Radiation Safety Manual

University of Massachusetts Amherst
Environmental Health and Safety
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January, 2007

This manual must be returned to Radiation Safety Services when the Approved Principal Investigator no longer uses radioisotopes or radiation generating machines and all permits issued by the Radiation Use Committee have been deactivated.

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Note: There are no forms in this manual. The current edition of any forms referenced in this manual can be found on the web at http://www.ehs.umass.edu

The Program & Basic User Requirements

How the Program Works

Radiation Safety Organization

University of Massachusetts Amherst (UMass) has an on-site Radiation Safety Officer (RSO). The RSO maintains direct line reporting to the Director of Environmental Health and Safety who keeps university management informed of significant radiation safety issues. The responsibilities of the RSO are described in the license issued by the Massachusetts Radiation Control Program (MRCP) which permits the use of radioisotopes at UMass. The RSO reports all issues concerning audits, inspections, licensing, waste management, direction and needs of the radiation safety program to the Radiation Use Committee (RUC).

The radiation safety organization at UMass is shown in **Figure 1**.

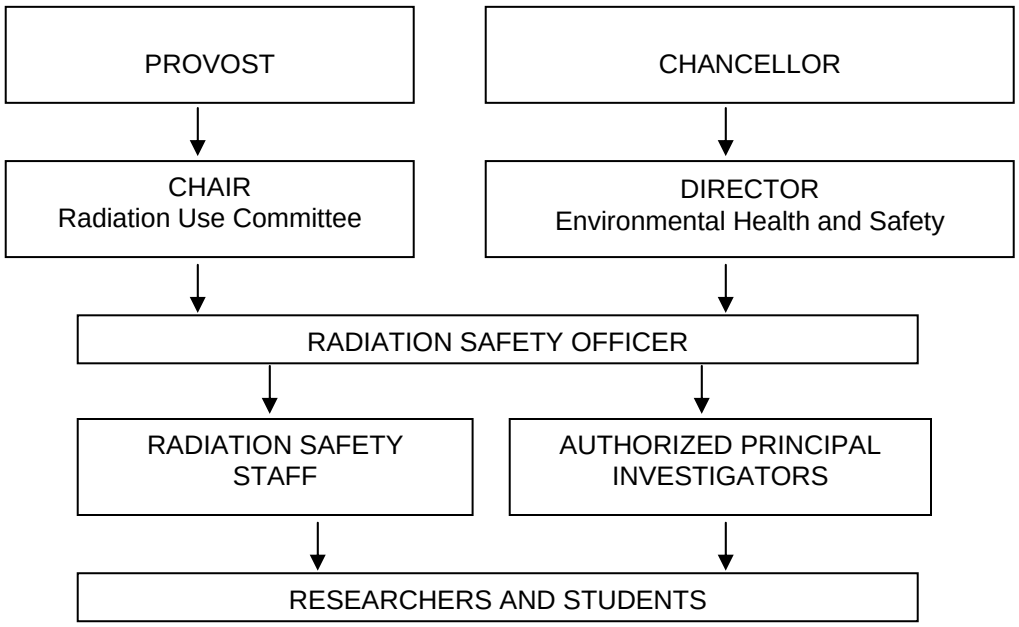

Figure 1. UMass Radiation Safety Organization

The RUC is composed of university professors and management with expertise in the use of radioisotopes and radiation generating machines who peer review all radiation experimental protocols. No radioisotopes or radiation generating machines may be used, ordered or transferred at UMass with the written approval of the RUC. The authority of the RUC comes from the Massachusetts Radiation Control Program (MRCP) which licenses the use of radiation in the Commonwealth. The function of the RUC is required by and its responsibilities described in MRCP regulations. The RUC meets once each calendar quarter.

The Authorized Principal Investigator (API), as designated within the protocol and as approved by the RUC, is the person responsible for ensuring compliance with all government regulations as well as all UMass policies and SOP's. This responsibility may not be delegated by the API to a colleague, subordinate or student.

As Low As Reasonably Achievable (ALARA)

UMass is committed to maintaining radiation exposures to staff, students, members of the general public, and the environment As Low As Reasonably Achievable (ALARA). This commitment from UMass management provides the basis for the radiation safety practices described in the UMass Radiation Safety Manual and in associated Standard Operating Procedures (SOP's). In addition, the RUC sets an ALARA dose limit for radiation users far below those dictated by regulatory agencies.

The current ALARA dose limit for personal exposures at the University of Massachusetts Amherst as set by the RUC is ten percent (10%) of any federal, state or local regulatory limit. Written approval is required from the RUC before any person exceeds the ALARA dose limit. Historically, the ALARA limit has been easily achieved given typical radiation uses at UMass.

The fundamental objective of ALARA is the reduction of radiation exposures to the minimum levels while trying not to restrict operational practices necessary for research and by considering the economic consequences of engineered solutions to dose issues versus the amount of dose reduction. In general, radiation safety programs that abide by the ALARA philosophy incorporate sound health physics concepts, the use of appropriate personal protective equipment as well as physical and administrative controls which are technically and economically feasible for the academic environment. The training of radiation users, the periodic inspection of radiation use locations and the periodic auditing of the radiation safety program augment these practices and assure that UMass will continue to be a responsible custodian of radiation sources.

The Definition of Compliance

Various designations and terminology used throughout this manual express the degree of rigor, i.e., compliance with or application to specific criteria.

The words "shall", "must" and "will" indicate an **absolute requirement** to maintain compliance with regulations, SOP's, UMass policies or directives from the RUC that ensure adequate radiation protection for employees. Upon determination by the RSO that any person found ignoring or not obeying the absolute requirements stated in this manual, SOP's, UMass policies or directives from the RUC, that person may have the privilege to use radioisotopes or radiation generating machines revoked immediately. The privilege to use radioisotopes or radiation generating machines may be reinstated by petitioning the RUC at the next scheduled meeting.

The Regulatory Agencies

All uses of "radioactive material or radiation generating machines" (RM) shall be conducted following the requirements established by the Nuclear Regulatory Commission (NRC) or by the Commonwealth of Massachusetts Radiation Control Program for the Massachusetts (MRCP). In addition to these agencies, that grant licenses to possess and use RM, other state agencies may also have regulatory oversight for certain operations involving radiation producing equipment, accelerator-produced radionuclides, or discharges of RM to the environment.

The use, handling, and storage of open and sealed source RM as well as the control of personal radiation exposure are regulated in Massachusetts by the MRCP under 105 CMR 120, a copy of which is available via the internet.

The release of radioactive materials (airborne and liquid effluents) to the environment is regulated in Massachusetts by the MRCP under 105 CMR 120.296.

X-ray equipment used for research is registered in Massachusetts by the MRCP under Chapter 105 CMR 120.400. MRCP conducts inspections related to radiation producing equipment for human or veterinary use. This agency also licenses the possession and use of accelerator-produced radionuclides.

A written copy of the UMass Amherst policy for ensuring the safe use of radiation-generating equipment is available from EH&S.

Regulatory agencies may also impose additional conditions and requirements that are more restrictive than those in published regulations, in the licenses or permits that are issued to UMass. These imposed "license conditions" have the same authority and weight of law as the requirements contained in MRCP and NRC regulations.

The UMass radioactive materials licenses in force as of the date of this manual are:

60-0107	Mass. Dept. of Public Health, Radiation Control Program
20-00882-08	U.S. Nuclear Regulatory Agency

The MRCP license is a License of Broad Scope, Type A which allows the RUC and RSO to act independent of direct oversight by the MRCP. This type of license contains many privileges, such as UMass being able to peer-review research protocols involving RM instead of sending each protocol to the MRCP for approval prior to beginning an experiment. However, a Type A license also requires that UMass research and support personnel act in a responsible and self-inspecting manner. UMass radiation safety program personnel, RUC members and Authorized Principal Investigators are all responsible for being knowledge of enforcing regulations. Anyone who is approved as an Authorized User or Approved Principal Investigator is personally responsible for reporting any real or suspected violation of regulations and license conditions as well as UMass radiation safety policies and procedures to the Radiation Safety Officer.

Audit of the Radiation Safety Office

As a part of the quality assurance program and to ensure compliance with the UMass Amherst ALARA policy, UMass EH&S may allow an outside entity to perform a formal audit of the radiation safety program to assure compliance with all regulatory requirements. Compliance audits are normally performed by individuals with expertise in university health physics and radiation safety, the applicable NRC or agreement state regulations and experience with experiments involving RM and radiation producing equipment. Auditors are typically not employed at UMass Amherst.

These audits consist of inspecting laboratories, dosimetry records, wipe test survey reports, external radiation survey reports, leak test reports, bioassay reports, training records, instrument calibration records, radioactive material inventory records, effluent releases, and waste management areas and records. The auditor summarizes findings and provides recommendations in a report submitted to the Radiation Safety Committee and, or to senior management. The RSO is required to provide a formal audit response, outlining necessary program modifications and enhancements, where needed on a timely basis.

Audit of API's & Authorized Laboratories

The RUC maintains an annual review program that examines the activities of the UMass Radiation Safety staff, API's, researchers and students who are authorized to use RM. Routine and unannounced laboratory audits, review of experimental techniques and contamination surveys ensure that radiation laboratory researchers and students are properly and safely using RM. These operations are performed by the RSO (or designee) as stated in this manual. These surveys and audits are designed to mimic those used by regulators during inspections of

academic institutions so as to determine if a particular RM use location needs adjustments in practices. The RSO is responsible for maintaining records of surveys and audits for the RUC.

All radiation monitoring techniques and radiological analyses are performed using current good health physics practices recognized as typical for an academic institution in addition to using NIST-traceable radioactive standards and sources. As part of its quality assurance program, Radiation Safety may send out samples for analysis by a third party laboratory. The analyses may be performed on bioassay samples, calibration confirmation samples or effluent samples, as needed.

Laboratory audits include a review of the devices in place to ensure the security of RM. To this end, RM inventory records are carefully reviewed for each use location. Receipts of RM are compared with standing inventories.

Internal and external dosimetry records are audited for discrepancies and compared with previous results. Investigations of non-typical results are performed by the RSO to ensure that doses are maintained ALARA. Historical trends in radiation exposures are tracked by the RSO.

UMass license requirements states that no radiation survey instruments shall be used if they are not calibrated within a twelve month period. Therefore, Radiation Safety ensures that survey instruments are calibrated every year and UMass only calibrated instruments are in use.

Finally, Radiation Safety reviews training requirements and documentation to assure that individuals working with RM have adequate training and credentials for the work being proposed.

These activities are ongoing and provide a strong degree of assurance that the radiation protection program at UMass is providing adequate safety for the research staff.

Radiation Safety Standard Operating Procedures (SOP's)

Specific SOP's are written which detail many of the requirements set forth in regulations, the UMass radiation use license and in this manual. All persons using RM are required to read those SOP's relevant to their operation. Radiation Safety SOP's are maintained either electronically (for example, on the UMass EH&S website (www.ehs.umass.edu)) or in print at the EH&S office. Because SOP's are added and updated continually, RM users are urged to visit the EH&S website periodically for the latest information.

Radiation Safety Records

Radiation Safety is required to maintain many different records to ensure compliance with regulations. In addition, other records are maintained to track trends and describe the historical use of RM. Some typical records kept by the radiation safety program are:

Personnel Dosimetry Records – These include whole body dosimeter and ring dosimeter reports from the dosimeter contractor. In addition, the RSO may require researchers to provide bioassay samples or measurements to determine if there has been a thyroid exposure or if a radioactive compound has been internalized. These records comprise a person's lifetime cumulative radiation dose exposure and are maintained for the life of the institution. These records are kept private and may not be released without a signed authorization from the researcher of record.

Training records – These documents are routinely audited by regulatory agencies during an inspection, such as radiation-safety training sign-in sheets for the various sessions. Also included are hardcopies of the presentations, quiz results, and on-line training session evaluations.

Radioisotope Inventory and Waste Records – Individual container records and cumulative totals of radioactive waste are routinely gathered and maintained by the RSO in order to satisfy the radioactive materials license requirements for UMass.

Effluent Monitoring Records – Measurements and calculations associated with legally permissible discharges to the air and water are routinely maintained to verify compliance with environmental regulations.

Survey and Decommissioning Records – The survey measurements performed by users and the Radiation Safety staff illustrate the contamination levels that arise due to typical operations involving radioisotopes. This data as well as an evaluation by Radiation Safety is used to show that locations that wish to no longer use RM were decontaminated to below legal limits. A "decommissioned" former use location has been cleared for unrestricted use. A decommissioned location may be reopened for use with RM by contacting Radiation Safety.

Other Records – The RSO must maintain many other records to indicate that the radiation safety program is operating at an acceptable quality level. Some examples of these records include survey meter calibration certificates, radioisotope incident reports, experimental protocol forms, radioisotope user application forms and sealed source surveys.

The record retention time for each record is dictated by the regulatory agency. All radiation safety records, except the private personnel dosimetry records, are available for public viewing by contacting the Radiation Safety Officer.

Responsibilities of Radiation Safety Program Personnel and Users

License Conditions and Regulations

MCRP regulations require that a Radiation Use Committee (RUC) be formed for the type of license that has been issued to UMass. The type of license held by UMass allows just about any use of radioisotopes on campus provided that the radioisotopes are not used in humans or in animals presented as food post the introduction of radioisotopes into the animal, pursuant to the conditions in the MRCP license and the representations UMass made to the MRCP during the licensing process. This means that instead of a researcher having to submit an experimental protocol to the state regulatory agency, a protocol must be submitted to the RUC for review and approval.

Upon approval of an experimental protocol using RM, the RSO keeps the protocol on file and audits the use of the RM to ensure regulations and license conditions are being followed by the users. In essence, the RUC and RSO perform some of the routine undertakings of the regulatory agency and must report certain violations to the MRCP as they occur.

Radiation Use Committee (RUC)

A viable and robust RUC is required by the type of MRCP license held by UMass. The RUC defines and implements policies necessary to assure the safe handling, monitoring, and inventory of radioactive materials.

The RUC is composed of experienced RM users who are familiar with the organization, acquisition and use of RM on campus. Typically, a member from each department that has RM users has a member on the RUC. However, all RM users must follow any directives issued by the RUC, even a representative form the RM user's department does not sit on the RUC.

The RUC administers the radiation safety program with the assistance of the RSO.

Typical duties and responsibilities of the RUC

- Maintain the radiation safety program in a manner conforming to the license requirements.
- Approve new uses and change of status of users with respect to radiation safety. This includes reviewing the training of new Authorized Principal Investigators, experience in handling RM safely and approving experimental methodology for the proper use of RM in the laboratory through peer review.
- Receive, peer review and act on all changes to existing applications for the use of RM.
- Provide technical advice to Authorized Principal Investigators on matters regarding radiation safety.
- Review reports from the RSO on radiation area monitoring, contamination, and personnel exposure.
- Issue corrective measures and, if appropriate, temporarily withdraw approval for the use of RM until a radiation safety issue is corrected.
- Conduct, or have conducted, an annual review of the Radiation Protection Program relative to regulatory audit requirements.
- Prescribe the appropriate safety standards for the safe use of RM in conforming to licensing requirements and conditions.

The RUC will meet at least quarterly. Records shall be kept of RUC meetings and transactions for review by regulators during an inspection.

Radiation Safety Officer

The RSO acts to monitor the RM users for the RUC. The RSO reports to the RUC any concerns that could lead to regulatory issues that could hinder the unencumbered use of RM at UMass. The RSO ensures that RM users implement of any decisions made by the RUC. The RSO ensures the RM users follow the radiation safety program as described by procedures and criteria contained in this manual, licenses and any other representations made to the regulatory agencies concerning the radiation safety program at UMass.

The RSO has experience and training in academic radiation protection programs, procedures and methods. The RSO maintains a current knowledge of all the applicable federal and state regulations dealing with the safe use, disposal and transport of ionizing radiation. The RSO shall advise the RUC on matters of radiological safety.

Typical Duties and Responsibilities of the RSO

- Monitor site-wide activities involving the use of RM, including the laboratory, the environment and personnel monitoring.

- Maintain records required to comply with Federal or State regulations

- Maintain liaison with Federal and State regulatory officials involved in radiation protection activities.

- Review and approve qualified requests for the procurement of RM and for shipment of RM from UMass Research facilities in accordance with criteria and procedures of this manual and Standard Operating Procedures (SOP's).

- Administer the personnel monitoring program for all radiation protection activities at UMass facilities, including issuance of dosimetry devices and overseeing the bioassay program.

- Supervise and coordinate the radioactive material waste storage and disposal programs.

- Investigate accidents or unusual occurrences and recommend appropriate corrective measures to ensure radiological safety.

- Oversee routine radiation safety tasks delegated to the API and other personnel involved with the radiation safety program. Delegation of these duties does not imply that the RSO relinquishes the responsibility for these safety issues.

Authorized Principal Investigator (API)

An individual who is granted authority by the RSO or RUC to use and supervise the use of RM or radiation generating equipment in approved laboratory areas are designated as Authorized Principal Investigator or "API".

> **Note: Each person requesting Authorized Principal Investigator status must first complete the requirements for an Authorized User (below).**

An integral part of the API approval process by the RUC is evaluating the experience in utilizing RM, the API familiarity with procedures and requirements set forth in Radiation Safety Manual and other pertinent radiation safety precautions for the experiment.

Each API and laboratory is separately authorized to use specific radionuclides in quantities not exceeding individual possession limits approved by the RUC (where applicable) or the RSO. Although the RSO is ultimately responsible for ensuring compliance with the total radiation safety program, the API is responsible for the daily compliance with radiation safety requirements and must, at a minimum:

- Ensure compliance in the laboratory to applicable program requirements and radiation protection criteria set forth in this manual or pertinent SOP's.

- Provide “hands-on” training to staff members who utilize RM, i.e., authorized users, in laboratory areas under the approved jurisdiction of the API.

- Ensure that RM is secured when in storage or under constant surveillance when in use.

- Ensure that visitors, students or staff that are allowed to access to areas designated for radiation use follow all applicable rules and are warned of any potential radiation hazards.

- Monitor laboratory areas as appropriate and maintain the documentation to assure compliance with limits set forth in this manual or pertinent SOP's.

- Contact the RSO in the event of an accident or unusual occurrence including: loss of RM, spills or discharges, real or suspected intakes of RM by laboratory personnel, and accidents that occur in areas where RM are utilized.

- Ensure that adequate planning is performed prior to the use of RM in experiments conducted in approved areas. Detailed procedures must be submitted to the RSO describing the use of RM and waste produced from RM in the experiment.

- Communicate with the RSO at least two weeks in advance whenever major changes are anticipated in operational procedures, radioisotope techniques, alterations in the laboratory setup (e.g., removal or modification of a radiochemical fume hood), change of laboratory

assignment, addition or removal of personnel, or new operations which might lead to personnel exposures or discharges to the environment.

- Cooperate with the RSO and RUC (where applicable) to assure the safe use of RM at UMass facilities.

- Maintain records in accordance with requirements set forth in this manual and pertinent SOP's, including radiation monitoring records, waste disposal records, and radioactive material inventory records.

The delegation of the above routine radiation safety tasks does not imply that the RSO relinquishes responsibility for these safety issues.

Authorized Users

An authorized user is an employee, investigator, researcher or student who has:

- Registered with the RSO to use radioactive materials.

- Completed the full course of introductory radiation safety training for the type of work begin done, including practical experience training from the API on the protocol to be used.

- Commits to following and demonstrates full compliance with government regulations and the requirements of the UMass Radiation Safety Program.

Typical Responsibilities of the API and Authorized User

- Must be familiar with and adhere to the requirements set forth in this manual, in pertinent SOP's, and in the radiation protection training programs.

- Notify the RSO when RM is ordered or transferred before it arrives at laboratory

- If an unsafe condition arises, such as a fire, while working with or while in the possession of RM, take appropriate actions as outlined in the UMass emergency procedures and immediately notify the RSO as soon as possible.

- Notify the RSO immediately of any change in exposure status, of any unusual exposure or of an occurrence that was not anticipated in the protocol (e.g., pregnancy, intake, ingestion or injection of radionuclides for medical purposes, loss of dosimeter, spill, explosion, overflow, equipment or lab ware failure, puncture wound or cut, etc.).

- Provide a safe working environment for other persons whose activities require access to areas designated for radiation use. These include (but are not limited to) students, researchers who do not use radioactive material, material handlers, maintenance workers, custodial staff, security personnel, OIT staff and outside contractors. Some of their activities may require coordination with the RSO so that persons who enter posted areas and the types of service conducted is performed following the guidance, restrictions and other requirements of a Radiation Work Permit, Maintenance Service Request, or other authorization from the RSO.

Visitors

Visitors entering radiological posted areas must abide by all radiation safety regulations in effect for the area, including donning the appropriate personal protective equipment (PPE). The API for

the area shall contact the RSO for radiation dosimeters for visitors, as required. Visitors shall be instructed of any potential radiation hazards by the API.

Obtaining Approval to Use RM

Qualifications for Authorized Users and API's

Individuals who wish to work with RM at UMass are required to attend a radiation safety training session given by RSS. Attendance at this session is mandatory. Once the training session is completed, an Authorized User is assigned to work under the permit granted to an API. The Authorized User must be instructed in the proper use of RM and/or radiation producing equipment prior to conducting work with RM. It is the API who must provide this "hands-on" experience sessions at the laboratory bench and provide any additional safety instruction regarding any expected safety issues during the use of any individual protocol to the new user.

Each person who wishes to use radiation must make a reservation to attend a training session and submit a "Radiation Worker Application" form (available on the EH&S website).

Training

UMass is committed to providing each user information about the radiation safety program. This training program ensures that persons who work with RM have the necessary training to understand policies and procedures specific to the UMass safety program. In addition, API's are responsible for providing the proper tools and methods necessary to safely perform research projects for each specifically approved activity. Experience and training credentials of API applicants are reviewed by the RUC (where applicable) and the RSO prior to final approval.

API's perform a vital part of the radiation safety training program by providing experience sessions and verifying that the trainee has obtained a level of competence to be able to perform the specifically approved activity without direct supervision.

The RSO (or designee) conducts radiation safety training sessions for employees prior to work with RM. Each new user must complete Introductory training which includes a traditional lecture where program requirements are discussed. Documentation of these meetings and attendance records are maintained by the RSO. Web-based introductory training may be taken at any time. Training sessions are typically conducted on a routine basis which is detailed on the UMass EH&S website.

A list of the typical topics covered during a radiation safety training session is presented in Appendix B, Table 1. The RSO may adjust these topics without notice depending on the needs of the audience. Both API's and the Authorized Users are instructed in the listed topics. Refresher training is required of all radiation users and supervisors biannually. Refresher training includes a subset of the listed topics. Other employees, such as maintenance personnel, animal care providers, material handlers, and law enforcement staff receive training that is commensurate with their responsibilities. In addition, special training sessions are also provided in specific areas such as radiosynthesis safety, the use of the gamma irradiator use and the use of radiation-producing machines or instruments.

Requesting an API Permit from the RUC

Designated API's usually have advanced degrees in their specialty field and several years of experience and/or training in the safe handling of RM or radiation-producing equipment.

Prior to being designated as an API, the candidate must demonstrate to the RSO knowledge and capability in radiation safety fundamentals and the requirements and procedures established in this manual and relevant SOP's.

The RSO reviews with API candidates the requirements set forth in this manual, relevant SOP's, and the RM license during the application process.

Explicit radiation safety procedures for each research experiment or operation are tailored to the experiment and are established by the API prior to its implementation. Where appropriate, the guidance and requirements presented in radiation safety SOP's should be incorporated into experimental protocols to assure the safe handling of RM. The uniqueness of an experiment may require modification of these procedures. Accordingly, the API should consult the RSO for technical guidance and to determine the proper methods for safely handling and disposing of RM, while maintaining the experimental objectives.

The API candidate completes the *Radiation User Application* and the *Request to Use Radioactive Material or Radiation Generating Machines* (see Forms Section at the back of the Manual) which contains relevant information for evaluating the protocol. A detailed procedure or flowchart showing how the RM are to be used in the proposed research is submitted at this time. The RSO and the Committee (where applicable) review these materials. During this review the RSO (or Committee) assesses the candidate's previous experience in the safe use of RM in light of the proposed usage. The RSO or the RUC uses this information as well as other information dealing with the nature of the proposed research to evaluate the safety competency of API candidates and staff. Any special requirements are noted by the RSO at this time and added to the request form.

Upon completion of application review by the RUC, a permit to use radiation is issued to the API by the RSO. The permit and associated procedure or protocol is reviewed and updated (if required) every two years.

Approved API's periodically receive continuing training via special meetings or via written memos by the RUC and/or the RSO on new policies and procedures that directly or indirectly influence research efforts utilizing RM.

Approval For Radioisotope Work in Experimental Animals

API's who wish to conduct research using radioisotopes in experimental animals must complete contact the UMass Institutional Animal Care and Use Committee (IACUC). This approval form is required prior to conducting any animal research involving the use of radioisotopes. The IACUC requires a completed approval form where radioisotope is reviewed as a part of the protocol the researcher submits to the IACUC for review and approval.

Laboratory Requirements & Access Control To Radioisotopes & Radiation

Access to RM is regulated and controlled by administrative procedures and physical security. All API's, Authorized Users, employees and visitors in a radiation use area must abide by any and all measures that are in place to maintain the security of licensed radioactive materials and radiation generating machines or instruments.

Administrative Controls In the Laboratory

Laboratory areas in which RM will be used must be formally approved by the RUC and/or the RSO depending on the level of activity requested by the API. Addition or deletion of approved

areas can occur at any time and a current listing of approved laboratories for radioisotope use is maintained by the RSO. The RSO also maintains a complete list of all formerly-used areas.

It is recognized that some radiation posted laboratories may also be used for non-radioactive work. These laboratories may have no entry restrictions, but access to RM within the laboratory must be restricted.

Note: Under no circumstances may RM stock samples be left unattended or unsecured in a laboratory.

Some laboratories or areas use high activity samples, have special radiological controls in place or have been deemed in need of extra precautions by the RSO. These laboratories or areas are designated controlled or restricted.

Controlled Areas

Laboratory areas that are posted and monitored for the expressed purpose of protecting individuals from exposure to radiation and radioactive material are termed *controlled areas*. These areas are designated for the use of radionuclides or radiation producing equipment such that:

- An individual in this laboratory or area could potentially receive a total radiation exposure in excess of 10% of the limits specified for occupational workers.
    - A minor may not receive a radiation exposure in excess of 10% of the limits specified for occupational workers.
- The laboratory or area may be used by a pregnant woman such that she may not receive a total radiation exposure in excess of 500 mrem in the course of her pregnancy.
- Airborne concentrations of RM could result in an intake in excess of 10% of the ALI as published by the appropriate regulatory agency.
- Unsealed RM is present such that surface contamination levels could exceed ALARA limits.
- The experimental protocol could lead to RM undergoing a process that could lead to a behavior that could cause cross-contamination.

Restricted Areas

A *restricted area* refers to a controlled area where access is restricted, usually by key-lock security, to authorized personnel only. Restricted areas may include certain special facilities, such as low level radioactive waste (LLRW) decay-in-storage areas, radiosynthesis or iodination laboratories. In restricted laboratories or work areas:

- It may be likely that an individual could get a dose, either internal or external, that exceeds 100 mrem.
- Radiation levels may be present that result in an external dose of 5 mrem/hr at 30 cm from any sources of radiation (defined as a Radiation Area).
- Radiation levels may be present that result in an external dose of 100 mrem/hr at 30 cm from any sources of radiation (defined as a High Radiation Area).

- Radiation levels may be present that result in a dose of 500 rem at 100 cm from any sources of radiation (defined as a Very High Radiation Area).

Surface Contamination Limits

In order to maintain doses ALARA, RSS performs routine contamination and radiation surveys of all laboratories that use open-source radioactive material, as in a wet lab. It is incumbent on all laboratory personnel to perform contamination surveys at the conclusion of an experiment or at the end of the work day. These surveys may be as simple as using the proper survey meter to survey a work area or they may be more involved for hard to measure radionuclides, such as tritium (^{3}H) compounds, which require a wipe test to be counted on a liquid scintillation counter.

The proper survey method for each radionuclide depends on the radionuclide energy, the type of survey instrument being used and the form (solid, liquid or gas) of the compound. Laboratory personnel should contact RSS regarding any questions concerning the proper survey instrument, the efficiency of their survey method and the proper technique for measuring the radionuclide and compound being used in their experiments.

Note: Wipe test results must be reported in disintegrations per minute (dpm).

All hand held survey meters report results in counts per minute (cpm). These values must be converted to disintegrations per minute (dpm). Contamination limits are in Appendix A, Table 1.

Physical Controls in the Laboratory

UMass Amherst maintains a security system and, in certain locations, a professional security team responds when certain alarms are activated.

The backbone of the security system at UMass Amherst are laboratory personnel, specifically the individual user and the API. It is the responsibility of laboratory personnel to maintain control of RM, to track the use and transfer of RM, to limit access to the laboratory when radioactive material is in use, to secure RM in locked storage locations when not in use and, in many instances, to ensure all doors are locked when a laboratory is unoccupied.

All radioisotope storage locations and those laboratories containing radiation producing equipment which are posted as "HIGH RADIATION AREA," "VERY HIGH RADIATION AREA," "AIRBORNE RADIOACTIVITY AREA," or "RADIOACTIVE CONTAMINATION AREA" shall be locked when not attended by personnel trained in the safe use of RM, have the correct instrumentation for the type and form of RM on hand all of times and assign knowledgeable, trained personnel assigned to handle emergency calls at all hours, especially non-routine and vacation schedule hours.

Radiation Warning and Postings Requirements for RM Use Laboratories or Areas

The purpose of posting and labeling is to identify the potential or actual presence of RM or radiation levels in excess of specified limits. Radiological posting is also used to identify areas, containers, or equipment which require special controls in order to assure the safe use of RM. Labels and signs shall not be used for any purpose other than radiological control as described below or as specified by the RSO. The radiation symbol as shown in Figure 2. is used to denote controlled areas, radiation areas, contaminated areas or contaminated equipment. The darkened area of the symbol and all lettering shall be purple, magenta, or black on a yellow background. Requirements and limits for posting are presented below.

The radiation symbol and the words "CAUTION, RADIOACTIVE MATERIALS" or "CAUTION, RADIATION GENERATING MACHINE or X-ray Equipment" shall be posted at the entrance of a laboratory or storage area when containing RM.

Figure 2. Radiation Warning Sign

The radiation symbol and the words "CAUTION or DANGER, RADIATION AREA" shall be posted at all entrance locations to areas where external exposures could exceed 5 mrem/hr at 30 cm from any sources of radiation. All personnel entering a radiation area are required to wear personal radiation monitoring devices assigned by the Radiation Safety Office.

The radiation symbol and the words "CAUTION or DANGER, HIGH RADIATION AREA" shall be posted at all entrance locations to areas where external exposures could exceed 100 mrem/hr at 30 cm from any sources of radiation. All personnel entering a high radiation area must wear assigned personal radiation monitoring devices and be under the supervision of the RSO.

The radiation symbol and the words "CAUTION or DANGER, AIRBORNE RADIOACTIVE AREA" shall be posted at all entrance locations to areas where internal exposures could exceed 10% of the ALI specified by the appropriate regulatory agency.

The radiation symbol and the words "CAUTION, RADIOACTIVE CONTAMINATION AREA." shall be posted at all entrance locations to areas where internal exposures (e.g., due to resuspension) could exceed 10% of the ALI by the appropriate regulatory agency.

No posting is required for a room or area if a sealed source is present provided that radiation levels at 30 cm from the source container or housing is less than 5 mrem/hr.

Labels and signs shall not be used for any purpose other than radiological control as described below or as specified by the RSO. Access to RM and radiation-producing equipment is regulated by administrative and physical controls.

Labeling Requirements For Containers

Containers of RM include laboratory waste pails and drums and some vessels used in the research protocols. All shall have a label affixed to the container that displays the radiation symbol and the word "CAUTION, RADIOACTIVE MATERIAL" or "DANGER, RADIOACTIVE MATERIAL." In addition, the label shall contain sufficient information pertaining to its contents, allowing individuals handling the container or working in its vicinity to take the necessary precautions and minimize radiation exposures. Labels are not required when: Labels are not required when:

The container is ready for transport and labeled according to State and Federal regulations (i.e., U.S. Department of Transportation Title 49), is in a secured area under the control of the RSO, and a description of the isotopic contents is in the room, or

Laboratory containers hold materials in transient procedures lasting only a few hours that are disposed of immediately upon the completion of an experiment and under the control of or in the presence of the Authorized User.

Decommissioning Requirements

A radiation use location is said to be "decommissioned" if all RM is removed from the location, all RM in inventory is checked as being accounted for, all radiation warning labels have been removed and a final contamination survey is performed by Radiation Safety. Upon completion of these steps, the RSO issues a document releasing the laboratory or equipment for unrestricted use and files the confirmation documentation.

Note: Only Radiation Safety may remove radiation warning labels, tape, signs or other markings from doors, laboratory benches, hoods, instruments, lab ware or other equipment used with radiation.

Decommissioning Individual Pieces of Equipment

Equipment with radiation warning labels or embossed tags must not be given over for disposal, transferred to another location or moved without it first being surveyed. Survey and decontamination of equipment to levels below the limits specified in this manual is must be done by the user for all equipment, instruments, refrigerators, freezers, lab ware or other apparatus where RM was used or stored. The RSO (or designee) shall confirm by both external survey (using an appropriate survey meter) and wipe tests that any residual radioactive contamination of the laboratory or equipment is both below acceptable levels and is ALARA. Upon confirming that the equipment survey is acceptable, Radiation Safety will remove any radiation warning tags, postings, stickers, labels or other signage.

NOTE: Only Radiation Safety personnel may remove radiation warning signage due to record keeping requirements.

Records of Decommissioning Installations or Equipment

All records, surveys, maps or lists of formerly used areas and equipment are maintained by the RSO indefinitely for inspection by state and federal regulators.

RM Inventory

Sealed Radioactive Sources

Sealed radioactive sources are any materials that are permanently bonded or fixed in a capsule or matrix designed to prevent the release or dispersal of such radioactive material under the most severe conditions that may be encountered in normal use and handling. Sealed sources controlled under the RM license are routinely inventoried and tested for leakage by the RSO or designee as follows:

Beta/Gamma emitters with >100 uCi, at least once every 6 months, or at any time it is suspected that physical damage has compromised the integrity of the source.

Alpha emitters with >10 uCi, at least once every 3 months, or at any time it is suspected that physical damage has compromised the integrity of the source.

Sealed sources exhibiting leakage greater than 0.005 uCi shall be removed from further operation.

A report will be submitted to the MRCP, as required. The report to the MRCP must include the source serial number, the isotope, the source activity, leak test results, and corrective action.

Inventory of Radioactive Materials

Records of the types of radionuclides and activities present at UMass facilities are maintained and updated regularly by the RSO on a schedule dictated by the MRCP license or other regulatory directive. The sealed source leak test, if performed by the RSO, qualifies as an inventory. The API is required to return to the RSO a completed inventory report on a standardized form within the agreed upon time frame. This report shall provide an accounting of RM received, transferred, and disposed of, as well as decay of current inventories of RM. The RSO audits these reports to assure accuracy relative to the previous inventory, the previous period's activities, receipts, and reported transfers from other API's. Inventory discrepancies are investigated by the RSO (or designee) and the records updated as needed.

Based on the inventory frequency, the RSO (or designee) generates a facility-wide radioisotope materials inventory. The inventory ensures that radioisotopes activity levels are maintained below the quantities authorized by license conditions. In addition, the RSO (or designee) maintains an annual summary of the RM inventory.

Control of Personal Exposure

Occupational Dose Limits for Persons 18 Years of Age and Older

The Radiation Use Committee has made it an **absolute requirement** to no researchers exceed **ten percent (10%) of any dose limit** without prior written consent from the Radiation Use Committee (see "ALARA Limit"). Radiation exposures (which include doses from radionuclides internal to the body and from sources external to the body) to laboratory personnel who utilize RM shall be limited to 10% those shown in Appendix A, Table 2 without special written permission from the RUC. As government regulations differentiate between persons 18 years of age and older, these ALARA dose limits only apply to persons over the age of 18.

Occupational Dose Limits for Persons Under 18 Years of Age

Employees under the age of 18 years who access areas where radioactivity is being used shall be limited to 10% of the ALARA dose limits previously described for laboratory personnel 18 years of age and over (Appendix A, Table 2).

Dose Limits to Embryo/Fetus

A female employee who is working in, or who has access to, areas utilizing radioactive sources shall immediately notify her Supervisor and the Medical Department when she knows of her pregnancy. Declaration of pregnancy to the RSO is voluntary. The "Radiation Safety Voluntary Pregnancy Declaration" form may be used to declare a pregnancy to the RSO.

External exposure to the embryo/fetus shall be limited to 0.5 rem during the entire pregnancy for the female authorized user who declares her pregnancy in writing. The dose to the embryo/fetus shall be determined as the sum of the deep dose equivalent and the dose to the embryo/fetus

due to radionuclides taken up during the entire pregnancy. The dose rate to the embryo/fetus shall also be limited to less than 0.05 rem per month. If, for example, the dose to the embryo/fetus has been calculated to have exceeded 0.45 rem by the time the employee declares her pregnancy, the remaining dose will be limited to 0.05 rem for the balance of the pregnancy.

Previous Exposure History

The Authorized User working with RM or radiation sources is responsible for insuring that the RSO receives employee records of prior radiation exposures from previous employers when required. The records will include the dose received during the current year, internal doses, and the lifetime cumulative occupational radiation dose. If the Approved User possesses copies of exposure records provided in previous employments, these copies of these shall be given to the RSO and added to Authorized Users dose current records.

In the event that the Approved User does not have records of previous radiation exposure, a copy of the request-for-dose-history form (also known as a "Form 5") can be used to request dosimetry records from previous employers. This form may be obtained from EH&S and must contain the signature of the Authorized User granting permission for the pervious institution to release the records. These records must be sent directly to the RSO and contain the signature of an authorized representative of the previous institution.

Medical Exposures

The following policies apply to employees who work with radioactivity and, during current employment, have been subjected to exposure of radiation and RM for medical purposes, e.g., nuclear diagnostic procedures or medical or dental x-rays.

External Radiation Exposure

Personal dosimeters (i.e., whole body dosimeters, ring dosimeters, etc.) are assigned to an employee by UMass Amherst Radiation Safety Services only for the purpose of monitoring exposure to radiation while working at UMass Amherst facilities.

Dosimeters must not be worn during:

- outpatient medical procedures (i.e., cancer radiotherapy, CT scan, chest x-rays, mammography, upper or lower GI scans, etc.).
- angioplasty or other heart surgery
- dental x-ray procedures.
- at another university (including those in the UMass system), an off-campus laboratory or other temporary work location.

Employees must notify the API and RSO if they believe UMass Amherst dosimeter has been contaminated or if an unplanned or non-work related exposure to a dosimeter, other than an occupational exposure, has occurred.

Internal Radiation Exposure

Employees who are administered RM as a result of diagnostic or therapeutic procedures under the control of a physician should report the exposure to the API and the RSO. These medical procedures involve injecting or implanting radioactive material into the human body (often called a "nuclear medicine" procedure). The employee ***must not wear a dosimeter*** issued by UMass Amherst Radiation Safety Services during or following medical procedures which include, but are not limited to:

- bone scans.
- thyroid ablations or inactivations.
- stress tests for the heart (Cardiolite^{tm}).
- prostate cancer “seed” implants.
- PET scans.

If necessary, the RSO will issue a temporary dosimeter to the employee and will determine if work with RM is to be temporarily restricted. This determination will be based on the capability of monitoring methods to distinguish between occupational and medical exposures as well as the potential for cross-contaminating university work areas.

Returning Dosimeters Upon Graduation or Transfer to Another Institution

Employees (terminating employment at a UMass facility) and API’s are responsible for assuring that all personal monitoring devices are returned to the RSO before the leaving UMass. Depending upon past uses of RM, the employee may be subjected to a final bioassay procedure, e.g., thyroid scan or urine bioassay.

A record of exposures and doses will be maintained by the RSO. Following employment termination, a former employee may obtain, by written request, a report summarizing the exposures and/or doses incurred at UMass facilities. The report will be submitted within 30 days after obtaining the results from the current dosimetry-processing vendor.

Incident Investigation and Reporting

If it is suspected that an employee's exposure exceeds limits specified in this manual, an immediate investigation will be conducted by the RSO to verify the details and extent of the exposure. For internally-deposited radionuclides, this investigation includes bioassay measurements and appropriate dose assessment. Upon completion of the investigation, results will be reported to the employee, RUC (if applicable) and senior management. The employee may be removed from work in areas where radioactive sources or materials are used and stored. The return to previous job activities will be determined pending the results of the investigation.

If it is concluded, after investigation, that an employee was exposed to levels of radiation at or over regulatory reporting limits, the appropriate regulatory agency shall be formally notified as required. Any injuries occurring as a result of the overexposure shall be attended to and immediately reported to the Medical Department.

Intake of Radioactive Material into the Body

The Radiation Use Committee has made it an **absolute requirement** to no researchers exceed **ten percent (10%) of any dose limit** without prior written consent from the Radiation Use Committee (see “ALARA limit”).

Derived Air Concentrations (DAC)

Internal exposures are primarily controlled by limiting airborne concentrations in the work environment. The controls also include limiting the presence of surface contamination levels that could result in resuspended airborne radioactivity and incidental intake.

The derived air concentration (DAC), in uCi/ml, is the annual inhalation intake limit (ALI), in uCi, divided by the total volume of air inhaled by a reference worker over a working year. It is assumed that the reference worker is breathing air at 20 L/min which is contaminated at the DAC for a working year (2,000 hours), or otherwise taking into the body one (1) ALI of any radioisotope. Either of these conditions will be recorded as a committed effective dose equivalent

(CEDE) equal 5 rem, which is the annual dose limit for the whole-body from the addition of both internal and external radiation exposure.

Annual Limit of Intake (ALI)

The ALIs differentiate between *stochastic* (a probability of a deleterious consequence occurring) and *non-stochastic* (a deleterious consequence being observed after a threshold dose is achieved) effect. The stochastic limits (5 rem/yr CEDE) are for health effects that occur randomly, i.e., fatal cancer, and for which the probability of occurrence (rather than the severity) is assumed to be a function of dose without a threshold. For non-stochastic or direct effects, such as organ or tissue dysfunction, the severity varies with dose and exposure thresholds, below which no effects have been observed. Thus the non-stochastic limits, e.g., 50 rem/yr to an individual organ, protect against acute injury to tissue or organ systems.

Summation of External and Internal Dose

The external exposure that yields a dose to the internal organs, also called the Deep Dose Equivalent (DDE) and dose calculated from the applicable ALI for an internal exposure are summed to demonstrate compliance with the applicable total effective dose equivalent. The determination of the total effective dose equivalent will take into account all significantly exposed organs and tissues from inhalation, ingestion intake, and intakes through wounds and absorption through the skin. The dose equivalents for the lens of the eye, skin, and extremities are not included in this summation, but are subject to separate limits.

The RSO will advise each worker annually of his/her exposures incurred over the past year. This information is made available under the requirements of radiation safety regulations and the records are kept by the RSO for the life of the license.
The determination of exposures and intakes may be made using a combination of radiation dosimeters, air sampling, bioassay results, respiratory protection factors, and other appropriate measurements. When information about the physical and biochemical properties of the radionuclide(s) or RM are known, adjustments may be made to the DAC and ALI to reflect compound class, aerosol size, density, and other physical and chemical characteristics.

Investigation Levels

ALARA Limit

The RUC has set an ALARA limit of ten percent (10%) of any regulatory limit. If any person's cumulative radiation exposure exceeds 10% of any regulatory limit listed in Table 4, the API for that person will have their permit to use RM suspended until a review of the ALARA over-exposure is completed by the RUC. The API may petition the RUC, in writing, to exceed the ALARA limit. The API may not proceed with any experiment that causes or could cause an exposure above the ALARA limit until approval has been received from the RUC, in writing.

NOTE: Under no circumstances will permission be granted from the RUC to exceed any annual dose limit.

All significant radiation exposures over historic levels as determined by pervious records and especially those over 10% of any applicable limit are investigated by the RSO.

External Exposure Investigation Level

For external exposures, established investigation levels correspond to 10% of the applicable exposure limits. For example, for the annual dose limit of 5,000 mrem to the whole body and a

monthly dose assessment period, an administrative limit of approximately 417 mrem is used (5,000 mrem/12 = 416.7 mrem). Ten percent of this monthly limit is approximately 40 mrem. Thus, if a worker received an external dose to the whole body of 40 mrem or more in a recorded month, an investigation would proceed and culminate in a report containing root causes and preventative measures. Similarly, for the extremities or shallow skin dose, the investigational dose criteria would be in a calendar month. Historically, records show that the majority of dosimeter readings are below the detection limit of current dosimeter technology, which is less that 0.1% of any annual limit.

Internal Exposure Investigation Levels

For internal exposures, derived investigational levels (DIL) which relate an individual bioassay measurement result. The DIL is used to signal when an in-depth evaluation is required. To calculate a person's true dose form internally deposited radionuclides, the RSO uses an appropriate biological model, the fractions of the intake deposited in the organ(s) of interest and the ALI for the radionuclide of interest.

Incident Reports

The RSO is required to submit incident reports to a radiation regulatory agency based on certain criteria published in the appropriate regulations. Some of these criteria include, but are not limited to:

- loss of RM
- loss of control of RM (personnel or equipment contamination)
- an exposure that exceeds regulatory limits
- receipt of a package that is wet, damaged or leaking that exceeds exposure or contamination limits

In addition, as part of the self-inspecting requirement of a License of Broad Scope the RSO must file internal incident reports that must be made available to regulatory agencies during an inspection. The following are the types of incident reports that are kept on file.

Incident Reports from Exposures

When a value exceeds the pre-established investigation level further investigation occurs. The investigation includes a determination of how the intake or external exposure occurred (and whether others could have been exposed), when it occurred, the taking of additional follow-up bioassay samples to examine clearance from the body (if from an internal exposure), a root-cause analysis, appropriate remedial actions to prevent future exposures, and an estimate of the radiation dose.

Based on the above discussion, not every exposure results in an investigation. However, each exposure is recorded, and the individual and their supervisor are informed. Exposures which are below the investigation levels may be investigated at the discretion of the RSO if the case is thought to be unusual in some aspect. Such reports are done for ALARA considerations and may serve to avoid a future dose.

Incident Reports from Spills

Spills are characterized as minor or major.

A minor spill is one in which posted "Spill Procedures" would be followed but prompt notification of the RSO would not be required. Minor spills are those that contain less than 10 μCi that are

not confined to a work area but remain within a posted laboratory. Work areas that can be cleaned to less than the

A major spill is any radioisotope activity greater than 1 mCi occurs, regardless of the location of the spill, including a posted work area. Smaller quantities may be considered a "major spill" if the spill involves more than one liter of liquid, if the spilled material contaminates a person or if the spill occurs in a non-posted area, like a hallway. Incident reports are generated for "major" spills only and distributed to the responsible individual, department management, safety and senior management as needed as soon as practicable after the event. The incident file must include a copy of the survey results and any data used to estimate radiation dose. Other incidents or "near-misses" may also be investigated at the discretion of the RSO for ALARA considerations.

Deficiencies Found During Routine Laboratory Audits

Radiation Safety routinely audits laboratories to determine if the conditions within the laboratory could successfully undergo an inspection by regulatory agencies. Conditions that might not meet with regulatory approval are documented. The API is required to rectify the condition and document to the RUC what steps have been taken to prevent a reoccurrence.

Contamination surveys are also conducted on a routine basis. If contamination is found in excess of ALARA limits, the API must clean the area, resurvey the area and submit a signed report to the RUC detailing the decontamination process and what steps were taken to prevent a reoccurrence.

Radiation Measurement

Wipe Test. Survey Requirements

Wipe tests in laboratories using unsealed RM are performed monthly at a minimum and weekly in certain laboratories by Radiation Safety.

Researchers who use H-3 must perform a daily wipe test of the work areas at the completion of each experimental run or before leaving the laboratory for the last time at the end of the each day that RM was used.

Results of these tests are reviewed and maintained by the user or by the Radiation Safety Office depending upon who performs the survey. Written notifications are issued to API's when removable contamination exceeds administrative limits published by the RSO. Responses from API's indicating corrective actions *are required upon receipt of a contamination notice.* More frequent wipe test surveys may be required by the RSO as needed to ensure compliance with administrative or regulatory limits.

In areas where RM is used, every effort should be made to maintain contamination levels as low as reasonably achievable (ALARA). Areas utilizing (or which contain) RM where access is restricted (by key lock security) to employees trained in the proper usage of RM are permitted to have surface activity levels in designated areas over the limits published by the RSO in order to fulfill research and development objectives. Therefore, limits for restricted areas where RM are utilized and stored are 10 times the limits given for unrestricted areas. Action levels are established by the RSO to ensure that administrative limits are maintained.

Hand-held Meter Survey Requirements

External radiation surveys using calibrated survey meters are conducted with each use of RM by authorized users in areas where RM are routinely used and stored. The SOP's issued by

Radiation Safety shall be consulted for additional survey recording requirements at each UMass facility. See Appendix B, Table 3 for common survey meter types and the isotopes they detect.

Researchers are required to perform daily surveys with a calibrated survey meter of work areas before leaving the laboratory for the last time at the end of the each day that RM was used. For tritium (^{3}H) users, a wipe survey must be performed at the end of each day that RM was used.

Each laboratory using radioactive material, with the exception of tritium, is required to have a calibrated portable survey instrument available to conduct external radiation surveys. Results of routine external surveys are maintained by the API and/or the RSO, The RSO reviews results of the surveys and institutes corrective actions, as needed. The RSO conducts periodic audits to ensure compliance with all applicable external exposure rate limits.

Dosimeters

Radiation dosimeters come in two forms, badges and rings. The badges and rings are provided by an outside vendor, who must retain the recover and read these devices each month.

It is your personal responsibility to know where your dosimeter is at all times. UMass is charged an additional cost for each lost dosimeter.

The badge dosimeter measures stochastic deep dose to the body organs from external radiation as well as the non-stochastic dose to the eye and skin. It must be worn on the collar of a lab coat to properly measure eye dose. A badge dosimeter is sensitive down to one (1) millirem, which is close to environmental background radiation levels.

The ring dosimeter measures the non-stochastic dose to the extremities, such as the fingers. It must be worn under a glove. A ring dosimeter is sensitive down to thirty (30) millirem.

Who Wears Dosimeters & Why

Radiation dosimeters are issued by the RSO depending on the evaluation of the work environment and the quantity of RM being used as described by API in the application that was submitted to the RUC to use RM. Tritium (H-3) users will not be issued dosimeters under any circumstances since tritium beta particles do not have enough energy to penetrate the dead layer of skin.

UMass contracts with a selected company that reads the dosimeter and records the dosimeter data in accordance with accreditation requirements established by the regulator, i.e., accredited by the National Institute of Science and Technology (NIST) under their National Voluntary Laboratory Accreditation Program (NVLAP).

All new radiation users must complete the form entitled “Radiation Worker Application.” Radiation exposures for routine operations shall be maintained ALARA. Compliance with these limits will be monitored using personal monitoring equipment. Dosimeters are exchanged at least monthly by Radiation Safety and research staff must have dosimeters in a location easily accessed by Radiation Safety staff.

Care must be taken not to cross-contaminate a badge or ring dosimeter. A contaminated dosimeter will give a false-positive dose reading since it continues to be irradiated even after work is completed.

If a dosimeter reading exceeds an ALARA limit, the user will be ordered by the RUC to cease work using radionuclides or radiation generating equipment. This restriction will remain in force until the cause of the high reading can be determined by the RSO and steps taken to help the Authorized User keep doses below regulatory and administrative limits.

Controlling Exposure and Contamination

Using Time, Distance & Shielding to Protect Yourself

a) Time
The time you spend is a radiation field is directly proportional to the amount of dose you will receive. The amount of dose you receive depends directly on how long you, your hands or your eyes spend in the radiation field.

Time is the one factor that you can **personally control in every experiment** involving the use of RM.

By performing dry runs, having implements or instruments close at hand, cleaning up contamination as is occurs and having a the experimental protocol posted in your work area are all methods of limiting your exposure time to RM.

b) Distance
The amount of distance you can put between you and RM is generally limited by your necessity to manipulate your experiment.

However, distance is very useful in the fact that radiation intensity decreases by the inverse square law.
For example, if your survey meter reads 100 mrem/hr at six (6) inches from vial of P-32, the survey meter will read 25 mrem/hr at twelve (12) inches from the vial.

So, when your samples are in storage, you can gain a measure of radiation protection by moving your storage container to the back of the refrigerator/freezer or my moving your waste container to the furthest location in the lab or workbench.

c) Shielding
The effectiveness of shielding is you can use is generally limited by your need to manipulate your sample during an experiment. But shielding is very effective when your samples are in storage as you can typically enough shielding in a storage container or refrigerator to reduce radiation exposure to background levels.

However, the one shield that helps everyone reduce their expose is safety glasses. The plastic (not glass) lenses in safety glasses absorb one hundred percent (100%) of all alpha and beta particles emitted by radioisotopes. This is important because live tissue is most susceptible to radiation exposure. As live tissue is wet tissue, the only live tissue that is exposed on the exterior of the human body is the eyes. Wearing safety glasses reduces alpha and beta particle exposure to the eyes to zero.

Your personal evaluation of time, distance and shielding must be the primary process used to prevent and minimize exposures to radioactive material or radiation generating devices. Sources that could cause exposure rates in excess of the limits specified in this manual shall be stored in specialized areas using shielding and/or distance to minimize exposures. The section of this manual titled Radioisotope Characteristics provides information concerning attenuation of photons and shielding requirements.

Protection From Getting Radiation Internally Deposited Into the Body

The control of internal intakes shall be accomplished by the use of *engineering controls* (e.g., ventilated enclosures, fume hoods, etc.), protective clothing, respiratory equipment (when needed), and administrative controls. Monitoring for internal intakes is accomplished via direct and indirect bioassay measurements of laboratory personnel. In addition, indicators of potential internal intakes (e.g., surface contamination levels, air concentrations, etc.) are monitored as necessary to assure that undetected internal exposures are minimized. Work with readily dispersible RM shall be performed in approved fume hoods drawing air away from the breathing zone. Work in fume hoods, exhausted glove boxes, or other controlled environment is required when volatile or gaseous chemicals containing radioactivity are being used. (The RSO maintains or has access to blue prints, or other drawings and a list of restricted areas (key lock security) where engineering controls are used.) The RSO may specify the use of engineering controls, as needed.

Monitoring for Internal Exposures

For the radionuclides used at UMass facilities, thyroid scans and urine bioassay measurements are the principle methods used to monitor radionuclide intakes as specified by the RSO in response the description of experiments detailed by the API in the request to use RM.

Persons working at one time with more than 25 mCi of tritium or 10 mCi or more of any other isotope, excluding radioiodine, shall be monitored within 24 hours after isotope use. For radioiodines, a thyroid scan shall be performed within 24-72 hours post use if single use of free radioiodine, e.g., as NaI, exceeds 100 uCi or if single use of organically-complexed or bound radioiodine exceeds 500 uCi.

Additional and confirmatory bioassay measurements may be required as determined by the RSO. In addition, in-vivo measurements, fecal bioassays, or breath bioassays may be requested, if deemed necessary by the RSO.

Personal Protective Equipment

a) *Laboratory coats* shall be worn at all times when working with RM. Some laboratories, such as those conducting radiosynthesis and iodinations, may require additional protective coverings, such as plastic-lined disposable coveralls and booties.

b) *Protective Gloves* (e.g., rubber, plastic, disposable vinyl, surgical) shall be worn when handling RM. Double gloves shall be worn during radiosynthesis and iodination procedures and are strongly recommended for all RM handling.

c) *Protective Eye Wear* is required in accordance with standard UMass requirements. This includes the use of safety glasses with side shields or full-face shields as applicable.

Note: Personal prescription eyewear or eye glasses, with or without side shields, are not a substitute for safety glasses unless they have been approved by EH&S.

d) *Respiratory Protection* will be used when required by the RSO. Only medically qualified and trained personnel will be allowed to use respirators. Respirator training will be conducted in accordance with Safety Department procedures.

Note: Open-toe footwear, including pumps, sandals and flip-flops, are not allowed to be worn at any time in any laboratory.

Good Laboratory Practices for Reducing Radiation Exposure

It is recommended that each API post this list of good laboratory practices in each RM use area as a ready reference for those persons listed on the radiation use permit.

a) Personal protective equipment will be worn whenever work is performed at a laboratory bench. The minimum personal protective equipment required is lab coat, safety glasses and disposable gloves.

b) Loose clothing or clothing that exposes body areas that could trap radioactive material, such as open-toed shoes, sandals or flip-flops, must not be worn in the lab.

c) Absorbent materials, with a plastic underlining or on a spill tray, shall be utilized on bench tops and work areas where RM are used and handled.

d) Secondary containers must be used to prevent spillage and contamination spread in the event that the primary container fails to contain the radioactive material. This is especially applicable to liquid radiation waste containers waiting sink disposal.

e) Spills of RM shall be contained immediately, the API and RSO notified, and the area decontaminated before resumption of work. Spill procedures shall be posted in the laboratory and followed under the guidance or direct supervision of the API, or the RSO, as is commensurate with the nature of the spill.

f) Breaks in the skin should be sealed and covered prior to using RM. Hands should be washed thoroughly after using RM, before going on breaks, and at the end of the workday or shift.

g) Eating, smoking, drinking, or the application of cosmetics in posted laboratory areas is strictly forbidden. Food and beverages must never be stored in areas where radioactivity is stored, such as posted freezers and refrigerators.

h) Calibrated portable radiation survey meters shall be used to monitor work areas and monitor laboratory personnel before, during, and after each use of RM, with the exception of tritium. Survey meters should be used continuously during handling of RM to ensure containment.

i) Wipe surveys shall be performed at least monthly in each laboratory or area using RM, and after each tritium use exceeding 10 uCi, to ensure contamination levels are below those specified by the RSO. More frequent surveys may be required in certain areas by the RSO or API as necessary to ensure compliance.

j) When leaving the laboratory, secure all radioactive containers or the laboratory door.

The Administrative Controls for Radiation Protection

Administrative controls are put in place by the RUC and the RSO to limit external exposures as needed. Some of the administrative controls published in the manual and as SOP's include the following:

Commitment to the ALARA principle
Conducting radiological surveys with each use of RM
Periodic training of laboratory personnel
Provisions for establishing controlled areas

Provisions for proper monitoring and investigation of exposures
Securing RM
Radiation Use Committee oversight (were applicable)

Emergencies Involving RM

Spills

Spills involving tracer levels of RM, generally of 10 uCi or less, not involving personal contamination, in volumes less than one liter, and not spread to non-posted areas, are cleaned by Authorized Users under the direction of the API. Spills in excess of 10 uCi, any spill resulting in personal contamination, spread of RM to non-posted areas or volumes greater than one liter are handled according to the following procedures.

Contain the spill immediately by placing absorbent material over the spill. Use sufficient absorbent to prevent the liquid from continuing to flow. Do not attempt to completely clean up the spill!

Contact the API and the Radiation Safety Officer, or have someone outside of the immediate area of the spill make the contact.

Isolate the area of the spill and prevent laboratory personnel from inadvertently entering the area by using barricades, warning tape, or posting a sentry in the area.

Monitor for contamination on shoes, clothing, hair, and hands of all personnel in the immediate area of the spill with appropriate survey instruments. Remember to survey the bottoms of the shoes.

If the laboratory area must be evacuated, make every effort to prevent the spread of radioactive contamination. Record all exit routes and objects that may have been cross-contaminated during the process of evacuation.

Retain, if possible, everyone who was in the laboratory area at the time of the accident excluding emergency medical services personnel. Attempt to keep them together until the API and/or RSO arrive.

Procure sufficient waste containers from Radiation Safety (or EH&S responders).

Demarcate clean areas from the contaminated area. Do not bring contaminated items, cleaning materials or radioactive waste from the contaminated area to the clean area.

Begin spill clean up activities. Move saturated absorbents or contaminated items into the clean area only after obtaining approval from Radiation Safety.

Continue decontamination and survey procedures under the direct supervision of the API and/or the RSO, until the decontamination and survey are complete.

A report on how the spill occurred with any recommendations to prevent a reoccurrence must be completed by the API and kept on file in the Radiation Safety Office. Documentation of the final survey must be submitted to the RSO for review. The RSO will determine that the decontamination activities are sufficient to allow routine work to resume in the area. Management responsible for environmental control is notified if the spill results in contamination to air, water, or soil.

Fires

Pull the fire alarm.

Follow facility fire safety requirements designed to contain fires and save lives.

Notify the UMPD or the RSO after vacating area that a fire has occurred involving RM.

The API and the RSO will advise fire and security personnel on methods to mitigate potential exposure of employees and emergency responders to radioactive materials, while allowing containment and extinguishing the fire.

Senior Management will maintain, as necessary, liaison with state and local officials (e.g., Fire and Police Departments) concerning the radiological implications of the fire.

Off-Hour Emergencies

Work with radioactive materials which is not performed during normal working hours must be approved by the API prior to the work.

Dial the site emergency phone numbers, **911**, for both general and **radiation safety incidents**. The appropriate number should be called befitting the incident.

For an off-hour emergency, the Security Department will contact the RSOs or back-up personnel at their pager, home or cellular phone numbers.

Remain on hand to direct responding personnel except in cases where evacuation is necessary.

Theft or Loss of Radioactive Material

In case of theft or other unaccountable losses of RM, the Authorized User or API will immediately notify Radiation Safety. The RSO will inform management and make a survey of the area. Sealed sources can sometimes be located by surveying the work area with a survey meter. The RSO and API are responsible for estimating and evaluating the amounts of RM lost based on current inventory and receipt records. The RSO is also responsible for organizing a survey or search to locate the lost materials. Appropriate notifications to the regulator will be made as directed by regulations.

Risk of Detrimental Effects from Radiation: An Overview

This section presents some background information on the basis and application of risk coefficient factors in risk assessment and radiation protection. In this context, it is presented for illustrative purposes only.

Risks are expressed in terms of the probability that an adverse effect will occur during a person's lifetime per rem delivered to the whole-body in discrete increments or over a lifetime. Risk factors are based on the assumption that the risk is independent of the rate at which the dose is delivered. In other words, the risk factors assume that the lifetime risk of a rad delivered in one minute or over the course of a year is the same. This assumption is used for regulatory purposes and performing risk assessments. However, it is important to recognize that a great deal of radio-biological data indicates that risks are reduced when doses are highly fractionated (i.e., spread out over a long period of time) primarily the result of biological repair mechanisms. In setting

radiation protection guidelines, it is also assumed, for conservatism, that the dose-response curve is linear and without a threshold.

For a given dose, a risk factor may be used to calculate the risk of adverse effects to individuals. For example, if it is known that an individual received a single whole-body dose of 1 rad of a low-LET radiation (i.e., low linear energy transfer radiation such as gamma- or x-rays, and beta particles), that individual's lifetime risk of fatal cancer attributable to this exposure is estimated to be 4×10^{-4} (i.e., 1 rad x 4.0×10^{-4} fatal cancers per rad). In other words, a dose of 1 rad received over one year may result in a fatal cancer risk of about 1 in 3,000. The risk coefficient factor used here is based on National Academy of Sciences (NAS) report (BEIR V). The range of uncertainty is sufficiently large for doses less than 10 rads, that the probability of fatal cancer would include zero.

For the purpose of providing a perspective on the risk of fatal cancers due to whole-body radiation, it is instructive to calculate the risk from background radiation to the U.S. population using the risk factor given above. The absorbed dose rate from low-LET background radiation has three major components:

Cosmic radiation, which averages about 28 mrad/y in the U.S. Terrestrial sources such as K-40, U, Th, and Ra in soil, which contribute an average of about 28 mrad/y, and the dose from naturally occurring radionuclides within the body such as K-40.

The last differs among organs, but for soft tissues it is about 24 mrad/yr. Other minor radiation sources, such as fallout from nuclear weapons tests, cosmogenic radionuclides, naturally occurring RM in buildings, airline travel, and consumer products, contribute about another 7 mrad, for a total low-LET whole-body dose of about 87 mrad/yr.

Although extremes do occur, the distribution of this background dose is relatively narrow. A population-weighted analysis conducted by the EPA indicates that 80 percent of the U.S. population receives annual doses (excluding that from breathing radon gas and daughter products) that are between 75 mrad/yr and 115 mrad/yr.

The risk of fatal cancer per person due to this dose can be estimated as follows:

Risk = $(4.0 \times 10^{-4}\ \text{rad}^{-1})$ $(8.7 \times 10^{-3}\ \text{rad/yr})$ (70.7 yr) or

2.4×10^{-3}, or about 0.24 percent of all deaths.

Vital population statistics used in EPA risk assessment analyses indicate that the probability of dying from cancer in the United States from all causes is about 16 percent. Thus, the 0.24 percent result indicates that about 1.5 percent of all U.S. cancer may be due to low-LET background radiation.

This approach in assessing the risks of exposure to radiation is a simplified approach. The reasons are that the cancer risk per rad varies as a function of age of exposure, total dose and dose rate received, type of radiation, exposed organs or tissues, and sex of the individual exposed.

The coefficient factors used in deriving the above risk estimates are based on both human and animal data. Human data include atomic bomb survivors, radiation-treated patients, underground miners, and radium dial workers. Animal data include studies involving mammalian species and tissue cultures. Evidence of the mutagenic properties of radiation comes mostly from animal data, in which all forms of radiation-induced mutations have been demonstrated, mostly in mice. Tissue cultures of human cells have also shown radiation-induced mutations.

The above discussion gives an indication of the degree of uncertainty associated with developing risk factors. In general, the epidemiological data upon which these risk factors are based are for exposures in excess of about 10 to 30 rads. Accordingly, most of the uncertainty is associated with the extrapolation of these risks to doses below 10 rads.

Zero risk at very low dose rates and doses, such as those delivered by natural background, cannot be entirely ruled out. The most important uncertainties in estimating risks for radiation relates to (a) the extrapolation of risks observed in populations exposed to very high doses, delivered acutely, to populations receiving very low doses in chronic exposures, and (b) the projection over a full lifespan.

For the purpose of setting standards, regulatory agencies have taken a conservative approach in interpreting the risks associated with low doses of radiation delivered at low dose rates, namely that the risk of developing a fatal cancer is linearly proportional to the dose received, regardless of the rate of delivery. The use of the so-called "linear no-threshold" model implies that for each increment of dose received, there is some finite increment of risk. Because of this, radiation dose limits have been effectively lowered by incorporating the As Low As Reasonably Achievable (ALARA) principle into law (see Section I of this manual).

Inventory, Purchases, Acquisition By Transfer & Shipments

Duties of the RSO and the API

The API is approved by the RSO or RUC (where applicable) to possess RM within specified limits and only in the locations stated in the “Request to Use Radioisotopes or Radiation Generating Machines”.

X-ray generating units require special permits from the MRCP. It is an **absolute requirement** that the API contact the RSO prior to the purchase of an x-ray unit.

Purchasing Radioisotopes or Receiving Radioisotopes form Another Institution

Radioisotopes are purchases as follows:

1. The API or designee notifies Radiation Safety by email that a purchase has been made. The following information must be contained in the email:
    a. Radioisotope
    b. Activity
    c. Chemical composition
    d. Use location
    e. Storage location
    f. Vendor or institution that the sample will be shipped from.

    Note: Samples from international origins may require special paperwork.

2. The API or designee places the order, ensuring the radioisotope’s activity is within the limits granted in the protocol approved by the RUC.
    Note: The API or designee must notify the vendor or institution that the shipment must be delivered to Radiation Safety Services.

3. When the package arrives at Radiation Safety, the following are performed:

    a. The package is inspected for damage and leaks as per MRCP regulations
    b. The package is surveyed for contamination on the shipping container

c. The contents are checked against the limits on the approved protocol
d. An inventory tracking form is generated

4. The package is delivered to location specified by the API

5. An Authorized User performs the following:

    a. Removes and surveys the inner container holding the sample
    b. Confirms the sample is what was ordered
    c. Obliterates all labels on the external package
    d. Secures the sample
    e. Retrains the inventory tracking form

Transferring RM Between Labs on Campus

When an Authorized User or API borrows a radioactive sample, transfers a radioactive sample to another API or moves an instrument that contains or generates RM, the following must be performed:

1. Review the approved protocol to confirm that the RM and/or activity level is allowed at the location where it is to be used.

2. Notify Radiation Safety by email of the following, as applicable:
    a. Radioisotope or radiation emitted
    b. Activity or instrument
    c. Chemical composition or sealed source
    d. Use location
    e. Storage location

3. The API must add or remove the sample or source that was borrowed or transferred from the appropriate inventory tracking form.

Any RM inventory must be physically transferred to another API or to the RSO prior to leaving UMass or transferring to another institution. A transfer memo stating the transferred quantities must be sent to the RSO. All posted work areas and apparatus must be surveyed and must be cleaned according to the decommissioning standards put into practice by Radiation Safety.

Purchasing Radiation Generating Machines

The API must contact the RSO prior to purchasing any radiation generating machine.

Once the machine arrives on campus, the RSO or designee will inspect the installation of the RM.

Radiation Safety will contact MRCP for a permit for the unit as required by regulations.

Radiation Safety will issue dosimeters as appropriate.

Radiation Safety will perform periodic leak tests as required by the MRCP.

Inventory

Records of the types of radionuclides and activities present at UMass facilities are maintained and updated as dictated by specific license conditions by the RSO.

Sealed-source inventory is assessed semi-annually at all UMass sites by the RSO, usually during leak testing periods.

All reports shall provide an accounting of RM received, transferred, and disposed of, as well as decay of current inventories of RM. The RSO will audits these reports to ensure the accuracy of the current records relative to the previous inventory, current activity in use, receipts of new RM, transfers of RM and the disposal of RM. Inventory discrepancies are investigated by the RSO (or designee) and corrective action is taken, as needed.

Based on the inventory frequency, the RSO (or designee) generates a facility-wide radioisotope materials inventory and stores this record for regulatory review as required by the MRCP or NRC. Isotopic inventory must be maintained below the quantities authorized by license conditions. In addition, the RSO (or designee) generates an annual periodic summary of the RM inventory for review by the RUC.

Shipping

Note: It is an absolute requirement that under no circumstances will UMass academic staff, support staff or students transport RM in private vehicles, either around campus or off-campus.

RM being shipped off-site shall conform to all applicable state, federal, and international regulatory requirements. To ship RM, the following must be performed:

1. The API must contact the RSO prior to committing to ship a sample so the RSO can review the radiation license of the recipient. If the recipient's radiation license does not meet the qualifications for possessing the sample, the shipment must be cancelled.

2. The API is responsible for ensuring that the shipment is properly described.

3. The API will package the sample as appropriate for it to survive shipment.

    a. **Note: The API must contact the RSO prior to packaging the sample to ensure that the packaging and any materials needed to ensure the survival of the shipment, such as dry ice, meet government regulations for air or ground transport.**
    b. The API must provide the proper containers used in the shipment.
    c. The API may work with the RSO to have Radiation Safety package the sample.

4. The RSO or designee will label, survey and inspect the package prior to shipment. The API is also responsible for updating the inventory for the next report, which is submitted to the RSO.

Any Radiation Safety personnel who offer RM packages for commerce (sign shipping papers) shall attend an appropriate DOT course within the previous three year period and be certified with respect to the course contents.

Disposing of RM Waste or Instruments Containing Radioactive Sources

Under no circumstance is radioactive waste, sealed sources, instruments used for counting radioactive samples, radiation generating machines or instruments with sealed sources inside, such as liquid scintillation counters or gas chromatographs to be given over for disposal or recycling.

Radiation Safety must confirm prior to the disposal or recycling of instruments or equipment that is free of contamination and the sealed sources, if any, have been removed.

NOTE: Only Radiation Safety personnel may remove radiation warning signage from instruments or equipment.

Disposal of Dry Radioactive Wastes or Contaminated Equipment

Low Level Radioactive Waste (LLRW) destined for offsite disposal shall conform to packaging requirements established by the contractor and/or disposal site operator. These requirements may change due to new regulations or administrative procedures. The objective is to ensure that the storage, transportation, and disposal of LLRW are conducted in compliance with current requirements.

The RSO will train all Authorized Users in the programs available to minimize radioactive waste help reduce the amounts of radioactive waste sent for disposal off campus. A decay-in-storage program for radioisotopes with relatively short half lives is an example of a waste minimization program.

The API is responsible for establishing methods of estimating activities of radioactive wastes (all forms) in accordance with the research methods being employed. Most often, estimates will be made on the basis of mass balance.

Within the laboratory, the API will:

1. ensure that all radioactive waste that is generated is properly separated and put in the appropriate containers in the laboratory.

2. have a system for tracking the isotopes as well as the activity put in each waste, container, which must be labeled with the isotope and activity of the waste.

3. ensure that the exterior of any waste container does not exceed 5mRem/hrand ensure that no liquid waste is put in solid waste containers

4. ensure that secondary containment is used for liquid waste awaiting disposal. The secondary containments must hold at least one-hundred and twenty-five percent (125%) of the volume of a the liquid waste container

5. within acceptable contamination levels on the outside surfaces of the container. The RSO (or designee) will maintain a file of current packaging requirements, provide the API's with information concerning packaging of radioactive wastes, perform additional radiological surveys, (as needed) and periodically remove the waste or oversee the removal of waste from laboratory areas to a central waste storage/pickup area.

The storage or disposal of radioactive wastes that contain an animal, hazardous biological or hazardous chemical component radioactive waste may required additional measures in accordance with requirements established by regulatory agencies other than the MRCP or USNRC. These wastes may have to be handled by a special radioactive waste disposal site operator and/or waste broker at additional costs. The current requirements for special radioactive waste disposal are maintained in the Radiation Safety Office.

All disposal of radioactive waste must be tracked by the API. The API must report the disposal of radioactive waste on the next inventory report submitted to the RSO.

Classification of Dry Radioactive Waste

Dry waste must not contain any free flowing liquids of any kind. Waste items such as, but not limited to, gloves, pipette tips, paper toweling, centrifugation tubes, aluminum foil and other types of sample holders must be dried or emptied of all liquid radioactive contents. Double plastic bags must be used to line any dry radioactive waste container.

Dry waste containers are classified by two types:

1. Cardboard boxes for compounds or trash containing long half life waste, such as, but not limited to, H-3 (tritium) and C-14. These containers are removed and new containers supplied by Radiation Safety.
2. Commercially available, durable trash containers for short half life waste such as, but not limited to, P-32 and I-125. These containers are kept in the lab until Radiation Safety removes the double plastic bags for disposal.

If discarding a particular item to dry waste is questionable, contact the RSO for clarification. Some items that may fall into this category include small bench-top equipment such as contaminated vortexors or stock solution ampoules containing a few drops of liquid.

Radioactive Waste Used in Scintillation Counting

Scintillation wastes are classified either as exempt (not regulated as radioactive), waste containing C-14 and/or H-3 only at concentrations <0.05 uCi/g of media, or non-exempt (regulated as radioactive) waste containing any other isotopes (as well as C-14 and H-3 >0.05 uCi/g) in scintillation media. Scintillation wastes may exist as

1. counting vials
2. beta plates
3. bulk fluid

Each of the above waste forms should be maintained separately.

In addition, some scintillation cocktails contain chemicals that are not considered environmentally benign by regulatory agencies. Scintillants such as toluene, methanol or acetylnitrile must be handled as hazardous chemical waste which, along with the radioactive component, makes them classified as “mixed hazardous waste”. The disposal of mixed hazardous waste is very expensive and researchers are encouraged to exhaust all other options when writing an experimental protocol before they decide to use hazardous chemicals for scintillation counting.

Aqueous Waste and Sewer Disposal

A review and approval of the solubility of the radioactive compounds to be disposed of via the sewer must be conducted prior to using sewer disposal. Only soluble aqueous radioactive waste or readily dispersible biological radioactive waste may be released into the sanitary sewer via approved and labeled sinks in the laboratories.

NOTE: Contact the RSO prior to using a lab sink for disposal of RM for the first time.
The RSO should always be consulted prior to an API establishing a routine for sewer disposal to ensure compliance with regulations. The RSO will evaluate the disposal of radioactive waste into the sanitary sewer prior to the approval of a new experimental protocol using radioisotopes to ensure the disposal into authorized sink is under the radioactive concentration limits set by regulatory agencies.

NOTE: Lab coat, safety glasses and disposable gloves are required when disposing of liquid radioactive waste into a laboratory sink.

When using the sewer for disposal, perform the following:

1. ensure that the liquid waste is poured directly down the drain

2. avoid spilling or splashing of any kind

3. run the faucet while pouring and for several minutes after pouring is completed

4. rinse the sink thoroughly after disposal

5. survey the basin and drain opening with a survey meter (or wipe test, if tritium was used) to ensure that no residual radioactivity remains behind in the sink basin. Also check faucet handles, the floor, and any vessels used during pouring to ensure that no removable contamination remains.

Report the isotope and activity disposed into a laboratory sink during the next RM inventory.

Storing Liquid Radioactive Waste Prior to Disposal

Liquid radioactive wastes are that are being temporarily stored at the laboratory bench or work location prior to final disposal must carefully poured into heavy duty Nalgene (or other) wide-mouth containers. All containers must have a screw-on lid which prevents leakage. All liquid waste containers must be placed or stored in a secondary container capable of holding the 125% of the volume of the primary container. Temporary liquid waste containers must not exceed five (5) gallons and should never be filled to capacity. All containers must be properly labeled with the "Caution Radioactive Materials" label. The amount of waste added to the container must be tracked and the information on the tracking document or card must include isotope, the activity added, the date the waste was added to the container and the name of the responsible API. All liquid radioactive waste containers are completed their useful life and are ready for disposal must be completely dry. If they are to be thrown out in non-radioactive trash, they must be wipe tested to ensure that removable contamination is less than 200 dpm/100 cm^2.

Note: Organic solvents or other hazardous wastes must not be placed in radioactive liquid waste containers that are going to be used for sink disposal or thrown away.

Contact the RSO prior to producing radioactive liquid waste that will be classified as mixed wastes.

Care must be used with disinfecting infectious agents that also have a radioactive component. Using a typical 10% bleach solution may cause ion transfer and cause some radioactive compounds, especially radioiodine compounds, to go airborne, which can cause an inhalation hazard.

Radioactive Biological Wastes

Radioactive biological wastes that are composed of animal carcasses, urine, feces or other animal tissue may be disposed of as non-radioactive waste if:

1. the radioisotopes in the experiment are either C-14 or H-3, only

2. total radioisotope concentration in the waste container is less than 0.05 uCi/g

Other C-14 or H-3 animal waste, such as bedding material, or animal tissue containing radioisotopes other than C-14 or H-3 must be stored for disposal by a licensed waste broker. These animal wastes are to be doubled bagged and kept in a freezer or cold storage room prior to disposal. The containers must be labeled with a radiation warning sticker and a label indicating isotope, quantity, API and date.

How to Get Radioactive Waste Picked Up From Your Laboratory

To have radioactive waste removed for the laboratory, the API must:

1. Contact Radiation Safety by email stating:
    a. Laboratory
    b. Isotope(s)
    c. Activity
2. For short half life waste, remove the double plastic bag. It is the API's responsibility to replace the double plastic bag in the waste container.

Radiation Safety will collect the either the cardboard box or double-plastic bag shortly after receiving the email request.

Radioisotope Characteristics

Appendix B contains information for selected isotopes that is provided for information purposes only. It is furnished to give the reader a better understanding of the radiation hazards for a certain select number of radioisotopes commonly used in research. The reader must not use the following information as the only source to develop individualized safe handling procedures for RM within a laboratory or RM use location. You must contact the RSO for technical guidance or for data on the safe use of radionuclides or for those radionuclides not appearing on the following list.

Appendix A

Regulatory and Administrative Radiation Exposure Limits

Table 1. Surface Contamination Limits*

Acceptable Wipe Test Contamination Levels - dpm/100 cm^2

Radionuclide	*Fixed (Average)*	*Fixed (Maximum)*	*Removable*	*Action Level** (removable)*
H-3, C-14, S-35, P-32, P-33, Ca-45, Cr-51, Sr-90, Cs-137, I-125, I-129, I-131, Ni-63	1,000	3,000	200	200
Beta-gamma emitters (with decay modes other than alpha or fission), except as noted above	5,000	15,000	1,000	200

Acceptable Meter Contamination Levels

Radionuclide	*Fixed (Average)*	*Fixed (Maximum)*	*Removable*	*Action Level** (removable)*
Beta-gamma emitters	3 times bkg*	3 times bkg*	3 times bkg*	3 times bkg*

*For hand-held survey instruments that are not calibrated to register dose rate (mrem/hr), the person performing the survey may use a value of three (3) times over background as the action level at which removable contamination must be remediated.

For the purpose of ensuring that removable contamination will be maintained below 1000 dpm/100 cm^2, an action (decontamination) level of 200 dpm/100 cm^2 will be maintained for all isotopes in posted but otherwise unrestricted laboratories. For posted areas with restricted access (key lock security) or for designated equipment, administrative limits are ten times the values given in **Table 2. Because additional restrictions or limitations may apply to certain areas, contact the RSO for up-to-date requirements concerning action levels.

Table 2. Personnel Exposure Limits

Exposed Area	***Annual Dose Limit***	***Dose Equivalent***
Whole Body	5 rem	total effective dose equivalent (TEDE)[1]
Lens of the Eye[2]	15 rem	eye dose equivalent (EDE)
Extremities[2]	50 rem	shallow dose equivalent (SDE)
Skin[2]	50 rem	shallow dose equivalent (SDE)

*Note: for gamma radiation, 1 rem = 0.01 sievert (Sv)

[1]The total effective dose equivalent (TEDE) is the sum of the deep dose equivalent (DDE) from external radiation added to the committed effective dose equivalent (CEDE) from the internal uptake of radioisotopes. This dose limit is based on a stochastic limit for a risk based occurrence, such as cancer.

[2] These are individual dose limits based on non-stochastic effects, such as the formation of cataracts or skin burns.

Appendix B

Definitions, Physical Data, Technical Information and References

Table 1. Typical Radiation Safety Training Topics

Radiation Fundamentals

- Types of radiation and their characteristics
  - Alpha, beta, gamma, x-ray
- Radiation interactions with matter
  - exposure
  - dose
- Radioactive decay process
  - half life
- Sources of radioactivity
  - natural background sources
  - man-made sources
    - radioactive material
    - radiation generating machines
- Specific types used at UMass Amherst
  - unsealed (wet lab) sources
  - sealed sources
  - gamma irradiator
  - x-ray machines

Biological Effects of Radiation

- Dose equivalent
- Dose-effect relationships
- Dose manifestations in the body
  - stochastic
    - carcinogenesis
    - genetic effects
  - non-stochastic
    - acute effects
      - Eye
      - Skin
  - latent effects
  - fetal effects

Protocols and Operating Policies

- New RM user and API authorization process
- Acquisition of RM
  - wet lab inventory
  - sealed sources
  - x-ray generating equipment
- RM security program
- Radioactive Waste
  - consolidation
  - sink disposal
  - removing waste from labs
- Emergency procedures
  - spill response
  - personal contamination response
  - injury involving radioactive material

Control of Exposure to Radiation and Contamination

- Safe handling various types and forms of RM
  - solid
    - powders
    - metals
  - liquid
    - frozen
    - volatile
  - gases
  - biological
  - special chemicals
  - sealed sources
- External and internal dosimetry
  - minimizing exposure
- Controlling exposure
  - time
  - distance
  - shielding
  - adjusting techniques
- Use of personal protective equipment
  - minimum requirement:
  - lab coat, safety glasses, gloves
  - radiosynthesis laboratories
  - other special requirements
- Contamination control
  - signs, labels, and posting
  - routine monitoring
  - adjusting techniques

Radiation Measurement

- Instrumentation
  - hand held survey meters
  - liquid scintillation counters
  - computer based analyzers
- Detection of contamination
- Contamination monitoring
- Bioassay
  - thyroid scan
  - urine analysis
  - other analysis

Radiation Protection Program

- Purpose
- Individual responsibilities
- Current good radiation safety practices
- ALARA policy
  - personal responsibilities
  - concepts for reducing dose
  - pertinent regulations and dose limits
  - reporting requirements

Table 2. Physical Characteristics for Commonly Used Radionuclides at UMass Amherst

Nuclide	***Half-Life***	***Decay Mode***	***E_{Max} (%abundance)***	***Approx.Range for Material*** [1]	***Material*** [2]
H-3	12.3 y	beta only	19 keV (100)	1.0 cm	air
C-14	5730 y	beta only	156 keV (100)	20 cm	air
P-32	14.3 d	beta only	1710 keV (100)	0.8 cm 6.2 m	plastic air
P-33	25.4 d	beta only	250 keV (100)	<0.1 cm 47 cm	plastic air
S-35	87.4 d	beta only	167 keV (100)	40 cm	air
Ca-45	163 d	beta only	257 keV (100)	48 cm	air
Cr-51	27.7 d	e^- capture gamma	~5 keV (89.2) 0.320MeV (9.8)	- 0.17 cm	- HVL, Pb
Fe-55	2.737 y	e^- capture	~6 keV (16.2)	-	-
Fe-59	44.5 d	beta beta gamma gamma	273.6keV (45.3) 465.9keV (53.1) 1.099 MeV (56.5) 1.291 MeV (43.2)	- 52 cm 0.6 cm - 1.5 cm	- air plastic - HVL, Pb
Co-60	5.27 y	beta gamma 	318.2 keV (99.9) 1549 keV (0.23) 1.173 MeV (100) 1.332 MeV (100)	50 cm 6.3 m - 1.7 cm	air air - HVL, Pb
Rb-86	18.7 d	beta gamma	1770 keV (91.2) 1.08 MeV (8.8)	0.9 cm 6.5 m 0.9 cm	plastic air HVL, Pb
I-125	60.1 d	gamma K x-ray(2) K x-ray	35 keV (6.5) 27 keV (113) 31 keV (22.4)	0.3 mm - -	HVL, Pb - -
Cs-137	30.0 y	beta gamma	513.9 keV (94.4) 0.6617MeV (85.1)	62 cm 0.65 cm	air HVL, Pb

[1] For each decay mode, data is given for the most energetic emission, not the most likely emission.
[2] HVL is the thickness of the indicated material required to reduce the initial photon intensity by half.

Table 3. Instrument Types for Detecting Some Common Isotopes

	Isotope					
	H-3	C-14	P-32	P-33	S-35	I-125
Instrument						
GM	-	G	E	G	E	P
NaI	-	P	G	P	P	E
LSC w/wipe	G	VG	E	VG	E	P
COBRA	-	-	-	-	-	E

P= POOR G= GOOD VG = VERY GOOD E= EXCELLENT "-" = NO DETECTION

GM on a Survey Meter

NaI on a Survey Meter

LSC means "liquid scintillation counter" where either a liquid or dry sample is put into a vial containing a counting fluid and capped.

COBRA means a gamma counter where a dry sample is put into glass or plastic tube and left uncapped.

Technical Information For Some Commonly Used Radionuclides

In the information that follows, DAC refers to occupational derived air concentration. The DAC limit is the concentration of radionuclide in air that if breathed for 2000 hours will result in one ALI. The term "ALI" refers to the "annual limit on intake" or the activity limit that if taken internally equals 5,000 millirem. The dosimetric and biological information currently used for regulatory purposes is based on data from ICRP 30.

H-3

Occupational Limits: DAC: 2.5×10^{-5} uCi/ml
ALI: 80,000 uCi, inhalation
Biological Half-Life: 10 days via urine
Radiological Half-Life = 12.3 years

Dosimetric Considerations:

Millicurie quantities of tritium do not present an external exposure hazard because the low energy betas emitted cannot penetrate the outer layer of the skin. The potential sources of internal occupational exposure from tritium are direct dermal contact, skin puncture, inhalation of tritiated water vapor, or inadvertent ingestion of tritiated water and tritiated organic compounds. The critical organ for tritium uptake is the whole body water. Three to four hours after intake, tritiated water is uniformly distributed in all body fluids, including urine.

Tritium elimination rates may be accelerated by increasing water intake. Many tritium compounds will penetrate gloves and skin, therefore these compounds should be handled while wearing two pairs of gloves and by changing the outer layer at least every 20 minutes. Tritiated DNA precursors are considered more toxic than tritiated water, however they are generally less volatile and do not normally present a significantly greater hazard.

C-14

Occupational Limits: DAC: 1.0×10^{-6} uCi/ml, compounds.
ALI: 2,000 uCi, inhalation of compounds
Biological Half-Life: 10 days for most compounds, ranging from minutes to up to about 42 days. Excretion occurs as $^{14}CO_2$ or as metabolites via urine.
Radiological Half-Life = 5,730 years

Dosimetric Considerations:

C-14 is a pure beta emitter and, on direct contact, can cause an external dose rate of 0.94 rad/h per uCi/cm^2 to the skin (at a density thickness of 7 mg/cm^2 or at 70 um depth). However, the range of C-14 beta particles in air is about 20 cm. Except for direct contact, the potential for external exposure from unshielded C-14 sources is small. The range of C-14 beta particles in unit-density material is less than 1 mm. Most plastic or glass containers will minimize or totally eliminate the risk of beta exposures. As a result, C-14 is primarily a potential source of external exposure for contaminated skin, or internal exposure if accidentally inhaled or taken in via a puncture wound. Millicurie quantities of C-14 do not present a significant exposure hazard because the low energy betas emitted barely penetrate the outer skin layer. The critical organs for many C-14-labeled carbonates are the bone, and fat for some C-14-labeled compounds.

Some C-14-labeled compounds may penetrate gloves and skin. Handle these compounds while wearing two pairs of gloves and change the outer gloves frequently.

P-32

Occupational Limits: DAC: 2.0 x 10^{-7} uCi/ml, phosphate compounds.
ALI: 400 uCi, inhalation
Biological Half-Life: about 2 days via urine from intracellular fluids and 19 days for soft tissues.
Radiological Half-Life = 14.3 days

Dosimetric Considerations:

P-32 is a pure beta emitter. However, because of the energetic beta emission (0.695 MeV average and 1.71 MeV max), it can lead to significant skin exposures. The eyes, however, may be the limiting organ unless adequate eye or face protection is provided. In addition, bremsstrahlung radiation can be produced by the interaction of beta particles with containers or shields made of high-Z materials, (i.e., Pb). On direct contact, P-32 can yield elevated skin dose rates, i.e., 6.2 rad/h per uCi/cm^2 (at a density thickness of 7 mg/cm^2 or at 70 um depth).

The range of P-32 beta particles in air is on the order of 6 meters. Skin exposures from beta particles passing through a container wall could be substantial if the wall thickness is less than 1 cm. The range of P-32 beta particles in unit density material is 0.8 cm. Accordingly, a one-cm thick plastic or glass container will nearly eliminate all beta exposures, with lead on the outside of the lucite to decrease bremsstrahlung emissions, if needed. For containers with walls less than 1 cm, or for portions of the container with minimal shielding (e.g., an injection septum), the beta dose rate could be considerably higher. Wear extremity ring and whole body dosimeters while handling mCi quantities. Use shielding to minimize exposure while handling P-32 and do not work over open containers. Use tools to handle unshielded sources and potentially contaminated vessels. Never handle mCi quantities unshielded.

Following an intake, P-32 is typically retained in blood plasma, intracellular fluids, soft tissues, and mineral bone for transportable compounds. The critical organ is the bone for transportable compounds of P-32, with the lung and lower large intestine being the critical organs for inhalation and ingestion of non-transportable P-32 compounds, respectively. Thirty percent of P-32 is rapidly eliminated from the body, 40% has a half-life of 19 days and 30% is permanently retained in mineral bone, where it decays.

P-33

Occupational Limits: DAC: 1.0 x 10^{-6} uCi/ml, phosphate compounds.
ALI: 3,000 uCi, inhalation.
Biological Half-Life: see P-32.
Radiological Half-Life = 25.4 days

Dosimetric Considerations:

P-33 is a pure beta emitter. However, it is less energetic than P-32 with a beta emission of 0.25 MeV (max) and an average of 76.6 keV. The lens of the eyes is the limiting organ unless adequate eye or face protection is provided. Because of the low energy, bremsstrahlung radiation is not significant when using containers or shields made of high-Z materials. On direct contact, P-33 can also yield elevated skin dose rates, about 2.2 rad/h per uCi/cm^2 (at a density thickness of 7 mg/cm^2 or at 70 um depth). The range of P-33 beta particles in air is about 0.5 meter.

See P-32 for biological dosimetric considerations.

I-125

Occupational Limits: DAC: 3×10^{-8} uCi/ml
ALI: 60 uCi, inhalation.
Biological Half-Life: 69 days.
Radiological Half-Life = 60.1 days

Dosimetric Considerations:

I-125 is a weak gamma and X-ray emitter (less than 35 keV). The radiation fields in the vicinity of various quantities of I-125 will vary, but is estimated to be about 0.28 mR/hr at 100 cm per mCi. The half-value layer for I-125 is 0.3 mm for Pb based on 35 keV photon emissions. However, in keeping with ALARA practices, millicurie quantities of I-125 will be kept in Pb containers or stored behind Pb shields (or foils) or kept in shielded storage cabinets, as practicable.

I-125 has an extremely restrictive intake limit because it accumulates in the thyroid gland (about 30% of intake). Iodine can, in addition to inhalation, be readily absorbed through intact skin. Protective clothing (at a minimum, lab coats, safety glasses and double gloves) must be worn when handling radioiodines. Since radioiodines are volatile, experiments using more than 0.5 mCi I-125 will be performed in vented hoods, glove boxes, or enclosures. Chlorine bleach must not be used, in any concentration, as a disinfectant. Depending upon chemical forms, the RSO may establish alternate limits for non-volatile compounds.

Individuals handling 0.5 mCi or more of bound I-125 or 0.1 mCi or more of free I-125 (single use), shall undergo routine thyroid scans and/or urine analyses. A bioassay program has been established. If bioassay results exceed specified levels, or an accident is suspected, additional bioassays and a follow-up investigation will be performed.

S-35

Occupational Limits: DAC: 7.0×10^{-6} uCi/ml, sulfides and sulfate compounds.
ALI: 20,000 uCi, inhalation.
Biological Half-Life: 90 days with elimination rates dependent upon the chemical form, ranging from less than a day to about 80 days.
Radiologic Half-Life = 87.4 days

Dosimetric Considerations:

S-35 is a pure beta emitter with a beta emission of 167 keV (max). The lens of the eye is the limiting organ unless adequate eye or face protection is provided. Because of the low energy, bremsstrahlung radiation is not significant when using containers or shields made of high-Z materials. On direct contact, S-35 can still yield elevated skin dose rates, about 1.0 rad/h per uCi/cm^2 (at a density thickness of 7 mg/cm^2 or at 70 um depth). The range of S-35 beta particles in air is about 0.4 meter.

When using S-35, an absolute requirement prior to beginning an experiment is knowing the characteristics of the labeled compound. For example, ^{35}S-methionine has volatile characteristics, even in the original vendor supplied container. Therefore, any experiment using S-35 methionine in excess in of 2 mCi (including, but not limited to, pipetting from the original vendor supplied container to make master dilutions) must be performed in a fume hood. Extra care and engineered controls must be used to prevent inhalation of volatile components and to prevent aerosolization during the experiment. Some examples of controls required include, but are not limited to, using screw-top Epindorff tubes, standing away from opening the centrifuge top, using charcoal paper over a sample in a incubator and using a disinfectant other chlorine bleach.

Depending upon chemical forms, the RSO may establish alternate limits for non-volatile compounds.

Some Common Definitions

Accelerator
A device used for imparting a large amount of kinetic energy to electrically charged particles such as electrons or protons.

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

Activation
The process of causing a non-radioactive active substance to become radioactive by irradiation.

Ampere
A unit of measurement of electric current. It is proportional to the quantity of electrons flowing through a conductor past a given point in one second. It is analogous to cubic feet of water flowing per second.

Anode
The electrode of an electrochemical cell at which oxidation occurs; the positive terminal of an electrolytic cell.

Annual limit on intake (ALI)
The derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in one year. The ALI is the value of intake of a given radionuclide in one year by Reference Man that would result in a committed effective dose equivalent of 5 rems (0.05 sievert) or a committed dose equivalent of 50 rems (0.5 sievert) to any individual organ or tissue.

Aqueous Liquid
A liquid that contains no organic solvents, hazardous chemicals or RCRA listed chemicals. Contact Radiation Safety Services before using a laboratory sink for the disposal of any radioactive liquid.

Atom
The basic component of all matter. The atom is the smallest particle of an element that has all of the chemical properties of that element. Atoms consist of a nucleus of protons and neutrons surrounded by electrons.

Atomic Number
The number of protons in the nucleus of an atom.

Atomic Mass Number
The number of protons and neutrons in the nucleus of an atom.

Background radiation
Radiation being observed or measured from sources other than those of interest. Usually referring to the measurement of radiation emissions from environmental, natural (such as radioactive substances in building materials), or cosmic sources.

Bequerel (Bq)
A unit of activity equal to one (1) disintegration per second. Since this is a very small unit, the typical values associated with samples used in the laboratory are in

Bremsstrahlung
Secondary photon radiation produced by deceleration of charged particles passing through matter. The process by which **x-ray** radiation is produced.

Cathode
The electrode of an electrochemical cell at which reduction occurs; the negative terminal of an electrolytic cell.

Cherenkov Radiation
Blue light emitted when a charged particle moves in a transparent medium with a speed greater than the speed of light in the same medium. It is usually observed when high speed beta particles are emitted within a water medium, like in a nuclear reactor.

Cloud Chamber
A device for observing the paths of ionizing particles. These devices are based on the principle that supersaturated vapor condenses more readily on charged ions than on particles with a neutral charge. A cloud chamber is typically used to visually demonstrate the range and path of alpha particle emission.

Contamination
Radioactive material in any place where it is not desired.

> **Fixed Contamination**
> Contamination on a surface that cannot be removed using common cleaning methods.
>
> **Removable Contamination**
> Contamination on a surface that can be removed so that any remaining contamination is below administrative limits.
>
> **Personnel Contamination**
> Contamination on a person's body or clothing.
>
> See also **Internal Deposition**

Coulomb (C)
A quantity of charge equal to one ampere per second.

CPM
Counts per minute.

Curie (Ci)
A traditional unit of activity equal to 3.7E10 disintegrations per second. Since this is a very large unit, the typical value associated with samples used in the laboratory are the **millicurie** (1E-3 Ci) and the **microcurie** (1E-6 Ci). One **microcurie** equals 2,222,000 disintegrations per minute or 37, 000 Bq.

Decay, Radioactive
Disintegration of a nucleus of an unstable nuclide by spontaneous emission of charged particles and/or photons.

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

Derived air concentration (DAC)
The concentration of a given radionuclide in air which, if breathed by Reference Man for a working year of 2,000 hours under conditions of light work, results in an intake of one ALI. For purposes of 105 CMR 120.000, the condition of light work is an inhalation rate of 1.2 cubic meters of air per hour for 2,000 hours in a year.

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 2,000 DAC-hours to represent one ALI, equivalent to a committed effective dose equivalent of 5 rems (0.05 sievert).

Disintegration
A spontaneous nuclear transformation characterized by the emission of particles and/or photons from the nucleus of an atom. Nuclear disintegration is a random event. However, large numbers of nuclei of the same radionuclide can exhibit a halflife.

Dose
The amount of energy imparted per unit mass of material. If unqualified, dose is a shortened phrase for the term "**absorbed dose**."

Dose rate
Absorbed dose delivered per unit time.

Dosimeter
A device, usually in the form of a badge or a ring, used to detect and measure radiation dose accumulated over a given time period.

DPM
Disintegrations per minute (see also **Disintegration**).

Efficiency
A measure of the probability that a particular radiation particle or photon will be counted by a radiation detection instrument. Efficiency is usually measured for hand-held survey meters by dividing the number of **cpm** observed by meter with the number of expected **dpm** for a radionuclide in the same geometry. Some efficiency values are written in "percent" which is an artifact of multiplying the cpm per dpm value by 100.

Electrode
A substance that conducts electricity used to establish electrical contact with a nonmetallic part of an electrical circuit.

Electron
A stable elementary particle having a rest mass of approximately 9.1091E-31 kg or 511 keV and an electrical charge equal to approximately 1.602E-19 C.

Electron volt
A unit of energy equivalent to the energy gained by an electron when it is passed through a potential difference of one volt. Most particles or photons emitted by radioactive atoms are measured in kilo electron volts (keV) or mega electron volts (MeV). The electron binding energy for a hydrogen atom is approximately 13.6 eV.

Fission
A nuclear transformation characterized by the spitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy, usually as heat and nuclear radiation. Most nuclear reactors are designed so that neutrons need to be "thermalized" (slowed down by colliding with the hydrogen in water molecules) to be absorbed into nuclear fuel to maintain the fission process. All commercial nuclear power plants in the United States are designed to shut down the nuclear fission process as the core of the reactor heats up.

Fissile or fissionable
A nuclide capable of undergoing nuclear fission by interacting with neutrons, usually slow (thermal) neutrons.

Fusion
The colliding of two or more nuclei with extremely high kinetic energy due to thermal agitation and high pressure to form a third nucleus with the release of a tremendous amount of thermal energy and nuclear radiation. This reaction is seen naturally in stars.

Geiger-Mueller Survey Meter (GM)
A hand-held survey meter using a Geiger-Mueller (GM) probe to detect radiation. The GM probe is filled with a counting gas. Radiation detection takes place when ionizing radiation with sufficient energy to pass through thin film or window interacts with the gas. The radiation event interacting with the gas causes a cascade of ions to migrate to a charged electrode yielding a single pulse. The pulse is independent of the energy of the initial event or the number of primary ions produced. Because the low density of the gas, the GM is good for detecting alpha and beta radiation. Only high energy, high fluence rate gamma radiation fields are detectable with a GM.

Hydrogen
An atom, which contains one proton in its nucleus.

Internal Deposition
Radioactive material from an inhalation, ingestion or injection that deposits in a body organ or enters the systemic.

Ion Chamber
An instrument designed to measure ionizing radiation in terms of the charge of electricity produced by ions from radiation interaction occurring within a defined volume inside the detector. Typically used for measuring gamma photons and x-rays.

Half-life
When very large numbers of radioactive nuclei are decaying, the half-life is the time it takes to reduce a given number of radioactive atoms to one half of their original number. For example, if a sample of a radionuclide contains 1,000 atoms and has a half life of 14 days, in 14 days there would be 500 atoms remaining.

Kilo Electron Volt (keV)
One thousand electron volts.

Laboratory Disposal Sink (see Radiation Disposal Sink)

Liquid Scintillation Counter (LSC)
An instrument where a radioactive sample is placed in a vial containing **scintillation** fluid. The vial is then moved into close proximity to photomultiplier tubes. The radiation in the sample interacts with the scintillation fluid and emits light. The light intensity is directly proportional to the radiation energy captured within the scintillation fluid. The light being emitted from the scintillation fluid is detected by the photomultiplier tubes. Through a series of electrical circuits and computer databases, a light pulse is converted to an electrical signal. Each electrical pulse is categorized and filed to yield a spectrum. The spectrum can be cross-referenced to identify radionuclides from a library of spectra.

Mega Bequerels (MBq). One millicurie (1 mCi) equals 37 MBq. One microcurie (1 uCi) equals 37,000 Bq or 2,222,0000 disintegrations per minute.

Mega Electron Volt (MeV)
One million electron volts.

Microcurie (µCi)
One millionth of a curie equal to 37,000 Bq or 2,222,000 dpm

Millicurie (mCi)
One thousandth of a curie equal to 37,000,000 Bq or 37 MBq

NaI Survey Meter
A survey meter that uses a scintillation probe composed of a NaI(Tl) crystal. When radiation interacts within the crystal, light is emitted at an intensity that is directly proportional to the energy that has been deposited in the crystal. A signal is sent to the meter by means of a photomultiplier tube. The pulse height emitted by the photomultiplier tube is directly proportional to the light emitted from the NaI(Tl) crystal. However, the survey meter cannot be used as a spectrometer as it converts any pulse it sees to a single count. So the readout of this meter is in counts per minute (cpm). Like any hand-held survey meter, the NaI survey meter must be calibrated and an **efficiency** conversion factor calculated for the radioisotope of interest. The efficiency factor must be used to convert **cpm** to dpm.

Neutron
An elementary nuclear particle with no charge with the approximate mass of a **proton.**

Neutron howitzer (neutron generator)

A device used to generate neutrons in thermal equilibrium for academic experiments or to test the operation of neutron detecting instruments.

Non-stochastic health effect
A health effect, the severity of which varies with the dose and for which a threshold is believed to exist. Radiation-induced cataract formation or a sunburn from the sun's ultraviolet radiation are examples of a non-stochastic effects. Another term for a non-stochastic effect is a "deterministic" effect.

Personal Protective Equipment (PPE)
Safety equipment worn by an individual to help prevent personal contamination (for example, using a synthetic rubber glove to stop a droplet of radioactive liquid contacting the skin) or exposure (for example, using plastic safety glasses to stop beta radiation exposure to the eye). The minimum PPE required when handing any radioactive material at the laboratory bench is a lab coat, safety glasses with side shields and synthetic rubber gloves.

Photon
When a wave of electromagnetic energy exhibits the property of a particle, such as mass, when interacting with matter, such as when a photon ejects an electron from an atom by imparting all of its kinetic energy to the electron.

Proton
An elementary nuclear particle with a positive electric charge numerically equal to that of an electron and an approximate mass of 1.6604E-21 kg.

Quench curve
A method for calibrating a liquid scintillation counter so that it recognizes a change in color within a scintillation fluid medium that may cause a dimming or shifting of the expected light spectra during a count that is identified by exposing a sample vial to a known radioactive standard prior to counting a vial.

Radiation
For the purposes of this manual, radiation refers to "ionizing radiation." Ionizing radiation is radiation that has enough energy to be capable of removing an electron from an atom or molecule. The most common removal mechanisms are by direct collision, repulsive magnetic force or annihilation by oppositely charged particle, like a positron. If the radiation originates from the nucleus, it may be known as nuclear radiation. If radiation originates from outside the nucleus or within the electron cloud, it may be known as extranuclear radiation.

Alpha radiation
A particle consisting of two protons and two neutrons bound together with no electrons emitted from the nucleus of an atom with a discrete energy. Since alpha particles are doubly charged, alpha particles are highly ionizing and stop within a very short distance. An alpha particle cannot penetrate the dead layer of skin on the human body or a piece of paper.

Beta radiation

A particle with the mass and charge of an electron emitted from the nucleus of an atom. The particle may be either negatively charged or positively charged.

- A positively charged beta particle is referred to as a "positron." Created from the transformation of a proton into a neutron and ejects a positron plus a neutrino.
- A negatively charged beta particle is referred to as a "beta particle. Created from the transformation of a neutron into a proton and eject a beta particle plus an antineutrino.

The vast majority of beta radiation emitted from the nucleus of an atom is negatively charged. Beta radiation emitted from a quantity of a single radionuclide varies in energy up to a beta maximum energy. The most probable beta energy emission occurs at one-third of the maximum beta energy. Beta radiation or a particular radionuclide is associated with the maximum beta energy emitted.

Gamma photon or gamma ray
Short wave length electromagnetic radiation emitted from the nucleus. Since a gamma photon has no charge, the probability of a gamma photon interacting with matter is proportional to the mass of a material.

Neutron radiation
Radiation in the form of an elementary nuclear particle without electric charge that is be ejected from the nucleus as well as by nuclear fission or nuclear fusion. The energy of a neutron is somewhat based on the speed with which it is ejected from the nucleus. **Thermal neutrons** have established a thermal equilibrium with their environment. **A neutron being absorbed** by a **stabile or non-radioactive nuclide** can yield a **radioactive atom.**

X-ray radiation
Electromagnetic radiation with wavelengths just shorter that those emitted by ultraviolet light. Also know as "**bremsstrahlung**". X-rays are produced using high voltage electricity in medical diagnostic and research devices. Devices that produce x-rays are not radioactive once the power is turned off.

RAD
A unit of absorbed dose equal to 0.01 J/kg

Radioactivity
The property of certain nuclides to spontaneously emit particles or photons.

Radiation Disposal Sink
A special sink designated for the disposal of radioactive liquids. This sink must be inspected and approved by Radiation Safety Services before any radioactive liquid is poured down the drain. Special warning signs and labels must be placed on the sink and connected plumbing. Only aqueous liquids may be poured down a sink that is being used for the disposal of radioactive liquids.

RCRA
The Resource Conservation and Recovery Act of 1976, which is administered by the U.S. Environmental Protection Agency (USEPA). For example, ethanol and muriatic acid are chemicals that may be purchased by the general public that are listed by the USEPA as being hazardous. Therefore, any liquid wastes generated in the laboratory the contain

ethanol or muriatic acid must not be poured down a laboratory sink. Instead, these liquids must be collected by laboratory personnel for proper disposal by EH&S.

Reference Man
A Hypothetical aggregation of human physical and physiological characteristics determined by international consensus. These characteristics may be used by researchers and public health employees to standardize results of experiments and to relate biological insult to a common base. A description of Reference Man is contained in the International Commission on Radiological Protection report, ICRP Publication 23, "Report of the Task Group on Reference Man."

REM
A special unit of dose equivalent. The equivalent in rems is numerically equal to the absorbed dose in rads multiplied by a quality factor. For example, since alpha radiation is doubly ionizing, a rad of alpha radiation striking lung tissue would be given a higher multiplier than a rad of gamma radiation striking the same type of lung tissue. Therefore, a rem of alpha radiation would be expected to cause the same amount of damage to the same type of tissue as a rem of gamma radiation.

Roentgen (R)
A special unit of exposure for air. One roentgen equals 2.58E-4 C/kg in air at S.T.P. Many survey meters are calibrated in roentgen units. One roentgen is approximately equivalent to one rad of gamma radiation emitted from a one MeV radiation source.

Sanitary sewer
A system of public sewers for carrying off waste water and refuse, but excluding sewage treatment facilities, septic tanks, and leach fields owned or operated by the licensee or registrant. See also **Radiation Disposal Sink.**

Scintillation
The ability of certain crystals, plastics or fluids to emit light when radiation interacts within the scintillating medium. Typically, the intensity of the emitted light is directly proportional to energy of the ionizing radiation particle or photon absorbed in the medium.

Scintillation Detector
A device used to measure radiation from the light emitted from a scintillation crystal or plastic. A detector commonly used to measure gamma radiation is the sodium iodide (NaI) detector coupled to a **NaI survey meter.**

Sealed Source
Radioactive material that is completely encased in a non-reactive material, such as plastic, or embedded onto a metallic surface. Because the radioactivity is bound to another material, sealed sources do not present a significant contamination hazard under normal conditions.

Shield
Any device used to reduce the exposure to radiation. The type and thickness of shielding material used depends on the type and intensity of the radiation field. One to two centimeters of clear acrylic sheet usually provides enough shielding mass to stop all beta particles. Lead shielding is used to reduce x-ray or gamma photon exposure.

Sink (see Radiation Disposal Sink)

Stochastic health effect
A health effect that occurs randomly and for which the probability of the effect occurring, rather than its severity, is generally used. The dose-effect relationship is assumed to be a linear function without threshold. Hereditary effects and the incidence of cancer are examples of stochastic effects. For regulatory purposes, "probabilistic effect" is an equivalent term.

Survey Meter (Hand-held)
A hand-held device used to measure radioactivity. The device usually consists of a radiation detector connected to a meter body by means of shielded signal wire. A survey meter must be calibrated and equipped for the type of radiation to be measured. For example, to measure P-32 (or other beta radiation emitter), a survey meter would consist of a meter body connected to a **GM** probe. To measure I-125 (or other low energy gamma emitter), the survey meter would consist of a meter body connected to a **NaI** detector. Some survey meters, like an **ion chamber** have the detector permanently mounted within the meter body itself.

Swipe Test: *See **Wipe Test***

Tritium
A hydrogen isotope containing one proton and two neutrons.

Volt
Basic unit of electrical potential. One volt is the force required to send one ampere of electrical current through a resistance of one ohm

Watt
A standard unit of power defined as one Joule of energy transferred or dissipated in one second

Wipe Test
A method for detecting removable contamination by taking a sample of an area by wiping the surface with a cotton swab or filter paper. The sample is typically counted on a liquid scintillation counter. A sample may be counted with another instrument which has been calibrated for the geometry of the sample position with relation to the radiation detector and if the geometry is reproducible from sample to sample.

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