RADIATION SAFETY MANUAL

Montclair State University
Montclair, New Jersey

MONTCLAIR STATE UNIVERSITY

RADIATION SAFETY MANUAL

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FOREWORD

Safety programs, including the radiation safety program at Montclair State University (MSU), are based upon the premise that exposure to hazardous materials must be minimized in all research activities. The lowest level of exposure is achieved through the constant application of good radiation protection planning and practices, and a commitment to policies that foster safe and conscientious use of radioactive materials for the protection of our faculty, students and the environment.

MSU shares the philosophy of the Nuclear Regulatory Commission (NRC), to maintain occupational radiation exposures As Low As is Reasonably Achievable (ALARA). It is the policy of MSU to go beyond regulatory compliance and avoid all unnecessary exposure to radiation. MSU endorses the principle that actual operational dose limits for any radiological activity be more restrictive than the maximum recommended dose limit.

The majority of our research uses only small amounts of radioactive material. It is the policy of MSU that research personnel continually review their procedures to ensure that the smallest amount of radioactive material is used and non-radioactive methodology is used wherever feasible.

The protection of faculty, students, and the environment is to be integrated into ongoing research practices. ALARA implementation will be reviewed during new employee orientation and in various training programs.

Ms. Amy Ferdinand has been appointed as the Radiation Safety Officer (RSO) for MSU. Ms. Ferdinand is responsible for managing the Radiation Safety Program, ensuring compliance with license conditions and with NRC regulations regarding radiation safety. She is also responsible for surveillance of overall activities involving radioactivity and has the authority to terminate any activity judged to be a threat to health, safety, the environment or in violation of license requirements. The RSO is prepared to discuss any questions or concerns involving the use of radioactive material, and welcomes any suggestions on radiation protection.

We are dedicated to providing a safe working environment, and compliance with this policy is important to achieving that objective.

R. Lynde
Provost & VPAA

A. INTRODUCTION

This Radiation Safety Manual has been developed by Montclair State University (MSU) to inform faculty and students of safe practices and procedures in the handling of radioactive materials. It is the policy of MSU to provide a safe and healthy work environment, to prevent significant adverse impact on the public and the environment, and to meet its legal, ethical and regulatory obligations while carrying out its research and development work.

Radioactivity is one of the most versatile and valuable tools of modern biomedical research. Isotopes such as carbon-14, hydrogen-3, sulfur-35, and phosphorus-32 provide the means to probe and understand metabolic pathways and biotransformation processes. The high specific activities attainable with hydrogen-3, sulfur-35 and iodine-125 allow for the location and identification of biological receptors. The list of practical and beneficial procedures that result from the use of radioactive materials is almost endless. Since radioactivity is a tool, it is no different from any other tool, and requires that it be used carefully with certain precautions and safety considerations.

The Nuclear Regulatory Commission (NRC) strictly regulates the possession and use of radioactive materials at MSU. NRC requirements are codified in the Code of Federal Regulations, Title 10 (10 CFR).

Based upon these regulations, MSU has established procedures for the safe handling of radioactive materials. These procedures will continue to be modified to ensure that exposure is minimized (ALARA) and that these exposures continue to be far below established limits. MSU welcomes input from faculty and students about the radiation protection program.

Faculty and students have a critical role in ensuring that radioactive materials continue to be handled safely. It is the responsibility of each radioactive material user to know and strictly follow all appropriate procedures for the safe handling of radioactive materials.

The information in this manual, along with various training programs and the assistance of the Radiation Safety Officer (RSO) are provided to help faculty and students fulfill this responsibility.

B. RADIATION SAFETY OFFICER

1. General Description

The Radiation Safety Officer (RSO) is that person, who is appointed by the authority of the University, and who by reason of education, training, and experience, is qualified to advise others in the safe use of radiation. The primary mission of the RSO is to execute established safety policies and to ensure compliance with Federal and State regulations.

The RSO reports directly to the Provost for matters of radiation safety concern.

2. **Radiation Safety Officer is Responsible For:**

a. general surveillance over all activities involving radiation and radioactive material, including routine monitoring and special surveys of all areas in which radioactive material is used;

b. furnishing consulting services on all aspects of radiation protection to personnel at all levels of responsibility;

c. controlling purchases of all radioactive material;

d. packaging and shipping of all radioactive material leaving the facility;

e. distributing and processing personnel monitoring equipment, determining the need for and evaluation of bioassays, keeping personnel exposure and bioassay records, and notifying individuals and their supervisors of exposures approaching any limits and recommending appropriate remedial action;

f. conducting training programs and otherwise instructing personnel in the proper procedures for the use of radioactive materials and other radiation sources prior to use, at periodic intervals (refresher training), and as required by changes in procedures, equipment, regulations, etc;

g. making arrangements for the annual independent audit of the radiation safety program;

h. supervising and coordinating the radioactive waste disposal program, including maintaining waste storage and disposal records;

i. proper storage of all radioactive material not in current use, including wastes;

j. maintaining an inventory of all radioactive material at the facility and limiting the quantity of radionuclides at the facility to the amounts authorized by the license;

k. investigating any accidents, spills, unplanned releases to the environment, and other abnormal occurrences regarding radiation or radioactive material;

l. assuring that the proper authorities (i.e., the NRC, local police, U. S. Department of Transportation, etc.) are notified promptly in case of accident, damage, theft, or loss of radioactive material; and,

m. assuring that the terms and conditions of the license are met and that the required records are maintained and reviewed for compliance with NRC regulations and license conditions.

2. The RSO has the authority to terminate immediately a project, activity, or use of radiation or radioactive material that is found to be a threat to health or property. This would include the closing of an area or the confiscation of radioactive material if such actions would remove or prevent the recurrence of a threat to health or property.

C. AUTHORIZED SUPERVISOR

1. General Description

Authorized Supervisors will assist the RSO in the performance of his/her duties. These supervisors must be approved by the Radiation Safety Officer and the NRC and will be directly responsible for the safe use and disposition of their radioactive materials. Other responsibilities of the Authorized Supervisor include:

a. taking an active role to ensure that the laboratory is compliant with all in-house and Federal and State rules and regulations;

b. ensuring that appropriate radiation protective equipment is available to laboratory personnel, and that personnel fully utilize such protection;

c. planning adequately for new procedures; (Before a new procedure is performed, the supervisor shall determine the types and amounts of radiation or radioactive material to be used. This will generally give a good indication of the protection required. The procedure must be well outlined. In most cases, before the procedure is actually performed with radioactive material, it should be rehearsed so as to preclude accidents or unexpected circumstances.)

d. instructing those persons for whom they are responsible in the use of safe techniques and in the application of approved radiation safety practice;

e. furnishing the RSO with information concerning individuals and activities in their areas;

f. contacting the RSO whenever changes in operational procedures which might lead to personnel exposure are anticipated;

g. complying with the license requirements governing the use of radioactive materials;

h. being aware of and taking responsibility for all radioactive materials they order; (Radioactive material purchases should be kept to a minimum consistent with good ALARA practices. Only the needed amount of radioactive material should be purchased, even if large discounts are applied to larger purchases. Safety considerations as well as cost of disposing of low-level radioactive wastes dictate that these wastes be minimized.)

i. limiting the use of radionuclides authorized to them to individuals working under his/her direct supervision and to the location specified on the authorization form;

j. ensuring that radiological surveys are performed as required;

k. ensuring that all personnel in the laboratory, including themselves, attend scheduled training sessions;

l. ensuring that each researcher in his/her laboratory has a full understanding of their assignments and the responsibilities associated with the handling of radioactive materials;

m. reporting any incident involving radioactive material to the RSO;

n. maintaining an accurate inventory of all radioactive material in their possession; and,

o. ensuring that dosimetry worn by laboratory personnel under their direction is turned in at the required frequency (as appropriate).

D. AUTHORIZED USERS

1. Each individual at MSU who handles licensed radioactive material is defined as an "Authorized User." Each Authorized User is responsible for:

   a. being familiar with the MSU Radiation Safety Manual and applicable Federal and State regulations regarding radiation;

   b. keeping exposure to radiation as low as is reasonably achievable (ALARA);

   c. wearing the prescribed dosimetry (e.g., TLD);

   d. surveying hands, shoes, and body for radioactivity, removing any contamination identified, prior to leaving the work area after working with radioactive material;

   e. wearing prescribed protective clothing and utilizing any prescribed protective devices;

f. keeping the laboratory neat and clean;

g. maintaining and transporting materials in such a manner as to prevent breakage or spillage (double container) and provide adequate shielding;

h. labeling and isolating radioactive waste and equipment, such as glassware, used for radioactive materials; (Once used for radioactive substances, equipment should not be used for other work, and shall not be moved from the laboratory until free of contamination.)

i. overseeing anyone temporarily in the laboratory (e.g., contractors) to ensure that they do not come in contact with radioactive materials;

j. checking the immediate areas in which radioactive materials are being used at least once daily for contamination and decontaminating as necessary;

k. reporting accidental inhalation, ingestion, or injury involving radioactive materials to the Authorized Supervisor, and carrying out the appropriate corrective measures;

l. complying with requests from the Radiation Safety Officer for thyroid measurements and/or the submission of urine samples for radioassay; and

m. following the safe laboratory practices as outlined in Section F of this manual.

E. APPROVAL FOR RADIOACTIVE MATERIAL USE

1. All personnel who intend to work with radioactive material must first complete the following forms:

   a. "Statement of Training and Agreement;" and a

   b. "Dosimetry Request."

2. Authorized Supervisors

   a. Application for possession and use of licensed radioactive materials and for Authorized Supervisor status will be made on the appropriate forms.

   b. The application procedure has been broken down into two parts to facilitate application and amendment and to minimize paperwork. Conceptually, these two parts are a "User" application (Form RSP-1) and a "Use" application (Form RSP-2). "Use" and "User" applications must be filed initially and whenever significant changes are made.

c. Each application must be submitted to the Radiation Safety Officer (RSO) for review and approval. The RSO will review the application and ensure that the applicant:

1) possesses adequate facilities and equipment, appropriate for the proposed use, which will ensure the safety of workers and the public, and prevent or minimize environmental damage;

2) has established safe and effective operating, handling, and emergency procedures;

3) has adequate training and experience to safely carry out the proposed use;

4) will maintain radiation exposures to workers and the public ALARA; and

5) will conform to all applicable regulations and procedures, such as recordkeeping, established by Federal and State authorities regarding all other aspects of possession and use of radioactive materials.

d. Once the RSO is satisfied that the proposed Authorized Supervisor meets the above requirements, the RSO will submit an amendment request to the NRC to have the proposed Supervisor added to the license.

F. LABORATORY SAFETY PRACTICES

1. The general safe laboratory practices that are required in any laboratory are applicable in a laboratory where radioactive materials are used.

2. No smoking, eating, drinking, application of cosmetics, or storage of food is allowed in an area where radioactive materials are handled.

3. Appropriate dosimetry must be worn whenever working with radioactive material.

4. As with any laboratory research activity, all individuals must wear safety glasses when working with loose radioactive material.

5. When working with radioactive material, wear a buttoned lab coat with sleeves rolled down, and plastic or rubber gloves for protection of clothes and skin. To avoid the spread of contamination, change gloves frequently and remove at the work area. Do not handle faucets, light switches, doorknobs, telephones, etc. with potentially contaminated gloves. Special protection may be required for open cuts or wounds.

6. After working with loose radioactive material, wash hands prior to handling any object

which goes into the mouth, nose, or eyes.

7. Radioactive material shall be used and stored in such a manner as to restrict unauthorized persons from using or removing such materials. All radioactive stock materials must be secured when not in use (e.g., locked refrigerator, freezer, or lab).

8. Designate and label the radioactive work area(s). Consider the consequences of leakage or equipment failure. Use stainless steel or plastic trays to help confine liquids if spilled.

9. Never pipette radioactive solutions by mouth. Mechanical devices must be used. Push-button pipettors with disposable tips are strongly recommended. Segregate pipetting devices used with radioactive materials from those used with non-radioactive solutions.

10. Confine radioactive solutions in covered containers plainly identified and with name of compound, radionuclide, date, activity, and radiation level if applicable.

11. Dispose of radioactive waste only in a manner designated by the RSO and maintain records as instructed.

12. Check the work area, hands and clothing frequently for radioactive contamination when working with loose radioactive materials. The immediate work area should be checked for contamination at least at the end of each working day.

13. All equipment that is suspected to have come in contact with loose radioactive material shall be considered potentially contaminated and shall be labeled as such. These items must be monitored for contamination before being removed from the laboratory for repair, modification, calibration, storage, or use elsewhere.

14. Know the location of and how to use survey instruments available to your lab.

15. Use designated containers for the disposal of radioactive waste and be familiar with proper disposal procedures. Label or otherwise identify all waste and waste containers to prevent inadvertent disposal to normal trash.

16. Always transport radioactive material in such a manner as to provide adequate shielding and prevent breakage or spillage (double container).

17. Use suitable ventilation systems when handling gases or volatile material.

G. TRAINING

1. General

In order to assure personnel safety, all personnel who work with radioactive material are required to receive training in radiation safety. Only appropriately trained personnel may handle radioactive material. Training may be performed by the RSO or other qualified individual or school.

2. Schedule

Radiation safety training is provided:

a. prior to personnel first working radioactive material at MSU;

b. annually (refresher); and

c. whenever a significant change occurs in duties, material use, or the license.

3. Content

Training will include the following topics (as appropriate):

a. Fundamentals of radiation safety

    1) characteristics of radiation
    2) units of measure
    3) dosimetry
    4) biological effects
    5) dose minimization (ALARA)

b. Radiation detection instrumentation

    1) choosing the appropriate instrument
    2) pre-operation checks
    3) survey techniques
    4) documentation

c. Applicable regulations and license conditions

d. Areas where radioactive material is used or stored

e. Appropriate radiation safety procedures
f. Potential hazards associated with radioactive material in each area where the employee will work

g. Radiation safety manual

h. Individual's obligation to report unsafe conditions to the RSO

i. Appropriate response to emergencies or unsafe conditions

j. Worker's right to be informed of occupational radiation exposure and bioassay results

k. Location where worker's may find a copy of the license and applicable regulations

4. **Records**

Training must be documented and records retained for at least 5 years. These records will include:

a. the name of the individual conducting the training;

b. the names of the individuals attending the training;

c. the date and duration of the training session; and

d. a list of topics covered.

H. RADIATION MONITORING AND CONTROL

1. **Surveys**

a. Radiological surveys of areas where radioactive materials are used and/or stored are an essential part of any radiation safety program. Records of such surveys are required by law. These records must be signed and dated. Survey records are the property of the licensee, not the Authorized User, and shall be retained as required by 10 CFR 20.2103.

b. A complete survey includes monitoring for fixed and removable contamination, as well as exposure rate (if applicable).

1) Fixed radioactive contamination can only be detected by a survey instrument appropriate to detect the type, energy and quality of radiation present. For C-14,

S-35, P-32 and P-33, direct monitoring may be performed using a ratemeter with a thin-windowed gas-filled detector (e.g., Geiger-Mueller). For I-125, direct monitoring should be performed using a ratemeter with a thin, thallium-activated sodium iodide scintillation detector, also called a low-energy probe.

2) Removable radioactive contamination is generally a more serious problem. It can be detected by wipe tests (also called smears or swipes). Wipe surveys are performed by wiping the surface to be evaluated with a small piece of wetted (50% ethanol solution or equivalent) filter paper or cotton swab. A surface of approximately 100 cm^2 (4x4 in^2) should be wiped, and the paper or swab should be counted in an appropriately calibrated liquid scintillation or gamma counter.

3) Exposure rate or absorbed dose rate measurements must be made and recorded in areas where they are significant.

c. Areas should be surveyed at reasonable intervals, depending on the amount and type of radioactive material used, and the nature and frequency of work. "Reasonable intervals" will be deemed to be at least monthly in areas where radioactive materials are used and/or stored. The immediate areas (e.g., bench tops) in which radioactive materials are being used should be checked for contamination at least once daily by the Authorized Users in the laboratory. More extensive surveys shall be performed at the completion of an experiment or if contamination is suspected.

d. Contamination survey results must be reported in units of activity, i.e., disintegrations per minute (dpm).

$$\text{DPM} = \text{Counts Per Minute (CPM)} \div \text{Instrument Efficiency}$$

Radiation surveys must be reported in units of dose (equivalent) rates, i.e., microrem per hour.

e. Other kinds of surveys may include air and water sampling as deemed necessary by the RSO.

f. It is imperative that every survey performed is properly documented. Surveys are a legal record and should be documented neatly and accurately in a black or blue ballpoint pen. The survey document should include a floor plan of the area surveyed and include the following information:

1) location of the survey;
2) purpose of the survey (routine, post-spill, etc.);
3) date and time the survey was performed;
4) make, model, and serial number of each instrument used for measuring direct radiation and/or for counting wipes;

5) efficiency of counting instruments;
6) calibration due date for each instrument (this date must be *after* the date of the survey); and
7) surveyor's name and signature.

g. Documentation of surveys required by the license (e.g., monthly) shall be maintained by the RSO.

h. The RSO will conduct an annual inspection of all radioactive material use and storage areas. This inspection will include an evaluation of radiation safety practices employed by laboratory personnel, such as proper signs and labels, postings, control of radioactive material, shielding materials, housekeeping, and waste disposal. A record of these inspections shall be maintained by the RSO.

2. **Acceptable Limits of Contamination**

Equipment and areas should be maintained essentially free of removable contamination. Radioactive contamination in excess of the levels specified in Table H-1 will be considered excessive unless they are of short duration, or, in the case of restricted areas, unless other steps are taken to limit personnel exposure. Barring these exceptions, action must be taken to reduce contamination levels as far as reasonably achievable below the levels listed Table H-1.

TABLE H-1: CONTAMINATION GUIDELINE VALUES

NUCLIDE	AVERAGE[b,c,f] (dpm/100 cm^2)	MAXIMUM[b,d,f] (dpm/100 cm^2)	REMOVABLE[b,c,e,f] (dpm/100 cm^2)
H-3, C-14, S-35, P-32, P-33	5,000	15,000	1,000
I-125	100	300	20

[b] *As used in this table, 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.*
[c] *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 object.*
[d] *The maximum contamination level applies to an area of not more than 100 cm^2.*
[e] *The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry 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.*
[f] *The average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/hr at 1 cm and 1.0 mrad/hr at 1 cm, respectively, measured through not more than 7 milligrams per square centimeter of total absorber.*

3. **Dose Equivalent Rate Limits**

Dose equivalent rates above the levels stated below will be considered excessive unless they are of short duration, or, in the case of restricted areas, unless other steps are taken to limit personnel exposure. Barring these exceptions, action must be taken to reduce the dose equivalent rates as far as reasonably achievable below the levels listed in Table H-2.

TABLE H-2: DOSE EQUIVALENT GUIDELINE VALUES

Area	Action Level
Restricted	2.0 mrem/hour
Unrestricted	0.2 mrem/hour

4. Authorized Users are required to have immediate access to a suitable survey instrument such as a ratemeter with a gas-filled or scintillation detector. Such instruments will be maintained and calibrated as stated in Section I of this manual.

5. In the event that the spread of radioactive contamination is suspected, all work in the area shall be halted immediately. The RSO shall be contacted as soon as possible. (See Section Q, “Emergency Procedures,” of this manual.)

I. INSTRUMENT CALIBRATION AND CHECKS

1. Radiation detection instrumentation requires periodic checking and calibration. Radiation detection instrumentation must be calibrated at least once annually and after repairs.

2. Portable radiation detection instrumentation will be calibrated by an organization specifically licensed by the U.S. Nuclear Regulatory Commission (NRC) or an Agreement State, to perform such services.

3. Prior to using any portable instrument to perform a radiological survey, the user should perform the following checks.

   a. Check the physical condition of the meter. Look for damage and listen for apparent loose internal components. Check the cable for a good connection and report any deficiencies to the RSO.

b. Ensure that the instrument has been calibrated within the last year.
c. Check battery/power supply.

d. Perform a source check. Put the selector switch on one of the operating positions, then expose the detector to a known source of radiation and ensure that the detector responds properly. Check the instrument again after use to ensure that it did not fail during use.

J. IONIZING RADIATION DOSE LIMITS

1. Dose Limits

a. No person shall be permitted to receive an annual dose in excess of that listed in Table J-1 below.

TABLE J-1: DOSE LIMITS

Exposure Category	Annual Dose Limit (rem)
Total effective dose equivalent	5
Lens of eyes	15
Extremities	50
Skin	50
Committed dose equivalent (organs)	50

b. In no case shall an individual under the age of 18 years be permitted to receive a radiation dose in excess of 10 percent of the limits set forth in Table J-1.

c. No individual shall be exposed to airborne radioactive material in concentrations:

1) In excess of the derived air concentrations (DACs) specified in Appendix B, 105 CMR 120.296, or

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

d. The dose to an embryo/fetus during the entire pregnancy, due to occupational exposure of a **declared pregnant woman***, shall not be allowed to exceed 0.5 rem. (*A **declared pregnant woman** is a woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception*.)

K. ALARA PROGRAM

1. **Commitment**

a. MSU is committed to the program described herein for keeping individual and collective doses as low as is reasonably achievable (ALARA). In accordance with this commitment, we have developed the following written policy to foster the ALARA concept within our organization.

b. We will perform a formal annual review of the radiation safety program, including ALARA considerations. This will include reviews of operating procedures and past dose records, previous inspection reports, etc., and consultations with the radiation safety staff or outside consultants.

c. Modifications to operating and maintenance procedures and to equipment and facilities will be made if they will reduce exposures unless the cost, in our judgment, is considered to be unreasonable. We will be able to demonstrate, if necessary, that improvements have been sought, that modifications have been considered, and that they have been implemented when reasonable. If modifications have been recommended but not implemented, we will be prepared to describe the reasons for not implementing them.

d. In addition to maintaining doses to individuals as far below the regulatory limits as is reasonably achievable, the sum of the doses received by all exposed individuals will also be maintained at the lowest practicable level. It would not be desirable, for example, to hold the highest doses to individuals to some fraction of the applicable limit if this involved exposing additional people and significantly increasing the sum of radiation doses received by all involved individuals.

2. **Radiation Safety Officer**

a. Review of Proposed Users and Uses

1) The RSO will thoroughly review the qualifications of each applicant with respect to the types and quantities of materials and methods of use for which application

has been made to ensure that the applicant will be able to take appropriate measures to maintain exposure ALARA.

2) When considering a new use of radioactive material, the RSO will review the efforts of the applicant to maintain exposure ALARA.

3) The RSO will ensure that the users justify their procedures and that individual and collective doses will be ALARA.

b. Review of ALARA Program

1) The RSO will encourage all users to review current procedures and develop new procedures as appropriate to implement the ALARA concept.

2) The RSO will perform a quarterly review of occupational radiation exposure with particular attention to instances in which the investigational levels in Table K-1 are exceeded. The principal purpose of this review is to assess trends in occupational exposure as an index of the ALARA program quality and to decide if action is warranted when investigational levels are exceeded. (See Section 6 below for a discussion of investigational levels.)

3) The RSO will ensure an evaluation of the organization's overall efforts for maintaining doses ALARA is performed as part of the annual radiation safety program audit.

Table K-1: Investigational Levels
(mrems per calendar quarter)

Exposure Category	Level I	Level II
Total effective dose equivalent	60	125
Lens of eyes	185	375
Extremities	625	1250
Skin	625	1250
Committed Dose Equivalent (thyroid)	625	1250

c. Education Responsibilities for ALARA Program

The RSO will ensure that personnel who may be exposed to radiation will be instructed in the ALARA philosophy and informed that management is committed to implementing the ALARA concept.

d. Cooperative Efforts for Development of ALARA Procedures.

   Authorized Users will be given opportunities to participate in formulating the procedures that they will be required to follow.

   1) The RSO will be in close contact with all users in order to develop ALARA procedures for working with radioactive materials.

   2) The RSO will receive and evaluate the suggestions of Authorized Users for improving health physics practices and will encourage the submittal of these suggestions.

e. Reviewing Instances of Deviation from Good ALARA Practices

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

4. **Authorized Supervisors and Users**

   a. New Methods of Use Involving Potential Radiation Doses

      1) The Authorized Supervisor will consult with the RSO during the planning stage before implementing new uses for radioactive materials.

      2) The Authorized Supervisor will review each planned use of radioactive material to ensure that doses will be kept ALARA. Trial runs may be helpful.

5. **Individuals Who Receive Occupational Radiation Doses**

   a. Workers will be instructed in the ALARA concept and its relationship to work procedures and work conditions.

   b. Workers will be instructed in the recourse that is available if they feel that ALARA is not being promoted on the job.

6. **Establishment of Investigational Levels in Order to Monitor Individual Occupational External Radiation Doses**

   MSU hereby establishes investigational levels for occupational external radiation doses which, when exceeded, will initiate review or investigation by the RSO. The

investigational levels that have been adopted are listed in Table K-1. These levels apply to the exposure of individual workers.
The RSO will review personnel dosimetry results not less than once in any calendar quarter. The following actions will be taken at the investigational levels as stated in Table K-1:

a. Personnel dose less than Investigational Level I.

Except when deemed appropriate by the RSO, no further action will be taken in those cases where an individual's dose is less than Table K-1 values for the Investigational Level I.

b. Personnel dose equal to or greater than Investigational Level I but less than Investigational Level II.

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

c. Personnel dose equal to or greater than Investigational Level II.

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

d. Reestablishment of investigational levels to levels greater than those listed in Table K-1.

In cases where a worker's or a group of workers' doses need to exceed an investigational level, a new, higher investigational level may be established for that individual or group on the basis that it is consistent with good ALARA practices. Justification for new investigational levels will be documented.

L. PERSONNEL MONITORING AND BIOASSAY PROCEDURES

1. External Monitoring

a. All persons who enter an area under such conditions that they may receive a radiation exposure greater than 10 percent of the limits set forth in Section J of this manual shall wear appropriate personnel monitoring devices. These monitoring devices shall be thermoluminescent dosimeters unless other devices are authorized by the RSO.

b. The RSO shall supervise the obtaining, distribution, and collection of personnel monitoring devices.

c. Dosimetry used to measure whole body exposure shall be worn on the upper chest area with open window facing away from the body. Ring badges shall be worn under protective gloves with the thermoluminescent dosimeter (TLD) chip facing the radioactive material.

d. TLD's will be processed as follows:

 1) monthly (or more frequently as determined by the RSO) where significant exposures are possible; or

 2) quarterly where exposures are expected to be low.

e. If an exposure in excess of the specified limits is suspected, the RSO shall be notified immediately so that the monitoring device may be processed for rapid analysis.

f. It is the responsibility of the Authorized Supervisor to notify the RSO whenever an individual will require personnel monitoring and whenever the need for personnel monitoring is terminated. The RSO will make the final determination on who is issued personnel dosimetry.

g. When not in use, personnel monitoring devices shall be stored in an area with low background radiation levels. Personnel monitoring devices shall not be taken home.

h. AT NO TIME WILL A PERSONNEL MONITORING BADGE BE DELIBERATELY EXPOSED TO RADIATION UNLESS IT IS WORN BY THE EXPERIMENTER OR UNLESS THE RSO APPROVES. The badge shall not be worn during non-occupational exposure such as a medical x-ray.

i. All personnel monitoring records shall be maintained by the RSO.

2. **Bioassay Procedures**

 a. Bioassays may be required at the discretion of the Radiation Safety Officer if an intake of radioactive material is suspected.

 b. Bioassay records will be maintained in accordance with 10 CFR 20.2106.

M. MARKING AND LABELING

1. All areas where radioactive materials are used and/or stored shall be conspicuously posted with a sign or signs bearing the radiation symbol and the words "CAUTION RADIOACTIVE MATERIAL(S)."

2. Each container in which licensed radioactive material is used, stored, or transported shall be labeled with the radiation symbol, the words "CAUTION RADIOACTIVE MATERIAL," and the radionuclide, quantity, and date of measurement. Exceptions to this rule are in cases where:

   a. containers holding licensed material in quantities less than the quantities listed in 10 CFR 20, Appendix C; or

   b. containers holding licensed material in concentrations less than those specified in 10 CFR 20 Appendix B, Table III; or

   c. containers attended by an individual who takes the precautions necessary to prevent the exposure of individuals in excess of the limits established by 10 CFR 20; or

   d. containers when they are in transport and packaged and labeled in accordance with the regulations of the U.S. Department of Transportation.

3. Prior to removal or disposal of empty, uncontaminated containers to unrestricted areas, the radioactive material label will be removed or defaced, or it will otherwise be clearly indicated that the container no longer contains radioactive materials.

   Labels and markings should be promptly removed from an apparatus which has been checked for contamination and is no longer to be used with radioactive materials. Don't abuse radiation markings and labels. Use them sparingly, and only where needed.

N. PROCUREMENT OF RADIOACTIVE MATERIALS

1. **Purchasing Procedures**

   All requests for purchase of radioactive materials and/or transfers must be approved by the RSO. The following steps must be carried out to process an order.

   a. Complete a "Radionuclide Request/Receipt Form."

b. Obtain an authorization signature from the RSO. The RSO will ensure that the order will not exceed the possession limit.
c. Once the "Radionuclide Request/Receipt Form" has been signed by the RSO, the radioactive material may be ordered.

2. **Receiving Procedures**

a. Radioactive materials will arrive at receiving. Radioactive packages will not be received outside of normal working hours.

b. The person receiving the shipment will perform the following duties with regard to radioactive material packages.

1) Observe the package. If the package appears to be damaged, ask the carrier to remain at the site until it can be determined that neither the driver nor the delivery vehicle is contaminated.

2) If the package appears undamaged, deliver the package directly to Lab SH315.

c. Packages will be surveyed and opened by trained personnel, according to the following procedure.

1) Packages will be surveyed for external radiation levels and radioactive contamination if necessary. Packages requiring monitoring include those that are:

a) labeled as containing radioactive material, (e.g., White I, Yellow II and Yellow III), or

b) potentially damaged, e.g., crushed, wet, broken, etc.

NOTE: Packages must be surveyed within three (3) hours of receipt.

2) Put on gloves to prevent hand contamination.

3) Visually inspect package for damage and leakage.

4) Survey package exterior with an appropriate instrument. If readings are higher than expected, contact the RSO.

5) Perform a wipe survey of the outside of the package. Analyze the wipe in an appropriate instrument, e.g., a liquid scintillation counter. If contamination readings are higher than expected (e.g., >2x background), notify the RSO.

6) Open the package with the following precautionary steps:

   a) Open the outer package and remove the packing slip.

   b) Open the inner package and verify that the contents agree with those on packing slip. Compare the requisition, packing slip and label on the container.

   c) Check the integrity of the final source container (i.e., inspect for breakage of seals or vials, loss of liquid, or discoloration of packaging material).

7) If there is reason to suspect contamination, wipe the inner source container and analyze the wipe on an appropriate instrument. If contamination readings are higher than expected, notify the RSO.

8) Check the packaging materials for radioactivity. If free of contamination, they may be discarded in ordinary trash after radioactive labels have been removed or defaced.

d. For packages which do not require monitoring the contents will be verified to ensure agreement between order and receipt.

e. A record of package surveys must be maintained.

O. INVENTORY CONTROL AND MAINTENANCE PROCEDURES FOR RADIOACTIVE MATERIALS

1. A continuous record of all radioactive material possessed is to be maintained; from receipt to final disposition.

2. It is the responsibility of the Authorized Supervisor to frequently audit isotope inventories in his/her area.

3. When original material is used to synthesize other useable material, this should be shown as deleted from the original inventory. A new inventory record should be initiated for the new material, including the original inventory lot number from which it was synthesized.

4. Except during periods of use, all isotopes will be stored in such a manner as to restrict unauthorized persons from using or removing such materials. All radioactive stock materials should be stored in a secured refrigerator, freezer or room.

5. The radioactive material inventory will be adjusted frequently based upon purchase, use, and disposal records.
6. A physical inventory of all radioactive materials on site will be performed at least annually, to verify inventory records.

P. RADIOACTIVE WASTE DISPOSAL PROCEDURES

1. Introduction

a. Radioactive waste (radwaste) disposal can be a messy, expensive, and time-consuming problem. All users of radioactive materials have a responsibility to minimize the volume of radwaste and to label it accurately so that it can be disposed of in an economical manner consistent with protecting human welfare and the biosphere. Records of radioactive waste disposal must be maintained to satisfy legal requirements and to decide the best method of disposal. Since radwaste may also be a toxic chemical hazard, a fire or explosion hazard, a biohazard, or some combination of these, care must be taken to ensure safe packaging and disposal from many points of view.

b. Handling and packaging of radwaste as well as recordkeeping are the responsibility of each Authorized User.

2. Treatment and Packing of Radwaste

a. General Considerations

1) Waste must be segregated by isotope.

2) Waste must be tagged with all the information upon which disposal decisions will be based: department, name of generator, lab number; date; volume of waste; isotope, activity and form (liquid-aqueous, liquid-organic, solid, etc.); chemical and biological names and percentages of all components.

3) Waste must be packaged and transported in a manner which prevents spills or leakage.

4) Waste must not be left unattended or unidentified outside of the laboratory.

5) Biological components must be deactivated prior to disposal; (bleach can usually be used).

b. Liquid Scintillation Vials and Fluids

1) Liquid scintillation vials (LSV) containing less than 0.05 microcuries/ml (~100,000 dpm/ml) of H-3 or C-14 are categorized as exempt LSV.

2) Scintillation vials containing greater than 0.05 microcuries/ml (~100,000 dpm/ml) of H-3 or C-14, and any activity of any other isotope are categorized as liquid scintillation vials nonexempt.

3) Do not mix exempt and nonexempt vials.

4) Scintillation fluids not contained in sealed vials may be collected in 1-gallon or larger plastic containers. Due to the stringent parameters for the disposal of this waste stream, consultation with the Hazardous Waste Coordinator is required prior to the generation of this waste.

c. Liquids

1) Aqueous liquids that meet the established daily activity limit may be disposed of to the sanitary sewer system provided they are acceptable to the drain system (e.g., aqueous, readily soluble in water, nontoxic, neutral, not hazardous waste, etc.). An accurate log of disposal to the drain must be maintained.

2) Liquids with activity that exceeds the established daily disposal limit or which are incompatible with the sewer system (e.g., solvents, toxins, non-soluble, etc.) must be stored in appropriate containers for off-site disposal or decay. The liquid waste containers must be tightly sealed with appropriate labeling.

3) Liquid waste must be pH adjusted between 5 and 10 prior to sink disposal.

d. Solid

1) Contaminated solid waste, which cannot be readily decontaminated, will be collected in sturdy polyethylene waste bags within appropriately shielded containers.

2) Sharps will be placed in puncture-proof containers.

3) No free flowing liquids are to be mixed with solid waste.

4) No lead, lead lined shipping containers or metal should be placed in normal solid

waste containers. This waste must be handled separately. Contact the RSO for support.

3. **Decay in Storage**

   Short-lived radionuclides with a half-life less than 90 days may be decayed-in-storage. This waste must be stored for a minimum of 10 half-lives. If decay-in-storage is utilized, the following procedure will be followed.

   a. Once a container is stored for decay, the container will be assigned a unique I.D. number.

   b. A written log will be updated with the container's unique I.D. number, initial storage start date, initial radiation survey results on container surface, contents of the container, and projected end-of-storage date.

   c. The log information will also be placed on each container, and a radioactive label will be applied.

   d. The container will remain in storage for at least 10 half-lives of the radioisotope being stored.

   e. Quarterly inspections of containers in storage will be performed, along with wipe surveys of the storage area. Any container that appears to be degrading will be repackaged.

   f. After the specified time period, the waste will be surveyed using the following procedure.

      1) Obtain an appropriate survey instrument for the radioisotope of concern and verify its proper operation.

      2) Plan to monitor in a low background level (<0.05 mR/h) area.

      3) Remove any shielding from around the container.

      5) Monitor all surfaces of each individual container.

      6) If the radiation level measured on the waste is indistinguishable from background, the material may be disposed of without regard to radioactivity. Ensure that all radioactive labels are removed prior to disposal.

      6) Final radiation readings, date and initials of the surveyor will be recorded in the log.

7) Waste with activity noticeable above background must be returned to the storage area for further decay or transfer as radioactive waste for burial.

Q. EMERGENCY PROCEDURES

1. Principles

Incidents involving the spillage or release of radioactive materials include a wide range of possibilities, ranging from minor to very serious, possibly involving injuries, radiation exposure to personnel, contamination of personnel, fire or explosion, and theft. Emergency procedures cannot cover all possibilities, so there are a few guiding principles to keep in mind:

a. Human health and safety is paramount. Radiation exposure must be minimized; however, it is possible that other injuries may be more critical in determining the course of action.

b. Containment of the radioactive materials involved is important to reduce and prevent further exposure, and to minimize costly cleanup.

c. Notification of emergency personnel such as Security, Fire Department, Medical Personnel, and Radiation Safety personnel.

d. Protection of property from fire, explosion, or other damage must also be considered.

e. Legal requirements of reporting and recordkeeping after the incident must be met.

Bearing these principles in mind, the following emergency action guidelines are issued.

2. Spills

Emergencies will generally be in the nature of spills involving radioactive contamination. Based upon MSU’s current license limits, all spills can be considered “minor.” The actions to be taken for a minor spill are as follows:

a. Notify persons in the area that a spill has occurred.

b. Prevent spread of contamination by covering spill with absorbent paper.

c. Clean up the spill using disposable waterproof gloves and absorbent paper. Carefully fold the absorbent paper with the clean side out and place in a poly bag for transfer to a radioactive waste container. Also put contaminated gloves and any other contaminated disposable material in the bag.

d. Survey the area with an instrument appropriate for the isotope involved. Check the area around the spill, hands, clothing, and shoes for contamination.

e. Report the incident to the Radiation Safety Officer (RSO).

2. **Accidents Involving Airborne Radioactivity**

   a. Notify all other persons to vacate the room immediately.

   b. Close all windows, escape valves, and switch off ventilation.

   c. Vacate the room.

   d. If there is radioactive contamination on the skin, flush thoroughly with lukewarm water. If the contamination is on clothing, discard outer clothing at once. Use emergency shower if necessary. If there are injuries, see Section 4 below.

   e. Notify the Radiation Safety Officer. Inform the RSO of the nature of injuries, if any; the radionuclide identity and activity involved; and any other pertinent information.

   f. Ascertain that all doors giving access to the room are closed and locked. If necessary, post guards to prevent accidental opening of doors.

   g. Permit no one to enter or leave the area until approval from RSO is obtained.

4. **Injuries to Personnel Involving Contamination**

   a. Make every effort possible to rescue injured and trapped persons and remove them from the incident area.

   b. Call Security. They will call for Emergency Medical Aid and the RSO.

   c. First aid should be provided to those persons where it is necessary to save life or minimize injury.

   d. Wash minor wounds immediately under warm running water for a minimum of 15 minutes if possible.

   e. Remove and save all articles of contaminated clothing, jewelry, etc.

f. Permit no person involved in a radiation injury to return to work or leave the premises without approval of the RSO or a physician.

g. When it is necessary to send an individual to a hospital or other medical facility before being surveyed, inform ambulance personnel who will be in contact with any injured individual, of the possibility of radioactive contamination. Also, inform the hospital or medical facility that the individual may be contaminated with radioactive material.

5. **Fire or Explosions Involving Radioactivity**

a. Notify all persons in the room and building at once.

b. If radiation hazard is not immediately present, attempt to extinguish fire with an appropriate type fire extinguisher.

c. Fire or explosion may result in airborne radioactivity. Keep upwind and avoid smoke, fumes, and dust.

d. If immediate attempts to combat the fire are unsuccessful, call the site emergency number.

e. Treat injuries and spills as above. Decontaminate personnel as specified below.

f. Restrict access to the incident area and prevent unnecessary handling of incident debris. Permit no one to leave except for medical treatment, and get the names and addresses of persons removed.

6. **Decontamination of Personnel**

a. Measures to be taken in case of external contamination

1) As a rule, except for decontamination of hands, or except in cases of emergency as agreed upon by the Radiation Safety Officer, all mild decontaminating procedures described in the two paragraphs below should be carried out under supervision of the Radiation Safety Officer. Attempts to remove contamination which resists mild procedures should only be made under medical supervision.

2) The immediate washing of contaminated areas with water and soap is the method of choice for removing loose contamination, subject to certain elementary precautions:

a) tepid water, not too hot, should be used;

b) soap should not be abrasive or highly alkaline;
c) washing can be helped by scrubbing with a soft brush only and in such a way as not to abrade the skin;
d) the skin should be washed for a few minutes at a time, then blotted dry and monitored.

3) Washing could be repeated if necessary (as indicated by monitoring) provided there is no indication of damage to the skin.

4) If this procedure fails, only mild detergent approved by the Radiation Safety Officer might be used, although repeated applications of detergents to the same area of the skin, hands for instance, might injure the skin and allow the contamination to penetrate.

5) Use of organic solvents or of acid or alkaline solutions should be avoided.

6) Special attention should be paid to proper decontamination of creases and folds in the skin, hair and of such parts of the hands as fingernails, inter-finger space and the outer edges of the hands.

7) Care should be taken to avoid as much as possible the spreading of the contamination to uncontaminated parts of the body and to avoid internal contamination. If there is a risk of such a spread, an attempt should first be made to remove the contamination locally with absorbent material, and, if necessary, with a proper masking of the adjacent non-contaminated areas of the skin. A non-contaminated open wound should be protected.

8) After each decontamination operation, the treated place should be dried with a fresh non-contaminated towel or swab, and monitored. All towels and swabs used in the decontamination process should be treated as contaminated material.

9) While decontaminating the face, special care should be taken not to contaminate the eyes or lips.

10) Decontamination of the eyes should be undertaken immediately. Not only the radioactive isotope is to be considered, but also the chemical nature of the contaminant and eventual complications due to foreign bodies and mechanical or chemical irritants. Additional irritation of the eyes by decontamination procedures should be avoided. Immediate irrigation of the eyes with a copious amount of water or with appropriate medically approved solutions is recommended. Immediate irrigation of the eyes for a minimum of 15 minutes using a plumbed eyewash is recommended. After this first procedure every case of contamination of the eyes should be submitted to medical control and further

treatment.

b. Measures to be taken in case of internal contamination.

1) Radioactive contamination of personnel can be internalized through ingestion, inhalation, wounds or skin penetration. If anyone suspects internal contamination in case of an accident during work, it should be immediately reported to the Radiation Safety Officer.

2) Internal contamination is essentially a medical problem, parallel in some ways to the absorption of chemical toxins. Special corrective procedures should, therefore, combine with normal medical practice under medical advice and supervision.

3) Aims of the corrective procedures are: (a) try to eliminate as much of the internally introduced contaminant still remaining in the mouth, gastro-intestinal or respiratory tract, as quickly as possible and try to prevent or reduce its uptake into the body; (b) try to prevent fixation of the contaminant in the body or try to increase its excretion from the body.

4) For the first of these aims it is sometimes necessary that the contaminated person or another non-medical person take immediate action (in the first seconds or minutes) for instance, to promote the mechanical elimination of the contaminant by vomiting or expectoration.

5) In case of contaminated small open wounds, cuts, punctures, or other injuries, the wound should be immediately washed and bleeding encouraged if necessary, and referred to a physician.

6) For the second of the aims indicated above, any further procedure of internal decontamination (e.g., more complicated chemical or physicochemical methods) is a matter of medical treatment. It should be undertaken as soon as possible but only under medical supervision by trained medical professionals.

7. **Loss or Theft of Radioactive Materials**

In case of loss or theft of radioactive materials, or suspected loss or theft of radioactive materials, contact the Radiation Safety Officer immediately.

8. **Incident Reporting to Press and Public**

Because of concern about radiation on the part of the media and nonscientific public, it is the policy of MSU that all releases to the press and public be made by the appropriate individual responsible for public relations. No other person is authorized to speak on behalf of MSU.

R. ISOTOPE SPECIFICS

The following pages contain general information for the radioisotopes that are currently licensed for use at MSU. This information is designed to provide a basic understanding of radiological safety concerns associated with each isotope.

Tritium (H-3)

Radiological half-life, $T_{1/2}$……………………..……….……………………12.3 years
Principle emission…………………………..………..…..…18.6 keV beta (maximum)
Annual limit on intake (ALI) by ingestion……..……………………..……..…$8x10^4$ µCi
Biological monitoring method………………...…………..……………………urine samples
Range in air………………………………....…………………………………4.7 mm
Range in water……………………………………..……………………..…$6x10^{-3}$ mm
Shielding required…………………………….…………………………………..none
Monitoring method for contamination……………......swabs counted by liquid scintillation
Sanitary sewer release concentration limit…..…..…..…………………………....$1x10^{-2}$ µCi/ml

Special considerations
• Tritium compounds can be absorbed through the skin therefore gloves must always be worn.

• Due to its low beta energy, tritium cannot be monitored directly, and therefore regular swipe surveys of the work areas are recommended.

• Although external contamination does not lead to significant radiation dose, it can lead to hazardous internal contamination.

• ALIs can vary considerably e.g. DNA precursors such as tritiated thymidine are regarded as more toxic than tritiated water partly because the activity is concentrated in cell nuclei.

Carbon-14 (C-14)

Radiological half-life, $T_{1/2}$……………………………………………………5730 years
Principle emission………………………………………..…...156 keV beta (maximum)
Annual limit on intake (ALI) by ingestion……………….……………..……….$2x10^3$ µCi
Biological monitoring method……………………….…………breath or urine samples
Range in air………………………………………………..…………………...22 cm
Range in water…………………………………………………………...…...0.28 mm
Shielding required……………………………………….………………1 cm Plexiglas
Monitoring method for contamination…………....…...…….. thin windowed GM counter
Sanitary sewer release concentration limit…..……………………………....$3x10^{-4}$ µCi/ml

Special considerations
• Some organic compounds may be absorbed through surgical gloves.

• Avoid generation of CO_2 which could be inhaled.

Sulphur-35 (S-35)

Radiological half-life, $T_{1/2}$……………………………………………………..……87.4 days
Principle emission………………………………………..…...167 keV beta (maximum)
Annual limit on intake (ALI) by ingestion……………….…………..………$6x10^3$ µCi
Biological monitoring method……………………….….…………..……urine samples
Range in air………………………………………………………………………..26 cm
Range in water………………………………………………………………..…...0.32 mm
Shielding required………………………………………….…………1 cm Plexiglas
Monitoring method for contamination…………....…...…….. thin windowed GM counter
Sanitary sewer release concentration limit…..…………………………....$1x10^{-3}$ µCi/ml

Special considerations

• Vials should be opened and used in ventilated enclosures.

• Avoid generation of sulphur dioxide.

• Radiolysis of ^{35}S-ammino acids may lead to the production of labeled volatiles which could contaminate internal surfaces and reaction vessels.

Phosphorus-32 (P-32)

Radiological half-life, $T_{1/2}$……………………………………………………..……14.3 days
Principle emission……………………………………………1,709 keV beta (maximum)
Annual limit on intake (ALI) by ingestion……………….…………..………$6x10^2$ µCi
Biological monitoring method……………………….….…………..……urine samples
Range in air………………………………………………………………………790 cm
Range in water………………………………………………………………..…...0.76 cm
Shielding required………………………………………….…………1 cm Plexiglas
Monitoring method for contamination…………....…...…….. thin windowed GM counter
Sanitary sewer release concentration limit…..…………………………....$9x10^{-5}$ µCi/ml

Special considerations

• Avoid unnecessary exposure to this high energy radionuclide, use tube racks or holders.

• Ring dosimeters should be used when handling quantities of 1mCi or greater.

• Lead shielding is required when handling quantities above 10 mCi due to the production of high energy Bremsstrahlung when the beta particles are absorbed.

Phosphorus-33 (P-33)

Radiological half-life, $T_{1/2}$…………………………………………………..……25.4 days
Principle emission……………………………………….…...249 keV beta (maximum)
Annual limit on intake (ALI) by ingestion…………….…………..……….6x10^{3} µCi
Biological monitoring method……………………….….…………..……urine samples
Range in air………………………………………………………………..49 cm
Range in water…………………………………………………………..…...0.60 mm
Shielding required……………………………………….…………1 cm Plexiglas
Monitoring method for contamination…………....…...…….. thin windowed GM counter
Sanitary sewer release concentration limit…...…………………………....8x10^{-4} µCi/ml

Special considerations
• ^{33}P does not require special precautions over and above those necessary for any beta-emitting radionuclide of this energy of emission.

Iodine-125 (I-125)

Radiological half-life, $T_{1/2}$………………………………………………………60.1 days
Principle emission……………………………………...…...35 keV photon (maximum)
Annual limit on intake (ALI) by ingestion…………….…………..………….40 µCi
Biological monitoring method…………………………direct monitoring or urine samples
Unshielded Exposure Rate…………………………………..1.4 R/h at 1 cm from 1 mCi
Half Value Layer………………………………………………………..0.02 mm (lead)
Shielding required…………………………………………………………...3 mm lead
Monitoring method for contamination…………....…...……..…. Low-energy Na-I detector
Sanitary sewer release concentration limit…...……………………………....2x10^{-5} µCi/ml

Special considerations
• Freezing or acidification of solutions containing iodide ions can lead to formation of volatile elemental iodine.

• Some iodine compounds can penetrate surgical gloves, two pairs or polythene alternatives are recommended.

S. GLOSSARY

Absorbed Dose. When ionizing radiation passes through matter, some of its energy is imparted to the matter. The amount of energy absorbed per unit mass of irradiated material is called the absorbed dose, and is measured in rads or grays. 1 Gy = 100 rad.

Activity. The rate of disintegration (transformation) or decay of radioactive material. The units of activity are the curie (Ci) and the Becquerel (Bq). 1 Ci = 3.7E+10 dps = 2.22E+12 dpm.
1 Bq = 1 dps.

Acute Dose. A large dose of radiation (far in excess of federal dose limits) delivered in a short period of time (a few hours).

Airborne Contamination. Radioactive material dispersed in the air as dusts, fumes, particulates, mists, vapors, or gases.

Airborne Radioactivity Area. A room, enclosure, or area in which airborne radioactive materials, composed wholly or partly of licensed material, exist in concentrations in excess of the derived air concentrations (DACs) specified in appendix B to 105 CMR 120.296, or to such a degree that an individual present in the area without respiratory protective equipment could exceed, during the hours an individual is present in a week, an intake of 0.6 percent of the annual limit on intake (ALI) or 12 DAC-hours.

ALARA. Acronym for "as low as is reasonably achievable;" means making every reasonable effort to maintain exposures to radiation as far below the dose limits as is practical consistent with the purpose for which the licensed activity is undertaken. In making this assessment the state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to using nuclear energy and licensed materials in the public interest may all be taken into account.

Alpha Decay. Radioactive decay in which an alpha particle is emitted. This lowers the atomic number (Z) of the nucleus by two and its mass number (A) by four.

Alpha Particle. A positively charged particulate radiation consisting of two protons and two neutrons, emitted during a nuclear transformation. It can be stopped by a few sheets of paper.

Annual Limit on Intake (ALI). The limit for radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. Inhalation or ingestion of one ALI will result in a committed effective dose equivalent of 5 rems (0.05 Sv) to the whole body, or a committed dose equivalent of 50 rems (0.5 Sv) to any individual organ or tissue. ALI values are given in appendix B to 105 CMR 120.296.

Attenuation. The reduction of a quantity of radiation as it passes through matter, resulting from all types of interaction with that matter.

Background Radiation. Radiation from cosmic sources; naturally occurring radioactive materials, including radon (except as a decay product of source or special nuclear material) and global fallout as it exists in the environment from the testing of nuclear explosive devises. Background radiation does not include radiation from source, byproduct, or special nuclear materials regulated by the State.

Becquerel (Bq). A unit of radioactivity equal to one disintegration per second.

Beta Decay. Radioactive decay in which a beta particle is emitted.

Beta Particle. A negatively charged particle emitted from an atom during radioactive decay. A beta particle has the same mass as an electron, which is equal to that of a proton. A beta particle can be stopped by an inch of wood or a thin sheet of aluminum.

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

Byproduct Material. Any radioactive material (except special nuclear material) yielded in, or made radioactive by, exposure to the radiation incident to the process of producing or using special nuclear material; and tailings or wastes produced by the extraction or concentration of uranium or thorium from ore processed primarily for its source material content, including discrete surface wastes resulting from uranium solution extraction processes. Underground ore bodies depleted by these solution extraction operations are not byproduct material within this definition.

Collective Dose. The sum of the individual doses received in a given period by a specified population from exposure to a specified source of radiation.

Committed Dose Equivalent (HT,50). The dose equivalent which will be delivered to the organs or tissues of reference (T), during the 50-year period following an intake of radioactive material by an individual.

Committed Effective Dose Equivalent (HE,50). The sum of the products of the weighing factors applicable to each body organ or tissue irradiated and the committed dose equivalent to these organs or tissues (HE,50 = Σ wTHT,50).

Contamination. Radioactive material in a form that's easily spread around (e.g., liquid, powder), in a place where it's not supposed to be, or in a place which is believed to be uncontaminated. Since this material is radioactive, it emits radiation.

Contaminated Area. An area within a restricted area in which radioactive materials are not or may not be specifically contained. That is, they are or may be present on surfaces within the contaminated area.

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

Count (radiation counters). (1) A pulse that has been registered, corresponding either to an ionizing event or to an extraneous disturbance (spurious count). (2) The number of pulses recorded in a specific period.

Curie (Ci). The basic unit to describe the quantity of radiation given off by a sample of material. The curie is equal to 37 billion disintegrations per second (3.7E+10 dps or 2.22E+12 dpm). This is approximately the rate of decay of one gram of radium-226.

Decay, Radioactive. Elements that give off radiation are in an unstable state. They continue to give off radiation until they reach a stable, non-radioactive state. This process is known as radioactive decay. An unstable element will decay into one or a string of different elements as it undergoes radioactive decay.

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

Deep-dose Equivalent (Hd). Applies to external whole-body exposure; it is the dose equivalent at a tissue depth of 1 cm (1000 mg/cm^2).

Decontamination. Removal or reduction of radioactive material.

Derived Air Concentration (DAC). The concentration of a given radionuclide in air that, if breathed by the reference man for a working year of 2000 hours under conditions of light work (inhalation rate 1.2 cubic meters of air per hour), results in an intake of one ALI. DAC values are given in appendix B to 105 CMR 120.296.

Derived Air Concentration-hour (DAC-hour). The product of the concentration of radioactive material in air (expressed as a fraction or multiple of the derived air concentration for each radionuclide) and the time of exposure to that radionuclide, in hours. A licensee may take 2000 DAC-hours to represent one ALI, equivalent to a committed effective dose equivalent of 5 rems (0.05 Sv).

Detector. Any device for converting radiation flux to a signal suitable for observation and measurement.

Disintegration, Nuclear. A spontaneous nuclear transformation characterized by the emission of energy and/or mass from the disintegrating nucleus.

Dose or Radiation Dose. A generic term that means absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, or total effective dose equivalent, as defined in specific paragraphs of 105 CMR 120.

Dose, Accumulated. The sum of the absorbed doses received by the system considered, despite whether it is exposed to radiation in a continuous or discontinuous fashion (also called dose, cumulative absorbed).

Dose Equivalent (HT). The product of the absorbed dose (rad) 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 (Sv).

Dose Rate. The rate at which radiation dose is absorbed.

Dosimeter. A device, such as a film badge, thermoluminescent dosimeter (TLD), or pocket ion chamber which can be worn and used to measure the radiation dose a person receives over a period of time.

Effective Dose Equivalent (HE). The sum of the products of the dose equivalent to the organ or tissue (HT) and the weighing factors (wT) applicable to each body organ or tissue that is irradiated (HE = ΣwTHT).

Electron Volt. The amount of kinetic energy gained by an electron when it is accelerated through a voltage difference of one volt.

Exposure. Being exposed to ionizing radiation or to radioactive material.

Exposure Rate. The exposure per unit time.

External Dose. That portion of the dose equivalent received from radiation sources outside the body.

Extremities. Hand, elbow, and arm below the elbow, foot, knee, and leg below the knee.

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

Film Badge. A package of photographic film worn like a badge by workers in the nuclear industry to measure exposure to ionizing radiation. The absorbed dose can be calculated by the degree of film darkening caused by the irradiation.

Fixed Contamination. The fraction of radioactivity present that cannot be easily removed or dislodged. It might be in the pores of a piece of wood, in the cracks between floor tiles, or in other hard-to-remove locations.

Gamma Rays. High energy, short wavelength electromagnetic radiation, similar to x rays. Gamma radiation is released when fission occurs and often when a radionuclide decays. Gamma rays are very penetrating and are best shielded by dense materials, such as lead, water, or concrete.

Genetic Effects. Radiation effects that produce changes in egg or sperm cells of the exposed individual, and therefore affect offspring of the exposed individual.

Gray (Gy). The International System of Units (SI) unit of absorbed dose. One gray is equal to an absorbed dose of 1 joule/kilogram (100 rads).

Half-Life, Biological. The time required for a particular substance in a biological system to be reduced to one-half of its original value by biological processes when the rate of removal is approximately exponential.

Half-Life, Effective. The time required for a particular radionuclide in a system to be reduced to one-half its value from both radioactive decay and other processes such as biological elimination and burn-up when the rate of removal is approximately exponential.

Half-Life, Radioactive. For a single radioactive decay process, the time required for the activity to decrease to one-half its value by that process.

Half-Value Layer. The thickness of a specified substance that, when introduced into the path of a given beam of radiation, reduces it to one-half the original intensity. It is sometimes expressed in terms of mass per unit area (also called half-value thickness).

Health Physics. The art and science concerned with recognition, evaluation, and control of health hazards from ionizing radiation.

High Radiation Area. (1) Any area in which a major portion of the whole body could receive a radiation dose of 100 millirem in one hour. (2) An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.1 rem (1 mSv) in one hour at 30 cm from the radiation sources or from any surface that the radiation penetrates.

Hormesis. Beneficial results from radiation received, potentially improving the health or extending the life span of the organism.

Hot. An expression commonly used to mean "highly radioactive."

Individual Monitoring. (1) Assessment of dose equivalent by using devices designed to be worn by an individual. (2) Assessment of committed effective dose equivalent by bioassay (see Bioassay) or by determination of the time-weighted air concentrations to which an individual has been exposed, i.e., DAC-hours. (3) Assessment of dose equivalent by using survey data.

Individual Monitoring Devices. Devices designed to be worn by a person for the assessment of dose equivalent, such as: film badges, TLDs, pocket ionization chambers, and personal (lapel) air sampling devices.

Internal Dose. That portion of the dose equivalent received from radioactive material taken into the body.

Ionization. Any process by which an atom, molecule, or ion gains or loses electrons.

Ionization Chamber. A gas-filled enclosure for measuring radiation by means of ions produced therein.

Ionizing Radiation. Any radiation displacing electrons from atoms or molecules, thereby producing ions. Examples: alpha, beta, x and gamma radiation.

Irradiation. Exposure to ionizing radiation (see Exposure).

Isotopes. Different forms of the same chemical element that are distinguished by having different numbers of neutrons in the nucleus. A single element may have many isotopes. For example, the three isotopes of hydrogen are protium (H), deuterium (H), and tritium (H).

Licensed Material. Source material, special nuclear material, or byproduct material received, possessed, used, or transferred under a general or specific license issued by the State.

Limits. The permissible upper bounds of radiation doses.

Lost or Missing Licensed Material. Licensed material whose location is unknown. It includes material that has been shipped but has not reached its destination and whose location cannot be readily traced in the transportation system.

Member of the Public. Any individual either in a restricted (controlled) or unrestricted area. However, an individual is not a member of the public during any period in which the individual is a radiation worker and receives an occupational dose.

Minor. An individual less than 18 years of age.

Monitoring. The measurement of radiation levels, concentrations, surface area concentrations, or quantities of radioactive material and the use of the results of these measurements to evaluate potential exposures and doses.

Neutron. An uncharged elementary particle with a mass slightly greater than that of the proton and found in the nucleus of every atom heavier than hydrogen-1 (H). Neutrons sustain the fission chain reaction in a nuclear reactor.

Non-stochastic Effect. Health effects, the severity of which vary with the dose, and for which a threshold is believed to exist. Radiation-induced cataract formation is an example of a non-stochastic effect.

NRC. Nuclear Regulatory Commission

Occupational Dose. The dose received by an individual in a restricted area or during employment in which the individual's assigned duties involve exposure to radiation and to radioactive material from licensed and unlicensed sources of radiation, whether in the possession of the licensee or other person. Occupational dose does not include dose received from natural background, as a patient from medical practices, from voluntary participation in medical research programs, or as a member of the public.

Photon. A quantum of electromagnetic radiation.

Positron. An elementary particle with the mass of an electron but charged positively. It is the “anti-electron.”

Rad (acronym for radiation absorbed dose). The special unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs/gram or 0.01 joule/kilogram (0.01 gray).

Radiation. Alpha particles, beta particles, gamma rays, x rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions. Radiation, as used here, does not include non-ionizing radiation, such as sound, radio, or microwaves, or visible, infrared, or ultraviolet light.

Radiation Area. (1) Any area accessible to personnel in which there exists radiation originating in whole or in part within licensed material at such levels that a major portion of the whole body could receive in any one hour a dose in excess of 5 millirem, or in any five consecutive days a dose in excess of 100 millirems. (2) An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 5 mrem (50 μSv) in one hour at 30 cm from the radiation source or from any surface that the radiation penetrates.

Radiation Source. An apparatus or a material emitting or capable of emitting ionizing radiation.

Radioactive. Exhibiting radioactivity.

Radioactive Decay. The process by which radioactive material emits energy in the form of radiation.

Radioactive Material. A material of which one or more of its parts exhibit radioactivity.

Radioactivity. The property possessed by the nuclei of some elements (such as uranium) of spontaneously emitting radiation.

Radioactivity, Natural. Radioactivity of naturally occurring nuclides.

Radioisotope. An unstable isotope of an element that decays or disintegrates spontaneously, emitting radiation. More than 1300 natural and artificial radioisotopes have been identified.

Radionuclide. A radioactive nuclide.

Radiosensitivity (radiation protection). The relative susceptibility of cells, tissues, organs, organisms, and other substances to the injurious action of ionizing radiation. Radioresistance and radiosensitivity are usually employed in a comparative sense, rather than in an absolute one.

Rem (acronym for roentgen equivalent man). The special unit of dose equivalent. The dose equivalent in rems is equal to the absorbed dose in rads multiplied by the quality factor (1 rem = 0.01 sieverts).

Removable Contamination. Loose or smearable radioactive material present on a surface that can be transferred to a smear medium by rubbing with moderate pressure. It can also be picked up unknowingly on shoes, hands, and clothing.

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

Roentgen (R). A unit of exposure to gamma or x radiation (see Exposure).

RSO. Radiation Safety Officer

Scintillation counter. A counter in which the light flashes produced in a scintillator by ionizing radiation are converted into electrical pulses by a photo-multiplier tube.

Scintillator. A material that gives off light when radiation interacts with it.

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

Shield. Material intended to reduce the intensity of radiation entering a region.

Shielding. The use of shields. Also the material of which a shield is composed.

Sievert (Sv). The SI unit of dose equivalent. The dose equivalent in sieverts is equal to the absorbed dose in grays multiplied by the quality factor (1 Sv = 100 rems).

Smear; Smear Test. A procedure in which a swab is rubbed on a surface and the smear's radioactivity measured to determine if the surface is contaminated with loose radioactive material (sometimes called swipe).

Somatic Effects. Those results of radiation exposure which act on the person who has been exposed to the radiation.

Source Material. (1) Uranium or thorium, or any combination of uranium and thorium in any physical or chemical form. (2) Ores that contain, by weight, one-twentieth of one percent (0.05 percent), or more, of uranium, thorium, or any combination of uranium and thorium. Source material does not include special nuclear material.

Special Nuclear Material. (1) Plutonium, uranium-233, uranium enriched in the isotope 233 or in the isotope 235, and any other material that the State determines to be special nuclear material, but does not include source material. (2) Any material artificially enriched by any of the foregoing but does not include source material.

Spill. The accidental release of radioactive materials.

Stochastic Effects. Health effects which occur randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a linear function of dose without threshold. Hereditary effects and cancer incidence are examples of stochastic effects.

Surface Contamination. The deposition of radioactive materials on a surface.

Survey. An evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal, or presence of radioactive material or other sources of radiation. When appropriate, such an evaluation includes a physical survey of the location of radioactive material and measurements or calculations of levels of radiation, concentrations, or quantities of radioactive material present.

Survey Meter. A portable instrument that measures the exposure rate or radiation intensity.

Swipe. Synonym for smear.

Thermoluminescence. A process of releasing radiation-induced energy as light in response to heating.

TLD (Thermoluminescent Dosimeter). A solid state radiation dosimeter that can absorb energy that may be released later, as light, by heating the material.

Total Contamination. The sum of the fixed and removable contamination. Total contamination is usually used to set limits on material and equipment which will be unconditionally released from radiologically controlled areas.

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

Tracer. A nuclide introduced into a system which permits investigators to follow the behavior of some component of that system.

Unrestricted Area. An area, access to which is not controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials, and any area used for residential quarters.

Waste, Radioactive. Equipment and materials (from nuclear operations) that are radioactive or have radioactive particles on them and for which there is no further use. Wastes are generally classified as high-level or low-level, depending on the amount of radiation emitted by the material.

Whole Body. For purposes of external exposure, head, trunk (including male gonads), arms above the elbow, or legs above the knee.

X ray. A penetrating form of electromagnetic radiation emitted either when the inner orbital electrons of an excited atom return to their normal state or when a dense metal target is bombarded with high-speed electrons. X rays are always non-nuclear in origin.