the air, and then into a food area when only partial barriers are present.

Section 23: Security of Radioactive Materials

Federal law requires that NRC licensed material must be under the immediate control and constant surveillance of the licensee, or otherwise be locked and secured to prevent tampering or unauthorized removal. The NRC has cited many facilities for violations of this law; therefore, precautions must be taken to prevent this from occurring. This means that radioactive materials in storage or unattended should be kept in locked containers or in areas that are not readily accessible to unauthorized individuals.

When working with radioactive materials, the room must be secured whenever a radiation worker is not present, or the radioactive materials must themselves be secured. Refrigerators and cabinets containing radioactive materials must be locked to prevent access. Any loss of radioactive materials must be reported to the RSO immediately.

The personnel present in the laboratory may provide security for radioactive materials by challenging unauthorized entry into the room.

Section 24: Inventory of Radioactive Materials

The NRC requires that all licensees maintain records tracking the receipt, use and disposal of radioactive materials. This is done with an inventory maintained by the RSO. Use logs are required in laboratories utilizing unsealed isotopes. The log should contain records of amounts used, who used them and dates of use for each shipment received.

Physical inventories are conducted at intervals not to exceed 6 months, to account for all sealed sources and devices received and possessed under the license.

Section 25: Shipment of Radioactive Materials

Shipments of radioactive materials leaving the university must have prior authorization of the RSO's at both the sending and the receiving institutions. Federal and

State law requires that the shipper must obtain the receiver's approval and the respective Nuclear Regulatory License number or the State License number prior to the shipment of the material.

Section 26: Terminating Employment

If an Authorized User terminates employment at Central Michigan University, the RSO shall be notified at least two weeks beforehand. Arrangements must be made to remove or reassign any radioactive materials. Before the termination date, the RSO will conduct a final radiation survey of the radioisotope laboratory in order to determine the presence of unused radioisotopes and/or the presence of contamination.

Records of spills, decontamination efforts, and surveys are to be turned over to the RSO when the AU terminates employment at CMU.

Radiation workers who terminate their education and/or employment at the university shall notify the RSO, and their badges must be returned.

Section 27: Leak Tests of Sealed Sources

Leak tests will be performed at the intervals approved by NRC or an Agreement State and specified in the SSD Registration Certificate. Leak tests will be performed by an organization authorized by NRC or an Agreement State to provide leak testing services to other licensees or using a leak test kit supplied by an organization authorized by NRC or an Agreement State, to provide leak test kits to other licensees and according to the sealed source or plated foil manufacturer's (distributor's) and kit supplier's instructions. As an alternative, we will implement the model leak test program published in Appendix R to NUREG-1556, Vol. 7, "Consolidated Guidance about Materials Licenses: Program-Specific Guidance About Academic, Research and Development, and Other Licensees of Limited Scope" dated December 1999. This program is as follows:

- For each source to be tested, list identifying information such as manufacturer, model number, serial number, radionuclides, and activity.
- If available, use a survey meter to monitor exposure.
- Prepare a separate wipe sample (e.g., cotton swab or filter paper) for each source.
- Number each wipe to correlate with identifying information for each source.
- Wipe the most accessible area (but not directly from the surface of a source) where contamination would accumulate if the sealed source were leaking.
- Select an instrument that is sensitive enough to detect 185 becquerels (0.005 microcurie) of the radionuclides and ensure that its calibration is current.
- Using the selected instrument, count and record background count rate.
- Calculate efficiency.
- Count each wipe sample; determine net count rate.

- For each sample, calculate and record estimated activity in becquerels (or microcuries).
- Sign and date the list of sources, data and calculations. Retain records for 3 years (10 CFR 20.2103(a) "Records of Surveys").
- If the wipe test activity is 185 Bq (0.005 μCi) or greater, notify the RSO, so that the source can be withdrawn from use and disposed of properly.

The sealed and foil source(s) shall be tested for leakage and/or contamination at intervals not to exceed 6 months. Any source received from another person which is not accompanied by a certificate indicating that a test was performed within 6 months before the transfer shall not be put into use until tested.

Notwithstanding the periodic leak test required by this condition, any licensed sealed source is exempt from such leak tests when the source contains 100 microcuries or less of beta and/or gamma emitting material or 10 microcuries or less of alpha emitting material.

Any source in storage and not being used need not be tested. When the source is removed from storage for use or transfer to another person, it shall be tested before use or transfer. No sealed source shall be stored for a period of more than 10 years without being tested for leakage and/or contamination. Sealed sources designed to primarily emit alpha particles shall be tested for leakage and/or contamination at intervals not to exceed 3 months.

The test shall be capable of detecting the presence of 0.005 microcurie of radioactive material on the test sample. If the test reveals the presence of 0.005 microcurie or more of removable contamination, the source shall be removed from service and decontaminated, repaired, or disposed of in accordance with NRC regulations. A report shall be filed within 5 days of the date the leak test result is known with the NRC. The report shall specify the source involved, the test results, and corrective action taken. Records of leak test results shall be kept in units of microcuries and shall be maintained for inspection by the NRC. Records may be disposed of following NRC inspection.

Section 28: Radiation Safety for Machine Produced Radiation

Radiation producing equipment such as X-ray diffraction, X-ray fluorescence, bone densitometers, and electron microscopes are all regulated by the Michigan Occupational Safety and Health Administration (MIOSHA), Radiation Safety Section. Equipment of this type must be registered with the State of Michigan. A copy of this registration must be displayed in the room with the radiation producing equipment. Posted information shall also include a notice of where to locate "Ionizing Radiation Rules" by MIOSHA and form MIOSHA-RSS-100 (Notice to Employees). Posted information can be obtained from the RSO. It is required that all work done with these machines be in accordance with the rules set forth by the State of Michigan.

The principal investigator possessing the machine is responsible for the operational training of workers using radiation producing machines. The RSO provides general radiation safety training. Appendix C includes the "X-Ray Diffraction Users' Guide" and "X-Ray Diffraction Primary Researcher's Approval Form".

Section 29: Authorized User (AU) Absences

Authorized Users (AU) may be occasionally absent from the laboratory for various reasons. During such absences, another individual must be named to assume the responsibility for the correct usage and management of radioactive materials. When the absence is less than 60 days, a responsible graduate student or technician may be appointed to assume responsibility. If the absence is greater than 60 days, an alternate AU with the appropriate radioisotope approvals must be designated and must agree to assume responsibility.

Before departure, the RSO must be notified in writing of the absence duration and the name of the alternate AU who will oversee the uses of radioactive materials during the absence. The stand-in AU must have all the authorizations necessary to oversee the uses of the radioactive materials possessed by the absent AU. The RSO must be notified in advance of the intended absence. During the absence, shipments will still be logged under the absent AU's inventory, but all oversight will be conducted by the stand-in AU.

Section 30: Laboratory Design and Equipment

Working with radioactive materials requires the use of specially designed laboratories and equipment, and may not be conducted in offices or other unapproved locations. Rooms to be used for such work must be approved by the NRC and listed on the CMU NRC license for the use of the types and quantities of radioactive materials to be used.

Smooth, contiguous, non-absorbent surfaces such as stainless steel or linoleum are preferred in a radiation work area. A properly working chemical fume hood with flow rates of 80-120 feet per minute is required if fume hoods will be used for containing radioactive materials. Special filters and/or design are not generally necessary, but may be prudent in special cases. The rooms used must be able to be locked to maintain the security requirements for radioactive materials.

In areas where contamination is likely, surfaces should be covered with absorbent and disposable material, such as poly-backed absorbent lab paper(paper should have the plastic side down, absorbent side up). If you are in the process of designing a radioisotope lab, consult the RSO. The license will need to be amended to allow radioisotope work in additional laboratories not currently listed on the license. Work areas should be localized to minimize the possibility of contamination spread.Surveys must be conducted for all areas where radioactive materials are used, stored or disposed.

Equipment such as glassware, tools, syringes, etc. used in the handling of radioactive materials should not be used for other work or allowed to leave the lab unless it can be shown that the equipment is free from removable contamination. It is strongly recommended that a designated and labeled storage area be used to store this equipment. Fume hoods with flow rates of 80-120 linear feet per minute should be used whenever working with radioactive materials where the potential for vaporization/volatilization exists (as is the case during iodination), or in handling stock solutions of radiotracers, because of the high activity concentration.

Section 31: Clean Laboratory Conditions and Containment

Good housekeeping is an important component of laboratory safety. Sloppy work habits, incorrect procedures or shortcuts, lack of containment, crowded or cluttered work areas and similar situations may cause or contribute to accidents or contamination. The following practices will assist in maintaining effective safety.

1. Maintain neat and clean work areas. Clutter, debris and crowded conditions interfere with the careful handling required in hazardous materials use.

2. Follow experimental procedures carefully. Radioisotope approvals are contingent upon following the procedures, statements and representations made in the Authorized User's approval. Departures from the procedures may place the approval in jeopardy.

3. Use absorbent poly-backed laboratory paper, with the plastic side down, to protect surfaces from inadvertent spills or splashes. Laboratory benches, fume hoods, trays containing samples, waste areas and floors in the radioactive work areas are some of the locations where absorbent paper is useful.

4. Use secondary containment for all radioactive solutions, samples, liquid waste or any other hazardous materials which may be spilled. Use trays, boxes, and other types of secondary containment to catch spills, splashes and possible container ruptures.

5. When transporting radioactive materials, use a cart; this will prevent accidentally dropping or tipping the container.

6. Clean up the work areas and survey for contamination after work is finished. If contamination is present, decontaminate or dispose of the contaminated materials.

7. Use tightly sealed or capped containers when moving, heating, centrifuging or vortexing. Spills, evaporation, gases, container breakage or splashes may occur in any procedure where energy is put into the system.

8. Label all radioactive materials and areas where radioactive materials are used, stored or disposed.

Section 32: Unattended Operations

An experiment is considered to be unattended if there is no one present who is knowledgeable of the operation and of the shutdown procedure to be followed in the event of an emergency.

Experiments that are left unattended must have overriding controls with automatic shutdown devices to prevent system failure that could result in fire or explosion, for example, the loss of cooling water, overheating, flooding, and pressure buildup. Permanent piping, and shields or barriers if necessary, should be provided.

Warning signs must be used if radiation, toxic fumes, or other hazardous conditions are present. Custodians, utility, or security personnel need to be warned of them.

The laboratory entrance door should display an Emergency Notification sign naming the people to contact in case of trouble.

All unattended electrical heating equipment must be provided with fail safe oven temperature shutoff controls, as overheating can result in a fire hazard.

Burners, induction heaters, ovens, and furnaces must be located away from areas where temperature-sensitive and flammable materials are handled.

Fan-cooled heating equipment must be equipped with an interlock arranged to disconnect current to the heating elements when the fan is inoperative.

If your equipment is potentially dangerous and must be left on overnight, consult with your supervisor to see whether it is permissible to do so. Ensure that persons who may have to check the room can re-enter exterior doors.

Post a notice on your equipment describing possible malfunctions, emergency shutoff procedures, and the nature of the hazards.

Bunsen and other gas burners without approved flame-failure devices must not be left on overnight. Gas pressure often fluctuates; an increase in pressure will cause a taller, hotter flame, overheating equipment and perhaps causing a fire. If the pressure decreases the flame may go out. Upon resumption of gas flow unburned gas will accumulate to create a fire or explosion hazard.

Over-temperature cutoff devices should be used on heated oil baths.

Use permanent piping if you must supply water to an overnight experiment. A sudden rise in pressure due to water fluctuations may rupture plastic or rubber experimental apparatus and cause flooding of lower floors. Floor flooding also takes place when water is left running into sinks to maintain a desired level and the drain becomes blocked or plugged. Consideration should be given to the use of standing overflow devices, which make drain plugging less likely.

Electrical extension cords shall never be left plugged in while unattended (they are for temporary use while working with portable equipment in rooms where receptacles are not available).

Protect the cords of electrical devices that must operate unattended. Prevent chemical or physical damage to the cords, by draping cords away from foreseeable hazards and heat sources.

Section 33: Monitoring Instruments

Every laboratory using radioactive materials must possess or have available for immediate use appropriate radiation monitoring equipment. This equipment must be in good working order and must be calibrated yearly. Equipment that has not passed this annual calibration must be removed from service until it is repaired or replaced. If you believe that there is a problem with your equipment, contact the RSO and arrange a time when the equipment can be inspected and calibrated.

Section 34: Calibrations

Radiation detection instruments used for contamination surveys must be operable and capable of detecting the radioisotopes used in the laboratory. Annual calibration of radiation detection instruments is required. Instruments will be calibrated upon request, and must be recalibrated after repair.

Section 35: Radiation Surveys

The frequency of surveys depends on the quantity and use of radioactive materials, as well as the specific protective facilities, equipment, and procedures that are designed to protect the worker and members of the public from external exposure to radiation. While the regulations do not specify a specific survey frequency, CMU is required to ensure that the dose rate limits are not exceeded.

Surveys should be sufficient to identify areas of contamination that might result in doses to workers or to the public. Combined removable and fixed contamination should be surveyed using appropriate radiation detection equipment. Removable contamination

can be detected and measured through a wipe test of the surface, which is counted in an appropriate counting instrument, such as a liquid scintillation counter, a sodium iodide or germanium gamma counter, or a proportional alpha/beta counter.

Contamination surveys should be performed:

- To evaluate radioactive contamination that could be present on surfaces of floors, walls, laboratory furniture, and equipment
- After any spill or contamination event
- When procedures or processes have changed
- To evaluate the potential contamination of users and the immediate work area, at the end of the day or prior to leaving the area of use, when licensed material is used
- In unrestricted areas at frequencies consistent with the types and quantities of materials in use but generally not less frequently than quarterly
- In areas adjacent to restricted areas and in all areas through which licensed materials are transferred and temporarily stored before shipment.

Personnel should survey for contamination in locations where individuals are working with an unsealed form of radioactive material. These surveys should be done at a frequency appropriate to the types and quantities of radioactive materials in use. By doing this, the potential for exposures can be evaluated and reduced, if necessary. Records of these surveys must be maintained for review.

The RSO will make independent surveys of all active radioisotope labs at least annually. Such things as inventory assessment, contamination control, personnel monitoring, training and waste disposal practices will be addressed during these surveys. (See the survey checklist form used by the RSO in Appendix B).

Copies of the results of surveys will be forwarded to the AU, and a recheck may be conducted in the event problems have been detected that need corrective action. The RSC may accompany the RSO on surveys as deemed necessary for problem laboratories or for purposes of auditing the radiation safety program.

When removable radioactivity is found, the area must be decontaminated and then re-surveyed and documented. Detectable levels of removable contamination should be removed, and non-removable contamination should be labeled and shielded whenever possible in order to maintain ALARA limits.

It is understood that certain areas may be routinely contaminated, such as internal parts of equipment and the inside areas of glassware, and that it may not be practical to decontaminate these surfaces. If this occurs, signs must be posted and protective clothing and gloves should be used when in contact with these areas. In some cases, such as ^{32}P contaminated equipment, shielding is required.

Contamination found in unrestricted areas should be immediately decontaminated to background levels. When it is not possible to get to background levels, the AU must ensure that the amounts of contamination on equipment do not exceed the contamination levels listed in the first table below (taken from Appendix M to NUREG-1556, Vol. 7, Rev.1, "Program-Specific Guidance About Academic, Research and Development, and Other Licenses of Limited Scope," dated February 2018). If the contamination is found on building surfaces, the AU must ensure that the amounts of contamination do not exceed the contamination levels listed in the second table below (taken from Appendix M to NUREG-1556, Vol. 7, Rev.1, "Program-Specific Guidance About Academic, Research and Development, and Other Licenses of Limited Scope," dated February 2018). Radioactive contamination found at or above these levels must be decontaminated or shielded and labeled. (Therefore, one of the advantages of using disposable lab paper on the benches is that one only has to dispose of the contaminated area of the paper in the radioactive waste, rather than decontaminating or shielding.)

Acceptable Surface Contamination Levels for Equipment

Nuclide[1]	Average[2, 3, 6]	Maximum[2, 4, 6]	Removable[2, 5, 6]
U-nat, U-235, U-238, and associated decay products	83.3 Bq/100 cm^2 [5,000 dpm/100 cm^2]	250 Bq/100 cm^2 [15,000 dpm /100 cm^2]	16.7 Bq/100 cm^2 [1,000 dpm/100 cm^2]
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	1.7 Bq/100 cm^2 [100 dpm/100 cm^2]	5.0 Bq/100 cm^2 [300 dpm/100 cm^2]	0.3 Bq/100 cm^2 [20 dpm/100 cm^2]
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	16.7 Bq/100 cm^2 [1,000 dpm/100 cm^2]	50.0 Bq/100 cm^2 [3,000 dpm/100 cm^2]	3.3 Bq/100 cm^2 [200 dpm/100 cm^2]
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above.	83.3 Bq/100 cm^2 [5,000 dpm/100 cm^2]	250 Bq/100 cm^2 [15,000 dpm /100 cm^2]	16.7 Bq/100 cm^2 [1,000 dpm/100 cm^2]

[1]Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides should apply independently.
[2]As used in this table, disintegrations per minute (dpm) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.
[3]Measurements of average contaminant should not be averaged over more than 1 square meter. For objects of less surface area, the average should be derived for each such object.
[4]The maximum contamination level applies to an area of not more than 100 square centimeters (cm^2).
[5]The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionally and the entire surface should be wiped.
[6]The average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h at 1 cm and 1.0 mrad/h at 1 cm, respectively, measured through not more than 7 milligrams per square centimeter of total absorber.

Screening Values for Building Surface Contamination

Radionuclide	Symbol	Screening levels for unrestricted release (dpm/100 cm^2)
Hydrogen-3 (Tritium)	H-3	1.2×10^8
Carbon-14	C-14	3.7×10^6
Sodium-22	Na-22	9.5×10^3
Sulfur-35	S-35	1.3×10^7
Chlorine-36	Cl-36	5.0×10^5
Manganese-54	Mn-54	3.2×10^4
Iron-55	Fe-55	4.5×10^6
Cobalt-57	Co-57	2.1×10^5
Cobalt-60	Co-60	7.1×10^3
Nickel-63	Ni-63	1.8×10^6
Zinc-65	Zn-65	4.8×10^4
Strontium-90	Sr-90	8.7×10^3
Technetium-99	Tc-99	1.3×10^6
Iodine-129	I-129	3.5×10^4
Cesium-137	Cs-137	2.8×10^4
Europium-152	Eu-152	1.3×10^4
Tungsten-181	W-181	1.1×10^6
Iridium-192	Ir-192	7.4×10^4

*Screening levels are based on the assumption that the fraction of removable surface contamination is equal to 0.1. For cases when the fraction of removable contamination is undetermined or higher than 0.1, users may assume, for screening purposes, that 100 percent of surface contamination is removable; and therefore the screening levels should be decreased by a factor of 10. Alternatively, users having site-specific data on the fraction of removable contamination (e.g., within 10 percent to 100 percent range) may calculate site-specific screening levels using DandD, Version 1 computer code.

The tables are not inclusive of all radionuclides and specifically do not include values for radionuclides that emit alpha particles. Screening values for radionuclides not listed in the table may be found in "Supplemental Information on the Implementation of the Final Rule on Radiological Criteria for License Termination," in the Federal Register 63FR 64132 (November 18, 1998) (for building surfaces).

Most of the radioisotope use areas on campus are treated as restricted areas and are characterized as locations with controlled access and have proper radiation safety controls in place. Contamination limits for surveys are the controlled and unrestricted area limits, due to the ALARA programs required of licensees.

Section 36: Routes of Exposure to Radiation

Minimizing the amounts of radioactive materials handled in all cases will reduce exposure potential, since exposure is directly related to the amount used and how it is handled.

The three routes of entry into the body for radioactive materials are inhalation, ingestion and skin contact (absorption/injection). The use of syringes increases the

potential for an accidental injection. Precautions should be taken to avoid all means of internal exposure to radiation. If there is any indication of internal exposure, contact the RSO.

External radiation exposure is possible with certain kinds of radiation. Methods of minimizing this potential are time, distance, shielding and minimizing the amount used. Precautionary measures are discussed further in the following sections.

Section 37: Monitoring Operations Involving Radioactive Materials

Due to the potential for contamination of work areas during use of unsealed radioactive materials, it is necessary to monitor as much as possible the operations performed. Work areas should be checked before use to determine background or prior contamination. The survey instrument should be turned on and placed proximal to the work area in order to check radiation levels, and to alarm the worker if radiation levels rise significantly. Hands should be checked frequently for presence of contamination due to splashing or aerosols. At the end of the use of the work area, or each day, work areas should be monitored to determine the presence of contamination. Note that worker clothing and shoes should also be monitored. If contamination is found, the area or equipment must be decontaminated.

Section 38: Time, Distance and Shielding

Radiation dose rate is the radiation dose delivered per unit of time. The unit of radiation dose rate is usually rem/hour, mrem/hour, or µrem/hour. To eliminate or reduce radiation exposure, one must reduce the dose rate or the time spent near a source of radiation. Three primary means of eliminating or reducing radiation exposures exist. They include:

Time: Minimize the time that radioactive materials are handled. Since the amount of exposure occurs as a function of duration of exposure, less time means less exposure. This may be achieved by conducting "dry runs" (practicing the procedures to be performed, with all of the steps and manipulations performed without the hazardous materials). Conduct the work quickly and efficiently, but do not rush.

Distance: Maximize the distance from the radioactive materials. For gamma radiation sources, the dose rate goes down rapidly with distance. Mathematically, $I_2/I_1 = r_1^2/r_2^2$. This is called the inverse square law.

For example, if the dose rate is 100 mrem/hour at 5 cm from a point source, you can calculate the dose rate at 20 cm from the source:

$I_{20cm}/I_{5cm} = (5cm)^2/(20cm)^2$

I_{20cm} = (100 mrem/hr) x $(5cm)^2/(20cm)^2$
I_{20cm} = 6.25 mrem/hr

When working with high energy beta and gamma emitters, remote handling tools can dramatically reduce your hand dose. Do not increase the distance to the point wherein dexterity or control of the materials is jeopardized.

Shielding: If the radiation source is a high energy beta or gamma emitter, shielding will reduce the dose rate. For beta emitters, use a low atomic number material such as plastic, Lucite, Plexiglas, and glass. For gamma emitters, high atomic number materials such as steel or lead are preferred (lead is also a toxic material, so use gloves when handling it, and wash your hands when you finish). Do not use lead with high energy beta radiation (e.g. ^{32}P) because it will cause secondary radiation of a more penetrating X-ray type radiation.

Use shielding wherever it is necessary to reduce or eliminate exposure. By placing an appropriate shield between the radioactive source and the worker, radiation is attenuated and exposure may be completely eliminated or reduced to an acceptable level. The type and amount of shielding needed to achieve a safe working level varies with the type and quantity of radioactive material used. The HVL (half-value layer) may be used as a guide to the thickness of the shielding necessary to block the radiation. The HVL is the thickness of the shielding necessary to reduce the intensity of an X-ray or gamma ray beam to half of the original value. A table of some measured HVL values for various shield materials is shown in the table below.

	HVL (cm)		
	Lead	Iron	Concrete
6 MeV X-rays	1.7	3.0	10.4
Cs-137	0.65	1.6	4.8
Ra-226	1.66	2.2	6.9
Co-60	1.2	2.1	6.2

(Adapted from Figure 8 in "Basic Radiation Protection Technology", 2nd Edition, Daniel Gollnick, Chapter 11.)

Section 39: Protective Equipment

In order to prevent contamination of skin, eyes or personal apparel, protective equipment should be utilized during use of radioactive material. The specific types of protective equipment needed are dictated by the nuclide, level of activity, chemical form and experimental procedures.

Two main categories of protective equipment are personal protective equipment and engineering controls. Personal protective equipment is protective equipment worn by the worker. Examples are gloves, laboratory coats and safety glasses. Engineering controls are external equipment designed to protect the worker or are a part of the design of the work area. Examples are fume hoods, biological safety cabinets, building ventilation systems and shields.

Individuals using radioactive materials must wear laboratory coats, gloves and eye protection. Additional protective equipment may be necessary or prudent. Contact the RSO about protective equipment.

Section 40: Airborne Radioactive Materials

Radioactive materials have the potential for release into the air, causing the worker to have an uptake of the material through one or more of the routes of entry into the body, particularly inhalation. Numerous situations may cause airborne release of radioactive materials.

Contamination present in a room may create airborne radioactivity by simple movement of the air over the contamination, spreading it around in the air. Most radioisotopes will be picked up by air and spread through this mechanism. This is one more good reason to keep areas free of contamination.

Use of volatile forms of radionuclides, such as ^{125}I for iodinations or ^{3}H-sodium borohydride may generate airborne radioactivity. Any chemical or physical form which readily volatilizes or evaporates into the air must be considered a potential airborne radioactivity risk.

Chemical reactions may generate radioactive gases or other airborne contaminants. An example is the labeling reaction for ^{35}S methionine, which generates a methyl mercaptan reaction which liberates HCl and $^{35}SO_2$ gas. Airborne radioactivity has resulted in unnecessary intakes and area contamination in laboratories where the users were unaware of this risk and did not taken precautions to trap or contain the liberated $^{35}SO_2$.

Heating or incubating may cause evaporation or chemical reactions which release radioactive materials into the air. Aerosols (tiny droplets or particles) are present with all materials and pose an increased risk when handling stock solutions or other high concentrations of radionuclides. Use chemical fume hoods or biological safety cabinets for high activity, concentrated or potentially volatile radioactive materials manipulations.

Materials which have been frozen may release substantial quantities of aerosols or gaseous radioactive material when the containers are opened. There have been numerous incidents at other institutions where this has occurred and has caused significant contamination of work areas, equipment and clothing of the worker opening the containers.

Another cause of airborne radioactivity is media or solutions containing cells, bacteria or other living organisms. The living organisms metabolize the radioactive substrates and may produce radioactive gases or vapors as a byproduct.

When hazardous chemical forms of the radionuclides are used, such as radiolabeled carcinogens or toxins, increased risks are presented by the vapors, aerosols or gases present or generated in the use. In this case, the hazard present is not only radioactive but may also pose airborne chemical risks.

To prevent uptake in these increased risk situations, fume hoods, biological safety cabinets or other containment must be used to protect the worker from uptake and internal deposition. Do not use clean benches (tissue culture hoods) for use of radioactive materials, or any other hazardous material. While the product is kept sterile by these hoods, the hazardous material present in the materials used are blown into the face of the worker, and into the room. Therefore, there is no protection for the worker.

In certain rare cases, respiratory protection may be necessary for certain radioisotope uses. However, respiratory protection should only be used when other means of control and containment do not provide enough protection. Respirators must be chosen carefully to ensure the proper fit and type of cartridge, and the use must be monitored carefully. For this reason, use of respirators for radioactive materials use must be pre-approved by the RSO, documented and monitored. Prior to using respirators for any reason, fit testing and medical approval are required.

If there is any indication that an intake has occurred, contact the RSO. Bioassays or other investigational methods may be employed to determine whether an intake has occurred and to recommend ways to avoid such undesirable situations in the future.

Section 41: Disposal of Radioactive Waste

At CMU all disposal of radioactive waste must be authorized by the RSO. All radioactive waste shall be separated from non-radioactive waste. All radioactive waste must be collected for proper disposal. Contact the RSO for radioactive waste pickup arrangements.

The issue of radioactive waste disposal is very complex, due not only to the radioactive nature of the waste and its inherent disposal problems, but also the recent

concerns with the chemical hazards associated with the same waste. Hence, it is possible to have mixed waste, which contains not only radioactive waste, but RCRA (Resource Conservation and Recovery Act) hazardous chemical waste. Some liquid scintillation fluids are an example, because they contain toluene or benzene, which is hazardous under the RCRA laws, due to flammability and toxicity. Consequently, radioactive waste must be properly manifested for the isotope and activity, and any other hazardous constituents, including chemical or biohazardous components. Consult with the RSO when planning your research. It may not be economically reasonable to do certain experiments due to the associated waste disposal costs.

Radioactive waste must always be labeled, from the time it is deposited into a container until final disposal. Records of radioactive waste disposal must be maintained by the University for NRC review, so this labeling is critical. Tags must be completely filled out at all times after any radioactive waste is placed in the container. (Note: The radiation warning label and certain other information on the tag must be present according to NRC regulation.) Bench top waste containers are considered part of the experiment, and must be labeled with the isotope, activity in DPM or μCi, and the date. It is not necessary to attach a waste tag until the waste is placed in the permanent waste container. The waste container must be labeled with the radiation symbol, the isotope, activity, date, inventory #, Authorized User, and building/room #.

It is the responsibility of the laboratory to supply primary and secondary containers to prevent the waste from leaking or contaminating surfaces. All radioactive waste must be stored in appropriate containers until its disposal, and the integrity of the waste containers must be assured. All radioactive waste must be secured against unauthorized access or removal. Laboratories must supply their own shielding for waste that may cause external exposures to workers in the area.

In order to dispose of waste under the current regulatory constraints, it is necessary to segregate all radioisotopes from each other (except ^{3}H and ^{14}C), and to segregate chemically hazardous waste from other radioactive waste. It is prudent that workers only place waste which is actually contaminated with radiation in the radioactive waste containers to control waste disposal cost.

No radioactive waste may be removed from the laboratory without the complete information on the tag. Chronic failure to thoroughly manifest radioactive waste may result in suspension of permission to use radioactive materials.

CMU currently manages radioactive waste by one or more of the following methods as directed by the RSO:

1. Decay-in-storage (DIS)
2. Release into sanitary sewerage

3. Transfer to an authorized recipient

1. Procedure for disposal by Decay-In-Storage (DIS):

- Only short-lived waste (physical half-life of less than 120 days) may be disposed of by DIS.
- Short-lived waste should be segregated from long-lived waste (half-life greater than or equal to 120 days) at the source.
- Waste should be stored in suitable well-marked containers, and the containers should provide adequate shielding.
- Liquid and solid wastes must be stored separately.
- When the container is full, it should be sealed. The sealed container should be identified with a label affixed or attached to it.
- Contact the RSO for waste pickup.
- The contents of the container should be allowed to decay for at least 10 half-lives of the longest-lived radioisotope in the container.
- Prior to disposal as ordinary trash, each container should be monitored as follows:

    - Check the radiation detection survey meter for proper operation.
    - Survey the contents of each container in a low background area.
    - Remove any shielding from around the container.
    - Monitor all surfaces of the container.
    - Discard the contents as ordinary trash only if the surveys of the contents indicate no residual radioactivity, i.e. surface readings are indistinguishable from background.
    - All radioactivity labels must be defaced or removed from containers and packages prior to disposal in ordinary (non-radioactive) waste. If waste is compacted, all labels that are visible in the compacted mass must be defaced or removed.
    - If the surveys indicate residual radioactivity, return the container to the DIS area.
    - If the surveys indicate no residual radioactivity, record the date when the container was sealed, the disposal date, type of waste (used or unused material, gloves, etc.), survey instrument used, and the name/signature of the individual performing surveys and disposing of the waste.

2. Procedure for disposal of liquids into sanitary sewerage:

- Confirm that the liquid waste being discharged is soluble or biological material that is readily dispersible in water.
- Calculate the amount of each radioisotope that can be discharged by using the information from prior, similar discharges and the information in 10 CFR 20, Appendix B “Annual Limits on Intake (ALIs) and Derived Air Concentrations

(DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage".

- Make sure that the amount of each radioisotope does not exceed the monthly and annual discharge limits specified in 10 CFR 20.2003(a)(4) "Disposal By Release Into Sanitary Sewerage" and 10 CFR 20, Appendix B "Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage".
- Record the date, radioisotope(s), estimated activity of each radioisotope, location where the material is discharged, and the name/signature of the individual discharging the waste.
- Liquid waste should be discharged only via designated sinks, toilets or release points.
- Discharge liquid waste slowly with water running from the faucet to dilute it.
- Survey the sink and surrounding work surfaces to confirm that no residual material or contamination remained in the sink or on work surfaces.
- Prior to leaving the area, decontaminate all areas or surfaces, if found to be contaminated.
- Maintain records of each radioisotope and its quantity and concentration that is released into the sanitary sewer system.

3. Procedure for disposal by transfer to an authorized recipient:

- The RSO is responsible for finding an appropriate company for waste disposal and will coordinate radioactive waste pickups for off site disposal

Section 42: Quantifying Levels of Radioactivity in Waste

Radioactive and other hazardous materials must be completely manifested in the waste. In order to accurately list levels of radioactivity on the tags, it is necessary to assess the levels which are disposed in both liquid and solid waste. Suggestions on methods to quantify the waste follow.

1. During a given experiment it is known that a certain quantity of radionuclide is used. At the end of each of several similar experiments, take a sample of liquid waste and count it with the appropriate counting equipment. The activity in the sample per unit volume is then multiplied by the total volume of the liquid waste generated. For the solid waste, the quantity of radioactivity in the liquid is subtracted from the total quantity used in the experiment, and the remainder is then the quantity in the solid waste.

Example:

Total Used in Experiment (corrected for age): 500 µCi
Liquid Sample Volume: 1 ml
Total Liquid Waste Volume: 4000 ml
Activity in Liquid Waste Sample: 8 E-2 µCi/ml
Liquid Waste Total Activity: 8 E-2 µCi/ml X 4000 ml. = 320 µCi in liquid waste
Solid Waste Total Activity: 500 µCi - 320 µCi = 180 µCi in solid waste

2. After the first few experiments, or when the waste carboy is full, take a sample of the pooled liquid waste, and count it as above. Multiply the activity of the sample per unit volume by the total volume in the carboy to obtain the total activity in the carboy. Quantify the solid waste as above by subtracting the liquid waste activity.

Section 43: General Rules for Radiation Safety

1. Follow the chemical safety requirements outlined in the chemical hygiene plan.

2. Do not eat, drink or smoke in radiation use, storage or disposal areas. "Eating" includes gum, candy, beverages and chewing tobacco. Do not apply cosmetics in the laboratory. Do not consume medication in radioisotope laboratories. Do not dispose of food, empty food wrappers or containers anywhere in the laboratories.

3. Laboratories must not be used for food storage, particularly refrigerators.

4. Gloves should be worn during operations in which contamination of the hands is possible.

5. Never pipette liquids by mouth.

6. Store and transport radioactive materials in containers which will prevent breakage and spillage. Secondary containment is important; when transporting radioactive materials, use trays and carts and provide 360 degree protection of the radioactive material. Secondary containment must be leak proof.

7. Use ventilation hoods or glove boxes if the radioactivity may become airborne and for high activity uses, such as stock solutions.

8. The individual(s) responsible for any contamination will be required to decontaminate the area of concern.

9. Regularly check your hands, clothing and shoes for contamination prior to leaving the work area after working with radioactive material.

10. Always dispose of radioactive waste in a radioactive waste container.

11. Always wear your assigned radiation detection badge(s) when working with radioactive materials.

12. Wear laboratory coats and eye protection when working with radioactive materials. Lab coats should be buttoned up, not worn open.

13. Users of high energy beta or gamma nuclides shall wear eye protection, such as safety glasses.

14. Secure all licensed material when it is not under the constant surveillance and immediate control of the user(s).

Section 44: Radiation Incidents/Emergencies

The following are the necessary reporting information to evaluate and respond properly to an abnormal occurrence involving radioactive materials:

- Radionuclide involved
- Amount of radioactivity
- Chemical form of released material, other hazardous chemicals involved
- Volume of released material
- Location of incident (building and room number)
- Persons contaminated or exposed, estimate of amount (e.g., 2,000 CPM, ^{32}P, 10 cm^2 on skin of arm)
- Any injuries, what they are, how serious
- Airborne radioactivity present or not
- What you have done so far
- Authorized User name
- Name of person reporting
- Telephone number where you can be reached

Name and telephone number of RSO should be posted conspicuously in areas of use, so that it is readily available to workers in case of emergencies. Labs should have emergency equipment readily available for handling spills. Spill kits may include some or all the following depending on lab operations and exposure potential:

- ✓ Disposable gloves
- ✓ Disposable lab coats
- ✓ Disposable head coverings
- ✓ Disposable shoe covers

- ✓ Roll of absorbent paper with plastic backing
- ✓ Masking tape
- ✓ Plastic trash bags with twist ties
- ✓ "Radioactive Material" labeling tape
- ✓ Marking pen
- ✓ "Radioactive Material" labels
- ✓ Box of wipes
- ✓ Instructions for "Emergency Procedures"
- ✓ Clipboard with a copy of the Radioactive Spill Report Form for the lab (see Appendix B)
- ✓ Pencil, pen, permanent marker
- ✓ Appropriate survey instruments including batteries (for survey meters)
- ✓ Radiation disposal bags
- ✓ Barricade tape
- ✓ Rad-Con spray decontaminant/surface cleaner

Some radiological incidents involve serious risk to life, health or property. In the event of serious injury coupled with exposure to radiation, fire, explosion, major release of health threatening materials or serious radiation exposure, an ambulance may be dispatched, and victims will be transported to a hospital for treatment. Be sure to inform CMU Police that radiological contamination is present so the emergency response personnel can take appropriate protective and decontamination measures.

Section 45: Handling Radioactive Incidents/Emergencies

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 abnormal occurrence involving low amounts of radioactive materials, 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 exposures or spreading within a reasonably short time. Notify the RSO promptly for assistance.

A major incident is an abnormal occurrence involving high amounts of radioactive materials, high-risk nuclides, large areas 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 the RSO during working hours; dial 911 during non-working hours.

An emergency is an incident that 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. CALL 911 IMMEDIATELY IF AN EMERGENCY HAS OCCURRED!!

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

1. Notify the Authorized User and people in the area that an incident has occurred.
2. Contain the spill. Cover with absorbent paper or dike with absorbent. Paper should be dampened if solids are spilled.
3. Isolate the area to prevent personnel exposures and the spread of radioactive material.
4. Survey using the appropriate monitoring equipment 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 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 area using decontaminant detergent (available from RSO), and resurvey.
8. Continue step 7 until the area is decontaminated completely.
9. Document spill in radiation survey logbook.
10. Notify the RSO promptly.
11. Allow no one to return to work in the area unless approved by the RSO.

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

1. Notify all people in the area that a major spill or incident has occurred and evacuate unnecessary personnel. Notify the Authorized User.
2. If possible, prevent the spreading of radioactive material by using absorbent paper. Paper should be dampened if solids are spilled. Do not attempt to clean it up. Confine all potentially contaminated individuals to prevent the further spread of contamination.
3. If possible, shield the source, but only if it can be done without significantly increasing your radiation exposure.
4. Leave the affected room and lock the doors to prevent entry. Post the room with a sign to warn anyone trying to enter that a spill of radioactive material has occurred. Attempt to prevent further contamination or spreading to unrestricted areas. (Hallways, non-radiation laboratories, etc., are unrestricted areas.)

5. Contact the RSO if the spill occurs during normal work hours. Call 911 outside of work hours.
6. Remove all contaminated clothing and await instructions concerning cleanup from the RSO.
7. 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.
8. Allow no one to return to work in the area unless approved by the RSO.

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

1. Notify all people 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 of emergency, using the reporting guidelines previously listed in this section.
3. AWAIT THE EMERGENCY RESPONDERS who will assist and provide directions, as well as contact any other necessary responders.
4. Allow no one to return to work in the area unless approved by the RSO.

All incidents involving radioactive materials must be reported as soon as possible to the Authorized User.

Section 46: Decontamination

When radioactive material is in an unwanted or unplanned location, it is called contamination. This may be floors, equipment, work areas, storage areas, people or areas outside the authorized radiation use laboratory. Fortunately, most radioactive contamination and/or spills are easy to clean to background levels in a reasonable time and with reasonable cost. Contact the RSO for assistance with all decontamination procedures. ***NOTE: The decontamination procedures will depend on the isotope, the quantity, and its use. In some situations, the water and detergent from decontaminating skin and work areas can be flushed to the sanitary sewer. In other situations, it may need to be collected. This will be addressed during training and preparing labs for isotope use to fit the needs of each radioisotope lab.*** Some methods of decontamination are as follows:

Liquid Radioactive Decontaminant: Concentrated liquid decontaminating agents are available from most scientific suppliers. This detergent is diluted with water and rapidly and easily cleans radioactive contamination without excessive effort. Mild wiping or scrubbing will remove most contamination using this detergent. The detergent Safety Data Sheet should be read by new radiation users so that they are aware of the hazards.

In dilute liquid form, radioactive decontaminants do not present a significant hazard to handlers unless ingested or splashed in eyes. Avoid prolonged skin contact with the concentrated material.

Foam Spray Decontaminant: A variety of foam spray decontamination products are available which are marketed as radioactive decontaminants. However, many other foam cleaning products accomplish decontamination just as effectively at a much lower cost; most of these are marketed in any store as bathroom or kitchen cleaning agents. Spray the foam on the contaminated areas, let sit for a few minutes, then wipe off with a dry paper towel.

Other Decontaminating Agents: Many other agents will work to clean radioactive contamination that has been resistant to the above methods. Contact the RSO for assistance with difficult to remove contamination. He/she will help identify a method of decontamination which will work for your particular surface, nuclide, chemical form and location. Depending on these factors, effective solutions to the problem will be identified.

Contamination on Skin: Use lukewarm (not hot or cold) water and a mild cleaning agent, such as soap. Do not rub hard or scrub with abrasives, which may break the surface of the skin. Clean the affected area in a downwards fashion, with the grain of the skin and hair, not against it, and towards the tips of extremities, not upwards. Check the area after gentle drying. If still contaminated, use a cream hand cleaner which contains no abrasives. Remember to notify the RSO immediately if personnel contamination occurs or is suspected. Also, note the readings of radioactive contamination detected with the survey instrument and the times that it was discovered and then removed.