RADIATION SAFETY GUIDE

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I. INTRODUCTION AND ALARA POLICY STATEMENT

A. Introduction

At RWJMS (Robert Wood Johnson Medical School), all potentially hazardous sources of radiation are controlled through an authorization program. The program considers the applicable state and federal regulations and standards, which are generally separated into two radiation categories: ionizing and non-ionizing.

All uses of ionizing radiation in New Jersey are controlled and regulated by either the Federal U.S. Nuclear Regulatory Commission or the New Jersey Bureau of Radiation Protection, a subset of the Department of Environmental Protection. RWJMS has received licenses from both of these agencies which permit considerable scope and autonomy in the use of ionizing radiation.

Work with sources of ionizing radiation can not be initiated until a written authorization has been received specifically permitting that work.

The use of non-ionizing sources of radiation are not presently controlled at RWJMS through a government licensing program. There are, however, federal standards and exposure limits and professionally accepted limits pertaining to these sources of radiation.

RWJMS has appointed a Laboratory Safety Committee to establish a comprehensive radiation safety program to assure that all potentially hazardous sources of radiation are used safely. In every facility where radioactive materials are utilized, it is necessary to maintain policies which establish specific methods to develop and maintain safety and compliance.

By contractual agreement, the Rutgers Environmental Health & Safety Department (REHS) is responsible for implementing radiation policies and procedures approved by the Committee through a broad range of services.

These services include radioactive materials delivery, radiation safety training, x-ray safety, radioisotope authorization and inspection, radioactive waste pick-up and disposal and emergency response.

This Guide (1) describes the organization of the Radiation Safety Program and the levels of responsibilities at RWJMS; (2) describes basic radiation theory; (3) specifies the regulations, policies and practices which must be followed when using sources of radiation; and (4) describes the radiation services which RWJMS makes available to assist the user in his/her safety program.

B. ALARA Policy Statement

In practice, radiation doses in the workplace must be maintained **A**s **L**ow **A**s **R**easonably **A**chievable. ALARA is a guideline meant to strike a balance between the cost of radiation protection and the health benefit derived from that protection. ALARA is also a requirement of the law, meaning all facilities possessing radioactive materials licenses must have an ALARA program. The regulatory guideline and our license require managing programs and procedures to achieve less than 10% of the applicable legal limits, such as air and water releases, exposure limits or contamination limits for radiation labs.

It is the responsibility of everyone, including radiation workers, authorees, REHS and the RWJMS administration to operate within the ALARA guidelines. This is achievable, in part, by outlining safe work practices for the use of radioactive materials and by monitoring the workplace to control contamination and minimize doses. Practical measures to incorporate ALARA into work practices are included in this manual to assist radiation workers. Simple concepts and easy precautions should prevent contamination, exposures and releases.

II. LABORATORY SAFETY COMMITTEE

The Robert Wood Johnson Medical School Research Committee has established a Laboratory Safety Sub-committee. One of its responsibilities is to set policy and establish the general procedures for the safe use of radiation sources. Its membership is representative of the areas within the Medical School in which sources of radiation are used. The Director of Rutgers Environmental Health and Safety, Rutgers University, is a permanent member of this Committee.

The Committee is appointed by the Dean of Robert Wood Johnson Medical School, and is charged with:

1. Developing the Medical School's radiation safety policy in such a manner as to:

    a. Assure compliance with all federal and state regulations;
    b. Promote, through a sound safety program, the use of radiation; and
    c. Assure against unwarranted radiation exposure of RWJMS personnel and the public and to protect RWJMS property and liability.

2. Acting as trustee to assure the continued quality of the Radiation Safety Program.

3. Adjudicating any difference between faculty and REHS concerning radiation safety.

The Laboratory Safety Sub-Committee meets as often as is necessary to carry out its functions, or when a Committee member so requests. Binding Committee deliberations require the presence of a majority of its members or alternates. (An alternate may be designated by an individual member who cannot attend a specific meeting. For that meeting, the alternate has the full rights of the member). Committee deliberations are normally informal, but will follow Roberts Rules of Order if so requested by a member. Minutes of all Committee meetings are recorded and kept by both the Chairman and the Secretary.

Where there are specialized geographical or professional needs, the Laboratory Safety Sub-Committee may establish sub-committees. These subcommittees serve at the pleasure of, and their deliberations are subject to the review of, the parent Research Committee. Communication between the sub-man of the sub-committee be a member of the parent committee and that the minutes of subcommittee meetings be filed with the parent committee. To assure liaison between subcommittees and REHS, it is required that the secretary of each subcommittee be a member of REHS.

III. AUTHORIZATION TO USE RADIOACTIVE MATERIALS

A. SOURCES AND USES

Research at RWJMS may involve the use of sources of ionizing radiation. Sources of ionizing radiation include any radioactive material or device emitting or capable of producing, radiation. The uses range from labeling of cell cultures and DNA to the determination of the structural integrity and composition of materials.

B. RESPONSIBILITIES - AUTHOREE

The authoree is the individual permitted to use radioactive materials by virtue of a written authorization and has primary responsibility for the safe practices of individuals working under his/her supervision. Authorees are obligated to:

1. Properly supervise all individuals working under their authorization to ensure a safe working environment and compliance with all RWJMS policies.
2. Maintain adequate inventory and knowledge of the various forms and quantities of radioactive materials that are present in their laboratories.
3. Conduct and document the appropriate contamination surveys to assure the lab is free of radioactive contamination.
4. Maintain immediate control of radioactive materials to prevent the unauthorized removal or tampering, and assure that workers occupying the area maintain security.
5. Assure all users under their authorization attend the required radiation safety training programs.
6. Report IMMEDIATELY any spills, emergencies or accidents to REHS (or to Public Safety after working hours.)
7. Notify REHS, in writing, <u>of any personnel changes, changes in the location where radioactive materials may be used or stored, or adjustments to the possession limits of radionuclides under their authorization</u>
8. Avoid any unnecessary radiation exposure either to themselves or to other workers by adhering to the ALARA policy.
9. Procure and dispose of radioactive materials according to the procedures established by REHS.
10. Be aware of the regulations and requirements pertaining to the use of radioactive materials, and to disseminate this information to all workers in the lab.

RESPONSIBILITIES - RADIATION WORKER

Each individual who works with radioactive materials or radiation-producing equipment under the supervision of an authoree is referred to as a radiation worker. Radiation workers are responsible for the following:

1. Each worker must attend an initial radiation safety orientation given by REHS. Workers should not handle radioactive materials until this has been completed, and they successfully pass the quiz. A refresher radiation safety session is required each year.

2. Workers must wear their personnel monitoring devices, if appropriate, while handling radioactive materials or operating radiation producing devices. Badges should be returned on time and any loss reported to REHS.
3. Workers must practice ALARA in their work and minimize the potential for exposures.
4. Radiation work areas must be monitored by the user after each use of radioactive material. If areas of contamination are detected, they must be cleaned up immediately.
5. Any abnormal occurrence, such as a spill, significant contamination, etc., must be reported immediately to the authoree and REHS.
6. No changes to experimental protocol should be made without the approval of the authoree and REHS.
7. Workers are responsible for adhering to all regulations, license conditions and guidelines pertaining to the use of radioactive materials.
8. Workers are responsible for maintaining the security of radioactive materials at all times.

C. INITIAL APPLICATION AND APPROVAL

Approval for the use of radioactive materials is given by the Laboratory Safety Committee for a period of two years. Approvals may be obtained by submitting a brief application describing the requested material and quantity to be used, the locations, the individuals who will handle the material, the training and experience of the applicant, a brief description of experimental procedures, *etc*. An authoree must have adequate training and experience commensurate with the proposed uses of licensed materials, *i.e*., authorees should have experience handling radionuclides of similar energy and activity. To be approved as an authorized user (authoree), an authoree must:

(a) Be a faculty or staff member with at least the rank of Instructor, Research Associate, or equivalent.

(b) Have a graduate degree in a Physical Science, Biomedical Science, Engineering, or a MD plus a minimum of one year of experience working with radioisotopes of similar characteristics and activity.

(c) Have the use of adequate facilities and equipment to contain and detect the presence of the radioisotopes authorized for use, so there is reasonable assurance that exposure to personnel will be minimized. "Adequate" facilities and equipment may include impervious floor and bench surfaces, a laboratory fume hood if volatile materials are used, radioactive waste containers and, if appropriate, shielding and portable survey instruments capable of detecting the authorized radioisotopes.

(d) Be approved by the Laboratory Safety Committee.

(e) Attend the REHS initial radiation safety training

Authorization applications may be obtained by calling REHS at 732-445-2550 or by accessing the REHS website at http://rehs.rutgers.edu.

D. EXPIRATION AND RE-APPROVAL

Radioisotope authorizations expire two years from the date of issuance, at which time they must be renewed for uninterrupted use of radionuclides. REHS will mail a copy of the authorization form to each authoree approximately one month prior to the date of expiration with instructions on how to renew the authorization.

E. AMENDMENTS

Amendments to current authorizations are given for increases in possession limits of a radioisotope, additions/deletions of authorized laboratories, additions of new radioisotopes, changes in chemical forms of previously approved material, *etc*. Amendments may be obtained by submitting a short memo stating the desired change, and the reason for the change, referencing the authoree number. The amended uses may not begin until authorization (approval) of the amendment is received, in writing, by the authoree.

F. TERMINATION OF AUTHORIZATION AND DECOMMISSIONING

The authorization will be terminated if the authoree leaves the employment of the University or ends his/her use of radiation sources. An authorized user (Authoree) who will not be using radionuclides in research for an extended period of time may, upon request and after completion of several steps, have an authoree status of "inactive". An inactive authoree will be relieved of the requirements to send in quarterly inventories, complete laboratory contamination surveys, and attend annual refresher training sessions when officially transferred to inactive status.

REHS has developed a procedure to deal with an authoree whose research involving radioisotopes is terminated or on hold for an indefinite period of time. In order to be granted inactive status, a letter should be sent to REHS requesting to become inactive, and ensuring the following:

a.) a decommissioning wipe survey has been completed and all results are background.
b.) all radioactive materials have been properly disposed of or transferred to another authoree.
c.) all radiation badges have been returned to REHS.

Once these steps have been completed, REHS will perform a final decommissioning survey (wipes and an instrument survey) and remove all radiation signage and labels from the lab.

Authorees are responsible for the contamination survey of any area where radioactive materials have been used or stored under their supervision. Laboratory benches, the floor, fume hood and any equipment that was used in experiments with radioactive materials shall be checked for contamination prior to being decommissioned. The following guidelines should be followed by an authoree when decommissioning a lab:

1. Send a memo to REHS indicating the location of the room you would like decommissioned. If you are moving to a new location, indicate the building, new room number and approximate date of the move.

2. Remove all sources of radioactivity from the lab by using proper radioactive waste disposal or isotope transfer procedures. If moving to a new lab, prior arrangements should be made with REHS to transport the radioisotope and/or to move radioactive waste containers.

3. Conduct a final contamination wipe survey of the lab and equipment to certify the area is free of contamination. If any areas show signs of contamination, e.g., greater than 100 dpm above background, they must be decontaminated and re-wiped.

4. Notify REHS that the contamination survey has been completed and all areas are free of contamination.

5. REHS will remove all radioactive postings after the performance of a confirmatory wipe survey.

G. REACTIVATION OF AUTHORIZATION

If you wish to re-activate your authorization at a later date, the following steps should be taken:

a.) send a letter to REHS requesting activation of your authorization.
b.) update all isotope protocols and possession limits.
c.) arrange for calibration of your survey meter.
d.) obtain all personnel dosimetry, if applicable.
e.) ensure that all personnel have satisfied the training requirements.

REHS will then make arrangements to post the labs, deliver radioactive waste drums, etc. after approval of the renewal by the Laboratory Safety Committee.

IV. TRAINING

Effective training is an integral part of our radiation safety program. Each individual working in a radioactive material use area, must be provided information on any potential radioactive hazards present in the area. Radiation safety training outlines those practices which contribute to a safe and compliant laboratory, and gives guidance on the services which are provided by REHS. All users, including the authoree, must attend annual radiation safety training given by REHS.

UMDNJ-RWJMS assures that the Nuclear Regulatory Commission regulations for radiation safety training as specified in 10 CFR 19 are met for persons working in the University as follows:

A. Initial Orientation

Users (those persons working directly with sources of radiation) are required to attend an initial orientation. The authoree is responsible for instructing the worker in the potential hazards of his/her work as interim training, however, initial orientation must be successfully completed <u>before</u> handling radioactive materials.

To ensure attendees have completed the training requirements, we will administer a basic test; all attendees must correctly answer 75% of questions.

B. Annual Refresher

After attending the initial orientation, all users are required to attend a refresher training session annually.

Both initial and refresher training are offered on a monthly basis. The dates, locations and times are indicated in the "Radiation Notes" sent to all authorees, or can be found on the REHS web page at http://rehs.rutgers.edu.

REHS will also design training courses for specific needs of individual lab.

V. ORDER, TRANSFER, AND RECEIPT OF RADIOACTIVE MATERIALS

A. Order of Radioactive Materials

REHS must approve **ALL** intended receipts and transfers of radioisotopes. This includes any licensed material received as gifts or samples from other licensees. A purchase requisition must be used to order radioisotopes must be countersigned by the Radiation Safety Office after the Purchasing Department assigns a purchase order number and before distribution to the intended user. The REHS address must be entered as the destination for all radioactive shipments, as follows:

Rutgers Environmental Health and Safety
Rutgers, The State University of New Jersey
24 Street 1603
Piscataway, New Jersey 08854-8036
Attention: Authoree name and number

The Nuclear Regulatory Commission or New Jersey State license number, whichever is appropriate, must be typed on the purchase order beneath the description and activity of the radioisotope being ordered. REHS must be notified whenever a radioisotope order is placed with a vendor. This notification may be made by calling REHS or by accessing the REHS web page at http://rehs.rutgers.edu. The authoree must inform REHS of the date of the order, isotope, quantity, chemical form, authoree name, location, etc. REHS will ensure the authoree is approved to possess the radioisotope and his/her authorization limits are verified. Authorees who exceed their possession limits will be denied receipt of the isotope until the discrepancy is resolved or arrangements can be made for a radioactive waste pickup.

Subsequent to the receipt of radioisotopes, the authoree must receive approval from REHS prior to:

a. Moving radioisotopes to locations other than those specified in his/her authorization,
b. Transferring radioisotopes to another authoree,
c. Shipping radioisotopes from RWJMS to another facility or licensee.

B. Transfer of Radioactive Materials

Authorees who wish to transfer isotopes to another authoree will be required to complete an isotope transfer form. Due to federal transportation regulations, authorees may not use personal vehicles to transfer the material; prior arrangements must be made with REHS. Inventory limits of both authorees will then be adjusted after the transfer. Prior to shipping radioisotopes to another licensee, REHS will contact the Radiation Safety Office to request a copy of their NRC or state license.

Shipments of radioactive materials leaving RWJMS must have prior authorization of the Radiation Safety Officer at the receiving institution. Federal and State law requires that the shipper must obtain the receiver's approval and respective NRC or state license number prior to the shipment of the material.

All shipments must be in accordance with the packaging and labeling requirements set forth by the Department of Transportation (DOT). An appropriate record must contain information on the shipper, receiver, radionuclide and activity (in Becquerels), and the phone number of the shipper and receiver. A record must be made of the radiation levels on contact with the package and at one meter using an appropriate instrument, and performance of a survey for removable contamination.

Contact REHS **in advance** of the desired shipping date to assure that all required license exchanges, shipping papers, etc., are completed, as the package will not be shipped until these requirements have been met. The authoree is required to make the necessary arrangements with a suitable courier to pick the package up at REHS, building 4127. Once the necessary arrangements have been made, REHS will pick up the package (to be shipped) from the lab, ensure that it is package properly, and bring it to REHS, where it will be sent by a suitable courier.

C. Receipt of Packages Containing Radioactive Materials

As stated earlier, all packages containing radioactive materials MUST be delivered to REHS. The major radioactive material vendors (ICN, Amersham, DuPont-NEN, etc.) are aware of where to ship your radioactive material. If you are receiving radioactive materials from any other university or company, it MUST be sent to:

Rutgers Environmental Health and Safety
Rutgers, The State University of New Jersey
24 Street 1603
Piscataway, New Jersey 08854-8036
Att: Authoree Name & Number

All radioactive shipments, when received by REHS, are checked for external contamination and their receipt recorded. The radioisotope is then delivered to the authoree's laboratory on the day of receipt, or in accordance with the authoree's instructions. The authoree or his/her representative must sign for the radioisotope.

Packages containing radioactive material will not be "dropped off" without obtaining a receipt signature. Each lab should keep a copy of the delivery form <u>for at least</u> <u>one year.</u>

All personnel are reminded to handle the isotope container and vial while wearing a lab coat and two pairs of gloves. REHS ensures that the outer shipping container is not contaminated, however, the isotope container and isotope vial are not surveyed and may be contaminated. REHS suggests that each isotope container and vial be wiped and the wipe run in a liquid scintillation counter (LSC) prior to placing the vial in secure storage.

Shipping boxes may be disposed of in the regular trash or recycled only if all shipping labels (radioactive, dry ice, etc.) are removed or completely defaced. Please be courteous and do not leave empty shipping boxes with legible shipping labels for the custodial staff.

VI. USE OF RADIOACTIVE MATERIALS IN THE LABORATORY

A. General Safety Procedures

1. Radiation laboratories must be posted with the appropriate radiation warning signs.

2. All personnel must wear laboratory coats and gloves while working with radioisotopes. Safety glasses must also be worn in all laboratories.

3. Lab coats worn in a radioisotope area must not be worn outside these areas, e.g., in the offices, cafeteria or classroom.

4. A double pair of latex gloves (or other appropriate gloves) should be worn when working with high specific activity radioisotopes. Care should be taken not to cross-contaminate items by touching surfaces with contaminated gloves.

5. Eating, drinking and smoking in radiation labs are strictly prohibited. No food or drink containers are allowed in radioisotope areas and must never be stored in refrigerators in the lab. Empty food or drink containers cannot be disposed in a laboratory.

5. Each authoree must have available a calibrated and operable radiation survey instrument appropriate for monitoring the radioisotope(s) in use in the lab.

6. No open containers may be used for transporting radioactive materials outside the approved labs, e.g., hallways, elevators, etc. Containers, test tubes, vials, etc. should be doubly contained while in transport.

7. If issued, radiation badges must be worn properly and exchanged in a timely manner. Badges must not be stored near sources of radiation or lent to others

8. Radioactive waste must be disposed of according to REHS guidelines. Drain disposal in the lab is strictly prohibited.

9. All operations involving potentially volatile radioactive materials should be conducted in a fume hood.

10. All users must satisfy the training requirements (initial and refresher training).

B. Iodination Procedures

Iodine labeling can create potential exposure to the thyroid in workers performing iodinations if proper safety precautions are not followed explicitly. I-125 in the NaI-125 chemical form is volatile and exposure through inhalation can occur. The following are procedures to be followed when performing radioiodination procedure:

1. All iodination procedures must be reviewed and approved by REHS in advance. A review of the procedure will be made to ensure the labelling will be performed in a “closed system”. Any additions or removals to the NaI vial should be made with a Hamilton syringe. It is also advisable to vent the vial with a charcoal trap to remove any build-up of Iodine in the head space of the vial. These can be purchased from Dupont-NEN (catalog number NEX-033T).

2. A baseline thyroid bioassay must be obtained at REHS for all first-time iodinators. (prior to use)

3. All individuals wishing to iodinate must comply with the training requirements and have a whole body and extremity dosimeter.

4. All iodination procedures must be performed in an approved fume hood.

5. A dry-run of the experiment should be performed (without radioactivity) to become familiar with the procedure.

6. Arrangements must be made with REHS to observe the first iodination procedure. All buffers, solutions, equipment, etc., that are to be used in the procedure should be assembled in advance.

7. A lab coat, eye protection and double gloves must be worn when working with I-125.

8. A low energy gamma probe must be available during the procedure.

9. REHS will deliver the NaI-125 and a calibrated air sampling pump on the day of iodination. The air sampling pump shall be used for one labeling procedure only.

10. A contamination survey must be performed and documented immediately after the iodination procedure. The survey forms will be delivered with the NaI and pump.

11. In order to keep exposures ALARA, radioactive waste should be shielded with lead foil prior to waste pickup.

12. The iodinator must report to REHS for a thyroid bioassay 24-72 hours after the iodination procedure.

VII. SECURITY OF LICENSED MATERIALS

Federal and State laws require that licensed material be under the immediate control and constant surveillance of the licensee, or otherwise be locked and secured to prevent unauthorized removal. The NRC and NJ DEP have cited RWJMS in the past for failure to secure radioactive materials; precautions should be taken to prevent a recurrence. RWJMS shall use any combination of the following to comply with the requirement to secure licensed material:

(a) Lock the laboratories where licensed material is used or stored when trained staff is not present;
(b) Lock storage areas for licensed materials, i.e., cabinets, refrigerators, freezers, etc.;
(c) Challenge unauthorized entry into the labs;
(d) Train employees and users in the security requirements and proper authorized uses of radioactive materials.

We rely on each authoree and user to maintain appropriate security of the licensed material in their laboratory.

VIII. RADIATION SURVEYS

Whenever unsealed radioactive materials (liquid solutions in vials, test tubes, flasks, etc.) are handled, it is possible to contaminate laboratory benches, floors and equipment, as well as hands, skin and clothes. Every laboratory handling radioactive materials must be frequently surveyed to detect the presence of any radioactive contamination. Surveying the lab for contamination is essential to prevent cross-contamination of equipment, experimental samples and personnel. Surveys are also a requirement of State and Federal materials licenses.

A. Requirements

1. Daily Surveys

Daily surveys are required after **every use** of unsealed radioactive materials, except for H-3. These surveys may be performed with an appropriate portable survey instrument as described below, or by a wipe survey. The survey must include gloves, clothing, shoes, the floor by the work areas, trash containers, lab benches and instruments used for the experiment. An area which shows a count rate of twice the background reading should be further investigated for contamination. <u>The survey must be documented by dating and</u> <u>initialing a checklist</u>. (See Appendix E)

An appropriate survey instrument is considered to be a Ludlum model 3 with a G-M pancake probe or equivalent. REHS will determine the efficiency of the instruments used for these surveys on an annual basis. End-window G-Ms are unacceptable as they lack sufficient sensitivity for these surveys.

2. Weekly Surveys

Weekly surveys must be performed following the use of more than 10 mCi of H-3. Only wipe surveys are effective in detecting H-3 contamination. <u>As in daily surveys, documentation consists of initialing a checklist.</u> (see appendix)

3. Monthly Wipe Surveys

Authorees must perform a **monthly** wipe survey in laboratories where radioactive materials are used (in addition to the daily survey) to ensure they are free of contamination. Counting of the wipes may be in a liquid scintillation counter or gamma counter, if appropriate. The efficiency and minimal detectable activity of the counter must be also be calculated. <u>Records of monthly wipe surveys, and the efficiency and the minimal detectable activity of the scintillation counter are to be maintained within</u>

the laboratory and will be reviewed by REHS during laboratory inspections. If no radiation was used in a given month, this must also be documented in the log book.

B. Procedures

1. Use of a survey instrument

Every laboratory using radioactive materials must possess appropriate radiation monitoring equipment. This equipment must be in good working order, and must be calibrated annually by REHS staff.

There are several types of monitoring instruments commonly used in teaching and research laboratories. The most widely used instrument is the **Geiger-Mueller detector**, a portable instrument capable of detecting beta and gamma radiation. The pancake detector is generally used for detecting beta radiation, and will detect all beta radioisotopes used at Rutgers University except H-3 and Ni-63. It will not detect those radionuclides because they do not have sufficient kinetic energy to penetrate the detector window into the gas-filled sensitive volume of the detector. Moderate (C-14, S-35) and higher energy beta particles (P-32) are detectable with varying degrees of effectiveness. GM detectors are comparatively poor at detecting radioisotopes that emit photon radiations only.

As the probability of a photon interaction occurring in a solid is significantly greater than in a gas filled detector, the low energy gamma **scintillation probe** is used to detect gamma radioisotopes of various energies. The radiation sensitive portion of a scintillation probe is made of a sodium iodide crystal. Thinner crystals are used for detecting low energy photons below 60 keV, such as those from I-125. Thicker crystals are used for detecting the higher energy photons, such as those emitted from Na-22, I-131 and Cr-51.

Many survey meters have both count rate (cpm or cps) and exposure rate (mR/hr) scales. The count rate scale is the appropriate scale to use when noting contamination levels. The mR/hr scale is only accurate in a radiation field produced by Cs-137; therefore, the mR/hr scale reading should **not** be used when reporting contamination.

When using portable survey instruments, it is essential that the proper techniques be employed to assure accurate results. The guidelines below must be followed when using a survey instrument:

1. Use the correct detector. Check the battery and ensure the instrument is operable by holding the detector near a source of radiation.
2. Ensure that you select the proper scale on the instrument for conducting the survey. Always start with the lowest scale available, i.e., x 0.1 or x 1 scale. Select higher range scales as necessary to obtain maximum readings if contamination is detected.
3. Hold the detector approximately 1 cm above the surfaces to be monitored. If the detector is too far away, underestimation of activity may occur. If the detector is too close to the surfaces being monitored, contamination of the detector may occur.
4. Survey slowly; the sensitivity of the detector is inversely proportional to increasing survey speed. As a rule of thumb, survey 1 to 2 inches per second.
5. Do not cover the probe with parafilm or Saran wrap. These covers will act as a shield and decrease or eliminate detection.
6. Use the instrument's audible response while conducting surveys. The audible response is faster than the meter scale indication. You should listen for any increases in "clicks" above background levels.

IMPORTANT: Remember that H-3 is such a low-energy beta that it can not be detected with a survey meter.

2. Wipe Survey Procedures

The only true survey for removable (loose) surface contamination is the wipe survey method. However, prior to taking wipe samples, an initial check for contamination can be performed using a survey meter to directly monitor surfaces of interest.

Use a survey meter with an appropriate detector to survey bench tops, fume hoods and other work areas. A survey instrument can be used to perform a quick check of the work area to draw attention to areas requiring possible decontamination. If any areas are found to exceed twice the background radiation levels, then decontamination procedures would be worthwhile prior to taking wipe samples.

Using filter paper disks or cotton swabs, take a series of wipes from working surfaces where contamination could be expected to exist or where radiation levels are elevated. Each wipe should be numbered and the location where they are taken shown on a diagram of the room. The wipes should be moistened with alcohol or water and should be rubbed firmly over a surface area of about 100 square centimeters. The wipes shall be analyzed using a gamma or liquid scintillation counter, as appropriate. The amount of removable contamination shall be recorded in the units of disintegrations per minute (dpm) /100 cm^2. The action limit for decontamination is 100 dpm/100 cm^2 above background. The frequency for performing wipe surveys is **monthly**. Refer to the procedure on liquid scintillation counting (below).

a. Deposit wipe sample in a clean scintillation vial.
b. Fill vial at least 2/3 full with scintillation cocktail.
c. Tightly cap the vial.
d. Mix the contents of the vial thoroughly.
e. Count the sample for at least 1 minute in the counter. Always include a background vial.
f. Examine the print-out. Any sample indicating levels greater than 100 dpm/100 cm^2 above background requires that the surface of concern be cleaned until the contamination is consistent with background.

Important Note: Scintillation counters should come equipped with a set of radioactive counting standards of known activity (H-3, C-14) which are to be analyzed by the counter periodically to check its operation. Ideally, the standards should be counted when the monthly wipe samples are run. The efficiency and Minimal Detectable Activity (MDA) must be calculated monthly.

IX. WASTE DISPOSAL PROCEDURES

REHS provides radioactive waste removal, management and disposal services. The following is a description of the radioactive waste removal services provided by REHS.

Definition of Radioactive Waste

Radioactive waste is defined as any waste that is contaminated with or contains a radioactive isotope.

A. Dry Solid Waste

Dry waste consists of paper, gloves, plastic containers, and other forms of contaminated laboratory waste.

Container Types

- Dry waste can be collected in 30 or 55-gallon drums provided by REHS.
- Dry waste may also be collected in waste containers purchased by the laboratory provided they meet the following criteria:

  *Containers must be rigid (e.g. plastic or heavy gauge cardboard – no bags)
  *Containers must be double lined (REHS can provide plastic liners)
  *Containers must have a lid or cover

Container Labeling

- Dry waste containers should be properly labeled with;

  *Radiation symbol
  *The words "Caution Radioactive Materials"
  *Properly completed Radioisotope Disposal Forms (yellow cards) describing the authoree name, the date(s) that waste was placed into the container, the isotopic content of the waste and the activity present in the container.

Waste Acceptance

- Dry waste containers should not contain the following:

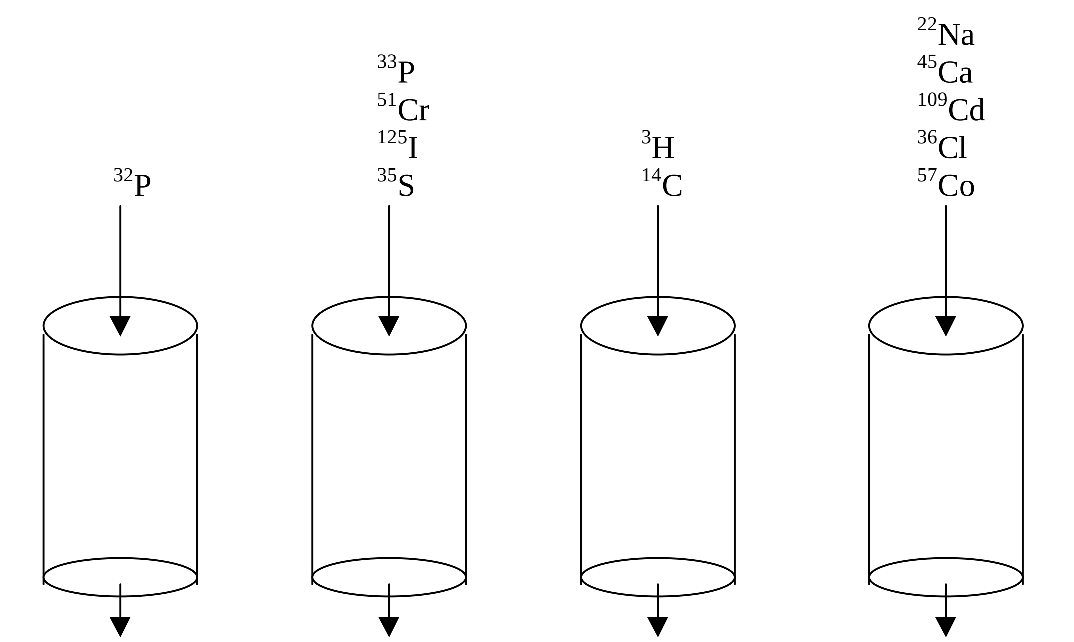
  *Free Standing Liquids
  *Biohazardous Material or Biohazard Bags
  *Sharps (see section entitled Sharps)

*Metals
*>5% PVC
*Teflon and fluorinated plastics
*Sealed Sources
*RCRA/TSCA hazardous wastes
*Explosives
*Pyrophoric materials

- Do <u>not</u> commingle solid waste with other waste streams (liquid, liquid scintillation vials, animal/biological).

Solid Waste Segregation Scheme

- Solid waste must be segregated based on half life and according to the following scheme:
  - * waste with half life ≤ 15 days
  - * waste with half life > 15 days and ≤ 120 days
  - * waste with half life > 120 days **^{3}H and ^{14}C only**
  - * waste with half life > 120 days **other then ^{3}H and ^{14}C**



$T^{1/2}$ ≤ 15 days 15 <$T^{1/2}$< 120 days $T^{1/2}$ > 120 (^{3}H & ^{14}C only) $T^{1/2}$ > 120 days (other)

B. Liquid Waste

Liquid waste consists of freestanding liquids only, such as isotopes dissolved or suspended in water including solutions of proteins, buffers, cell media, etc.

Container Types

- Liquid waste should be collected in 1.0, 2.5 or 5.0-gallon polyethylene carboys, provided by REHS.

- Liquid waste may be collected in containers purchased by the laboratory provided they meet the following criteria:

  *Containers are plastic (no glass)
  *Containers have properly fitting lids (screw on)
  *Containers are stored in appropriate secondary containment
  *Containers are used with the understanding that they will not be returned for reuse

Container Labeling

- Liquid waste containers should be properly labeled with ;

  *Radiation symbol
  *The words "Caution Radioactive Materials"
  *Properly completed Radioisotope Disposal Forms (yellow cards) describing the authoree name, the date(s) that waste was placed into the container, the isotopic content of the waste and the activity present in the container.

Waste Acceptance

- Liquid waste containers should not be overfilled

- Do not commingle liquid waste with other waste streams (solid, liquid scintillation vial, animal/biological).

- Liquid waste containers should be stored in secondary containment

- Liquid waste should pH between 6 and 9

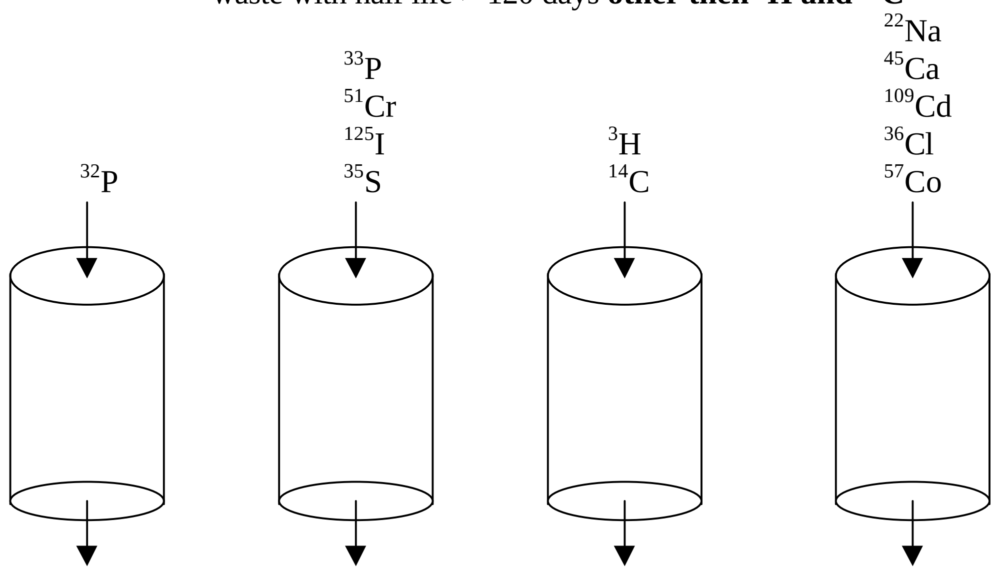
- If your waste contains any etiologic agents you must notify REHS.

- If your waste contains any hazardous materials (e.g. flammables, corrosives, reactives, and poisons), even if it is mixed with water, you must notify REHS and note this information in section III of the yellow Radioisotope Disposal Form.

Liquid Waste Segregation Scheme

Liquid waste must be segregated based on half-life and according to the following scheme:

* waste with half life ≤ 15 days
* waste with half life > 15 days and ≤ 120 days
* waste with half life > 120 days **^{3}H and ^{14}C only**
* waste with half life > 120 days **other then ^{3}H and ^{14}C**



$T^{1/2} \leq 15$ days 15 < $T^{1/2}$ < 120 days $T^{1/2}$ > 120 (^{3}H & ^{14}C only) $T^{1/2}$ > 120 days (other)

C. Liquid Scintillation Vials

Container Types

- Liquid Scintillation Vials can be collected in 30 or 55-gallon drums, provided by REHS.

- Liquid Scintillation Vial waste can be collected in containers purchased by the laboratory provided that they meet the following criteria:

  *Container is rigid (capable of containing liquid)
  *Container has a capacity of 10 gallons or less
  *Container is double lined (REHS can provide plastic liners)

Container Labeling

- Liquid scintillation vial waste containers should be properly labeled with;

  *Radiation symbol
  *The words “Caution Radioactive Materials”
  *Properly completed Radioisotope Disposal Forms (yellow cards) describing the authoree name, the date(s) that waste was placed into the container, the isotopic content of the waste and the activity present in the container.

Waste Acceptance

- Do <u>not</u> commingle liquid scintillation vial waste with other waste streams (solids, liquids, and animal/biological).

- Do not place small vials of stock solutions with scintillation vials.

- Vials containing residual fluids must be capped. If the liquid were to leak, it would damage the heavy plastic liner.

- Containers must not be overfilled; the lid must fit properly.

- Use approved Biodegradable Scintillation Fluid unless otherwise authorized. (See attached list)

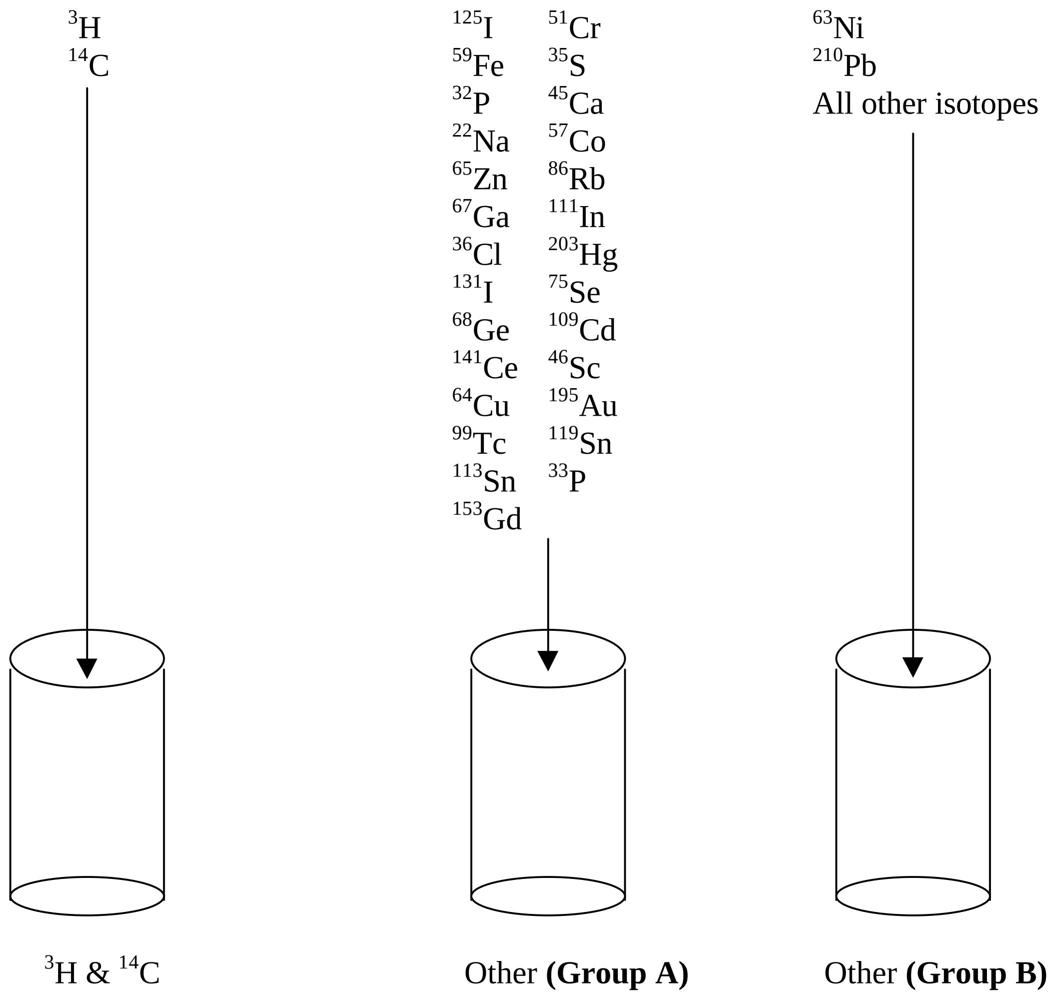
- Liquid scintillation vial waste containing ^{3}H and or ^{14}C in concentrations greater then 0.05 microcuries/gram may require special consideration (roughly 1 mCi/30 gallon drum and 2.5 mCi/55 gallon drum). Please contact REHS if you plan on generating this type of waste.

- Yellow Radioisotope Disposal Forms should be marked with the name brand of the liquid scintillation cocktail.

Liquid Scintillation Vial Segregation Scheme

- Liquid scintillation vial waste must be segregated by isotope according to the following scheme:

  *Waste containing ^{3}H and/or ^{14}C
  *Waste containing the other isotopes **(Group A)**
  *Waste containing the other isotopes **(Group B)**



<u>D. Animal Carcasses and Biological Waste</u>

Container Types

- Animal carcasses and tissues can be stored in the 30-gallon drums with double plastic bags and lime absorbent supplied by REHS.

- Animal carcasses may also be stored in chest freezers in sealed double bags.

Container Labeling

- Liquid scintillation vial waste containers should be properly labeled with;

  *Radiation symbol
  *The words "Caution Radioactive Materials"
  *Properly completed Radioisotope Disposal Forms (yellow cards) describing the authoree name, the date(s) that waste was placed into the container, the isotopic content of the waste and the activity present in the container.

Waste Acceptance

- Do <u>not</u> commingle animal/biological waste with other waste streams (solids, liquids, liquid scintillation vials).

- Keep animal carcasses and tissues frozen until removal by REHS personnel.

- Prevent sharp edges from puncturing the bags.

- Immediately after the animal is sacrificed and before it is frozen, the carcass must be packed with a one part lime and ten parts Chemsil absorbent. The absorbent mixture must be in direct contact with the carcass.

- Animals contaminated with H-3 and C-14 at a concentration less than 0.05 microcuries per gram can be disposed of as non-radioactive. When the radioactivity is concentrated in certain organs, these parts can be removed for radioactive waste disposal as tissues, and the remaining carcass can be treated as non-radioactive waste if the remaining activity for H-3 and C-14 is less than 0.05 microcuries per gram.

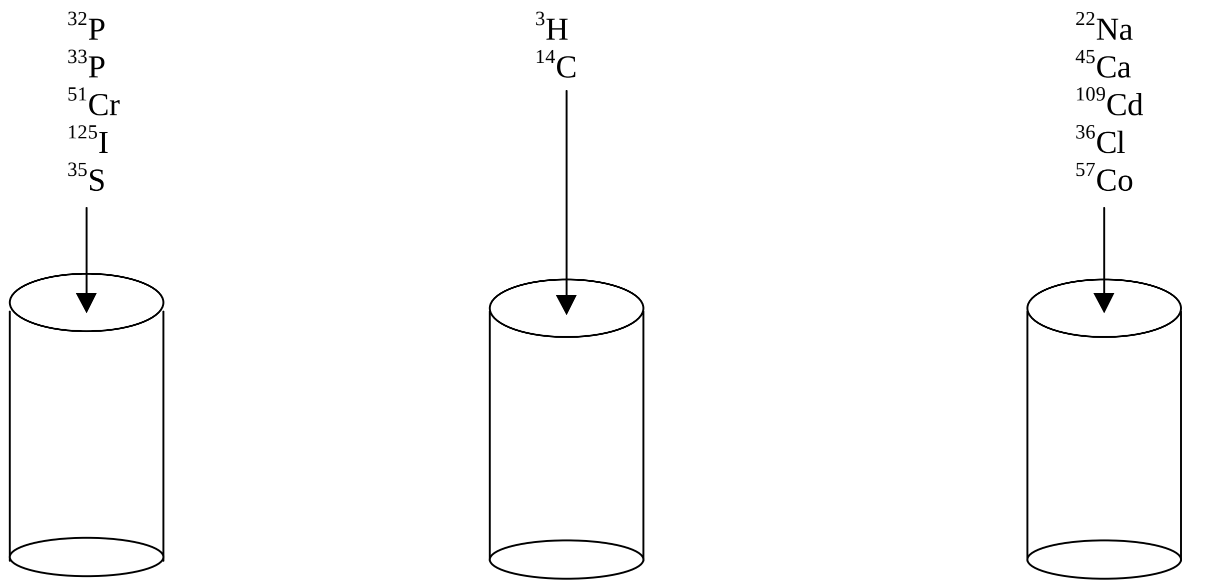
- Animals containing isotopes with a half-life of less than 120 days will be held for decay to background at REHS storage facility.

- Animals that are known to contain active pathogens, as well as radioactive materials, must receive special attention; REHS must be notified.

Biological/Animal Carcass Segregation Scheme

Biological/Animal Carcass waste must be segregated by half life according to the following scheme:

*Waste containing isotopes with half lives < 120 days
*Waste containing isotopes with half lives > 120 days **^{3}H and ^{14}C only**
*Waste containing isotopes with half lives > 120 days **other then ^{3}H and ^{14}C**



$T^{1/2}$ < 120 days | *$T^{1/2}$ > 120 days* ***^{3}H & ^{14}C only*** | *$T^{1/2}$ > 120 days* ***other***

Sharps

Sharps consist of any sharp object contaminated with radioactivity (see list below).

- Sharps must be collected only in approved sharps containers.
- Do not cap syringes before placing in the sharp containers.
- Sharps containers must be sealed and properly labeled as radioactive waste.
- Sharps containers should be presented for disposal as radioactive waste. Do not place sharps containers into solid waste containers.

- The generator is responsible for purchasing sharps disposal containers.

- If sharps are considered to be regulated medical waste, the sharp containers must be logged on the Regulated Medical Waste Log.

- The presence of loose sharps intermixed with dry waste represents a great hazard to REHS personnel and constitutes a serious violation that could result in the revocation of the Authoree's license.

- Sharps include the following items:

  hypodermic needles
  syringes
  Pasteur pipettes
  scalpel blades
  blood vials
  culture dishes
  slides
  cover slips
  broken glass
  needles with attached tubing

Radioisotope Disposal Forms (Yellow Cards)

The terms of the University Radioactive Materials License requires detailed records of receipt, use and disposal of radioactive materials. All radioactive materials must be accounted for. To facilitate the tracking of radionuclides, a radionuclide inventory log should be kept for each isotope used. Always make sure that the total activity in the lab does not exceed the maximum possession limit for the isotope in question. Always compute the balance on hand (mCi). This information is essential for the completion of the yellow disposal cards.

A yellow disposal card is to accompany each container of radioactive waste. Disposal cards should be completed as waste is placed into the container. Do not wait until the waste container is full to complete the disposal card. Please fill in all the required information with careful attention to the following:

Section I.

Authoree: Name of the authorized user.

Auth. No.: 4 digit number assigned to the authoree.

Pick Up Date: To be completed by REHS upon removal.

BLDG: Building in which waste is located.

Room No.: Number of the room in which waste is located.

Container Volume: Volume of the container in which waste is located.

Section II.

Date: Date isotopes were placed into the container.

Isotope: Isotopes present in the container.

Chemical Name: Name of the radiolabeled chemical.

Chemical Form: General chemical family to which the radiolabeled chemical belongs.

Activity: Radioactivity (mCi) contained in each waste entry.

Section III.

Chemical Name: Chemical names of all remaining chemicals (other then those noted in section II).

Total Activity: Activity totals for each isotope entered in section II.

Authoree Signature: Signature of laboratory employee who is responsible for collection of radioactive waste.

Things to remember while completing Yellow Disposal Cards:

- Do not perform any correction for decay.

- Enter the activities in millicuries.

- Clearly state the chemical name and chemical form of the radiolabeled chemical (Section II).

- List each chemical component, other then radiolabeled chemicals recorded in section II, and its percentage (Section III). Remember that the objective is to identify mixed waste, e.g., waste that is both hazardous and radioactive. This is especially important for liquid waste.

- For liquid scintillation vial waste indicate the name brand of the liquid scintillation cocktail.

- Do not forget to sign the card.

- Keep the card clean and avoid contamination.

Unless the disposal cards are properly completed, REHS personnel will not pick up the radioactive waste.

It is important that the activity in the radioactive waste being picked up is subtracted from the total possession limits allowable to the authorized user. Authorees exceeding their maximum possession limits will not be permitted to order more radionuclides.

Request for Radioactive Waste Removal

Removal of radioactive waste takes five to ten working days from the date of request, depending on your location. Please plan accordingly. When you contact REHS, have the following information ready:

*Authoree name and number,
*Building and room where waste is stored
*Type of waste (dry, liquid, vials, animal)
*Isotopes present in waste
*Yellow disposal ticket numbers
*Number and size of containers.

To request a radioactive waste pick-up contact REHS at 445-2550 or http://rehs.rutgers.edu.

Using the Website to Request Waste Removal

1. Go to http://rehs.rutgers.edu
2. Click on Environmental Services
3. Click on Radioactive Waste Disposal
4. Click on Request Radioactive Waste Disposal Form

X. INCIDENTS AND EMERGENCIES

A. What is an incident or emergency?

Incidents may occur during the use of radioactive materials, such as spills, contamination of the worker or work area and accidental release into the air. When an incident occurs, the worker must first make a judgement as to whether the incident is a **minor** or **major** incident. The chart on the following page will help you to make the determination as to a minor or major incident. When in doubt, call REHS. <u>**There are no penalties for reporting an emergency or requesting assistance**</u>.

B. Notifications

The proper response to an emergency depends upon a thorough understanding of the magnitude of risks, priorities for action and the application of common sense. When calling REHS to report a spill, the following information should be provided:

- location of incident
- authoree
- name and telephone number of person reporting
- persons contaminated or exposed, estimate of amount on skin
- radionuclide involved
- amount of radioactivity
- volume of released material
- what steps have been taken so far

In the event of a spill or emergency during normal business hours (Mon – Fri 8 am to 5 pm), REHS should be contacted at 732-445-2550. After business hours, Public Safety should be contacted at 235-4000.

C. Basic Procedures

When radioactive material is in an unwanted or unplanned location, it is called contamination. This may be on floors, equipment, work areas, people or areas outside the authorized laboratory. Fortunately, most radioactive contamination is easy to clean to background levels in a reasonable time and with reasonable cost. Concentrated liquid decontaminating agents are available from most scientific suppliers. Other foam cleaning products, such as bathroom or kitchen cleaners, are just as effective at a much lower cost. Many other agents will work to clean radioactive contamination that has been resistant to other cleaners. The following are two formulas that have been found to work.

SURFACE DECONTAMINATION SOLUTIONS

A. For I-125

25 g Sodium Thiosulfate
2 g Sodium Iodide

in l Liter of 1M Sodium Hydroxide

B. For P-32, etc.

50 mL Triton
20 g EDTA
100 mL decontamination detergent (such as Count-Off, Contrad 70, or any other cleaner)

Add enough distilled water to make 1 liter of solution.

Emergency Procedures for Radiation Incidents

Minor Incident

< 1 mCi of RAM (Radioactive Material)
No personnel contamination

Localized contamination
present
No spread of RAM outside licensed areas
Proper tools and knowledge available for clean up.

Laboratory Guidelines:

Stop source of the spill
Warn other personnel

Survey and mark the affected area
Minimize exposures
Notify Authoree or designee

Begin cleanup

If area cannot be cleaned notify REHS
Document incident in laboratory survey book

Major Incident: (Any of the following conditions)

> 1 mCi of RAM
Skin and/or clothing contamination is involved (any quantity)
Airborne RAM is thought to be

Large areas are contaminated
Contamination has spread outside licensed areas
Personnel injury or fire
Unsure of what to do, or how to do it

Laboratory Guidelines:

Treat life threatening injuries first
Evacuate and lock (or post) laboratory if airborne or fire hazard exists
Perform first aid, if applicable
Remove contaminated clothing
Measure and record amount of contamination on skin with applicable
meter and wash area gently with warm water and soap
Warn other personnel
Notify REHS 445-2550 and Authoree. If after hours, call Campus Police or Public Safety
Try to prevent the spread of contamination if possible
Await the arrival of REHS

Rutgers Police: **Piscataway 6-911**
Newark 5111 or 80
Camden 6111 or 8

UMDNJ Public Safety 5-4000

D. Skin Decontamination

REHS shall be notified immediately if any personnel contamination occurs or is suspected. Also note the amount or measure of radioactive contamination detected with a calibrated survey instrument, the area of skin involved, and the time it was discovered and then cleaned off skin.

a. Decontamination of personnel will be done under the supervision of REHS.

b. Personnel assisting in decontamination will use necessary precautions and protective clothing to prevent the spread of contamination to themselves or the surrounding area.

c. Decontamination will be performed in a manner which will not spread contamination to other parts of the body. All cleaning should be from the periphery of the contaminated area towards the center.

d. When washing a contaminated area of the body, care must be taken to prevent abrasions or cuts of the skin to prevent internal contamination. Do not scrub or abrade the skin.

e. Wash skin with mild soap and lukewarm water only. Work up a good lather and use plenty of water.

f. When drying an area of the skin that has been decontaminated by washing, do not rub the skin; pat it dry.

g. In the event that decontamination does not occur using the techniques above, further efforts should be determined by a competent medical authority in consultation with REHS.

XI. REHS (RADIATION SAFETY OFFICE) SERVICES

The following services are provided through REHS at no charge, except where noted.

1. Laboratory Inspections

   The REHS staff will periodically inspect the labs check the survey records, advise in the establishment and maintenance of the authoree's survey program and occasionally conduct surveys. They will also conduct contamination surveys after any major spills or upon special request.

2 Radiation and Contamination Surveys

   During laboratory inspections REHS will conduct periodic surveys with a portable instrument and perform wipe surveys in all radiation laboratories on an annual basis. Radiation producing machines are surveyed when they are installed, after a major configuration change and biannually as required by the NJ DEP.

2. Radioactive Waste Pick-up and Disposal

   No individual is permitted to dispose of radioactive waste except through REHS. All the waste generated must be collected, including first washings from vessels containing radioactive liquids and contaminated animal tissue. Authorees shall not dispose of radioactive liquid down the sanitary sewer.

3. Personal Radiation Monitoring

   Persons who use sources of radiation may be required to wear personnel monitoring badges. Authorees are required to ensure that all badges assigned to their laboratory are worn properly and returned to REHS on a timely basis. REHS will maintain all radiation exposure records; records of exposure are available to wearers upon request.

4. Bioassays

   Persons working with ^{125}I in iodination procedures will be required to come to REHS for a thyroid count to determine if there was an iodine uptake during the procedure. Bioassays associated with other uses of radioisotopes, and in the event of personal contamination, are also provided as deemed necessary by REHS.

5. Instrument Calibration

   All radiation detection instruments in an Authoree's laboratory will be checked for proper operation by REHS staff in the course of their lab inspections. Instruments used for the performance of contamination or radiation surveys must be calibrated by REHS annually. REHS has very limited capability to repair instruments.

6. Radiation Safety Training and other instruction

7. Emergency response and assistance with incidents involving radioactive materials

The duties and responsibilities of the Radiation Safety Officer (RSO) are as follows:

1. Provide consultation to authorized users on good radiation safety practices, experimental design, adequate facilities, selection of monitoring equipment, etc.

2. Maintain surveillance of the uses of radioactive materials.

3. Oversee the receipt, delivery, and survey of shipments of radioactive materials.

4. Determine compliance with rules and regulations, license conditions and the conditions of project approvals authorized by the Radiation Safety Committee.

5. Immediately terminate any activity that is found to be a threat to public health and safety or property.

6. Provide necessary information on all aspects of radiation protection to personnel at all levels of responsibility pursuant to 10 CFR 19.12 and 10 CFR 20.

7. Periodic meeting with and reports to licensee management and the Radiation Safety Committee.

ALL USERS ARE ENCOURAGED TO CALL REHS (445-2550) WITH ANY QUESTIONS REGARDING THE USE OF ANY SOURCES OF RADIATION OR TO DISCUSS THEIR PERSONAL SAFETY.

XII. OTHER RULES AND POLICIES FOR THE USE OF RADIOACTIVE MATERIALS

A. Personal Exposure Monitoring/Dosimetry

RWJMS shall monitor exposures to radiation and radioactive materials at levels sufficient to demonstrate compliance with the occupational dose limits as specified in Title 10, Code of Federal Regulations, Part 20. At a minimum:

RWJMS shall monitor occupational exposures to radiation and shall supply and require the use of individual monitoring devices by:

- Adults likely to receive, in 1 year from sources external to the body, a dose in excess of 10 percent of the limits in 20.1201(a).
- Individuals entering an area designated as a “Radiation Area."
- Individuals who use X-ray producing equipment, as required by the NJ DEP.
- Declared pregnant women.

This policy excludes most RWJMS personnel from the need to wear dosimetry for radiation dose monitoring purposes. A determination as to which individuals require such monitoring will be made by the RSO on a case-by-case basis based on the potential hazard and exposure histories for such use. In general, the following uses of radioactive materials or radiation will require a monitoring badge: radioiodination protocols using NaI^{125}, cell labeling experiments using greater than 1 mCi of P^{32} per experiment, use of any X-ray producing machine, or the use of other gamma emitters.

TLD (thermoluminescent dosimeters) whole-body badges are provided to all users of radiation or radioactive materials who are likely to receive 10 percent of permissible exposure limits. They must be worn to provide an indication of the maximum dose received by any portion of the trunk of the body.

Finger ring TLD’s are issued to and used by any individual whose work involves handling intense or penetrating sources of radiation, such as high energy beta or gamma sources (P-32, I-125, Cr-51). Ring TLD’s should be worn so that the portion containing the LiF ‘chip’ is facing the direction of the radiation source. The ring should be worn under the glove of the dominant hand (i.e., whichever hand holds the radiation source most frequently).

Radiation dosimeters are not assigned for work with all radionuclides, since the energies of some are below the detection limit of the TLDs. This is not a risk to the worker, however, because these kinds of radiation are not penetrating enough to cause a deep radiation dose. Examples of these radionuclides are H-3, C-14, and S-35.

Monitoring badges provide legal documentation of external radiation exposure received while working with radioactive materials. Care should be taken to make sure that badges do not become contaminated with radioactive materials. Lost or misplaced badges should be reported immediately to REHS in order to receive a replacement. Under no circumstances should workers wear a dosimeter belonging to another individual. It is also important to return your badge at the proper time.

Individuals may contact REHS at any time to obtain their dosimetry data. It typically takes up to 4 weeks to have the badges exchanged, sent out and processed. In the event any doses are higher than normal (i.e., greater than 250 mrem on a whole-body badge), the individual will be contacted by the Health Physicist and an investigation initiated.

B. Pregnant Occupational Workers

A special situation arises when a radiation worker becomes pregnant. Under these conditions, radiation exposure could also involve exposure to the embryo or fetus. A number of studies have indicated that the embryo or fetus is more sensitive than the adult, especially during the first trimester of pregnancy. This can be a problem since many workers are unaware of their pregnancy during the first month or two of gestation. Hence, the NRC requires that all occupationally exposed workers be instructed in the potential health protection problems associated with prenatal radiation exposure.

As defined in 10 CFR 20.1003, a "declared pregnant woman" means a woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception. The maximum permissible exposure for a declared pregnant worker during the gestation period is 500 mrem. Exposures must be maintained below a cap of 50 mrem per month in order to prevent exposure variations.

There are few laboratories where radiation levels are high enough that a fetus would receive this dose. If a radiation worker becomes pregnant, she is advised to call REHS and then declare the pregnancy in writing by filling out (and signing) an application for a monthly fetal monitoring badge. At this time the prenatal exposure limits take effect. The pregnant worker may then meet with a member of REHS to assess her potential radiation exposure and measures to keep her exposures ALARA. Early declaration of a pregnancy is encouraged and confidentiality is maintained at all times.

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

C. Bioassays

Conditions of the license issued by the Nuclear Regulatory Commission require that bioassays be provided for workers using certain types and amounts of radioisotopes. This includes:

Individuals performing iodination where one millicurie or more of ^{125}I is used are required to obtain a thyroid scan after the iodination procedure. Individuals must receive a thyroid bioassay at least 24 hours after each iodination, but not more than 4 days afterwards.

Also, individuals handling greater than 100 mCi of tritium (^{3}H) must submit a urine sample to REHS for bioassay within 24 hours of the handling. This bioassay must be performed each time this quantity of tritium is handled.

In the likelihood that a significant internal exposure has occurred, e.g., during a spill or contamination incident, REHS may require further bioassays as deemed necessary.

D. Posting Requirements

Each laboratory or area where radioactive materials are used or stored must be posted at the entrance with a **"CAUTION RADIOACTIVE MATERIALS"** sticker. The following contact person(s) should be indicated on the caution sign:

(a) The room supervisor who should be contacted first for routine questions regarding work in the room.

(b) The individual who should be contacted first in the case of an emergency. This may be the same person as above.

(c) An alternate individual who should be contacted if (b) is not available in an emergency.

Include: Name, campus address (building and room number), campus phone number, and home phone number

The principal investigator or lab supervisor at RWJMS is responsible for the proper posting of laboratories, equipment rooms, and other work areas where hazardous materials, including radioactive materials, may be used or stored.

Refrigerators, freezers, storage areas, and containers in which materials are stored or transported must have a visible label with the radiation warning symbol and the words **"CAUTION RADIOACTIVE MATERIALS".** The label should also indicate the radioisotope and the quantity (activity) in the container. Radioactive warning labels should be removed from containers if the are empty and not contaminated.

Laboratory equipment, such as flasks, beakers, centrifuges, etc., containing radioactive materials, or are contaminated, must be labeled with radioactive warning labels or tape.

Areas in the laboratory where radiation levels might expose a person to 5 mrem in one hour at 30 cm from the radiation source must be posted with the sign **"CAUTION RADIATION AREA".**

E. Inventory of Radioactive Materials

We are required to maintain a strict inventory of the radioactive materials present at RWJMS. Therefore, all authorees are required to maintain an adequate inventory, and have knowledge of the various forms and quantities, of radioactive materials present in their laboratories.

Every calendar quarter, REHS will furnish each authoree with a copy of all transactions that affected their radioactive materials inventory during the previous quarter. This includes, but is not limited to, delivery of radioactive materials from the vendor; removal of radioactive waste; transfer of radioactive material to another authoree withinRWJMS; transfer of radioactive material to another institution; or correction of data entry errors.

Each authoree must review the inventory form, and if correct, sign and date it prior to returning a copy to REHS. If there are errors, the appropriate corrections should be made along with a short explanation prior to returning a copy to REHS. REHS will make the necessary changes to the data base, which will be reflected on the next quarterly inventory.

The failure to return a signed copy of the inventory form in a timely manner will result in the suspension of delivery of radioactive materials. Delivery will be reinstated upon receipt of assigned copy of the inventory.

F. Occupational Exposure Limits

Exposure standards have been established by the NRC and set at a level where apparent injury due to ionizing radiation during a normal lifetime is unlikely. This limit is called the "maximum permissible exposure." It is the responsibility of each individual to keep his/her exposure to all radiation ALARA, and to avoid all exposures to radiation when such exposures are unnecessary.

Part of Body	**Adult exposures (mrem/year)**	**Minors (< 18 yrs.) exposures (mrem/year)**
Whole body, head, trunk, active blood forming organs (TEDE)	5,000	500
Lens of eye (LDE)	15,000	1,500
Extremities (SDE)	50,000	5,000
Single organ dose (TODE)	50,000	5,000
Skin of whole body (SDE)	50,000	5,000

New dose quantities were incorporated in the 10 CFR 20 regulations which took effect January 1994. Notice that each of the following quantities are types of dose equivalents. The following definitions describe the new quantities; the units for these quantities are the rem or the Sievert (Sv).

- DE: Dose Equivalent. The product of the absorbed dose in tissue, the quality factor, and all other modifying factors.
- CDE: Committed Dose Equivalent. The dose equivalent to organs and tissues of reference that will be received from an intake of radioactive materials by an individual during the 50 year period following the intake.
- EDE: Effective Dose Equivalent. The sum of the products of the dose equivalent to the organ or tissue and the weighting factors applicable to each of the body organs or tissues that are exposed.
- CEDE: Committed Effective Dose Equivalent. The sum of the products of the weighting factors applicable to each of the organs or tissues that are exposed and the committed dose equivalent to these organs or tissues.
- DDE: Deep Dose Equivalent. Applies to external whole body exposure. It is the dose equivalent at a tissue depth of 1 centimeter (1000 mg/cm^2).
- TODE: Total Organ Dose Equivalent. The sum of the CDE and DDE for the maximally exposed organ.
- SDE: Shallow Dose Equivalent. Applies to the external exposure of the skin or an extremity, and is taken as the dose equivalent at a tissue depth of 0.07 centimeters (7 mg/cm^2), averaged over an area of 1 square centimeter.
- LDE: Lens of Eye Dose Equivalent. Applies to the external exposure of the lens of the eye and is taken as the dose equivalent at a depth of 0.3 centimeter (300 mg/cm^2).
- TEDE: Total Effective Dose Equivalent. The sum of the DDE (for external exposures) and the CDE (for internal exposures).

G. Exposure Limits for the General Public

Visitors to a radiation laboratory who are not classified as occupational radiation workers by their employers, lab workers who are not trained in radiation safety, custodial and maintenance staff, and any non-radiation worker are all considered members of the general public. In accordance with 10 CFR 20.1301, members of the general public shall not receive a radiation dose in excess of 100 mrem in any one year, or a dose from external sources of 2 mrem in any one hour.

In the labs, this can be achieved by storing radioactive materials appropriately, labelling all radiation sources and instruments, using appropriate shielding, cleaning up spills promptly and advising other staff when they enter lab.

XIII. RWJMS RADIATION SAFETY ENFORCEMENT POLICY

A good radiation safety program requires consistent adherence to the policies and procedures for the safe use of radioactive materials. This concept is reinforced by the following basic assumptions of the U.S. Nuclear Regulatory Commission:

1. Consistently following requirements leads to safety; and

2. The only way to ensure consistent compliance and therefore, safety is through comprehensive management controls.

The NRC expects us to have a rigorous program of laboratory audits and correction of issues of noncompliance, and further, they hold the institution responsible for the actions of our employees and students when using licensed materials.

Routine audits are conducted by REHS, typically on a quarterly basis. The results of these audits are discussed with the individuals present in the lab at the time of the inspection and a written report is sent to the authoree. When necessary, a formal Notice of Violation is issued indicating the noncompliant condition. The Radiation Safety Committee expects that any issues of noncompliance will be corrected as soon as possible. A written note must be sent to REHS advising them of the corrective actions. More importantly, authorees should implement promptly any necessary actions to maintain compliance and avoid any future problems.

During the audit, items of noncompliance will be evaluated based on the potential to cause a risk to safety, health, or the environment. This would include any substantial doses to human, releases of reportable quantities, items of significant regulatory concern, or issues that could jeopardize the NRC license (i.e., a reportable incident to the NRC). These violations will be considered CLASS I violations.

Other violations will be designated as CLASS II violations. These violations are not likely to cause exposure to individuals or immediate significant regulatory concern, but are items that need to be corrected.

(Listed below are the classifications for those items typically reviewed during the audit.)

Management Meeting

When *two* inspections during a nine month period have resulted in “CLASS I” violations, a mandatory *Management Meeting* with the Associate Dean for Research and the Radiation Safety Officer will be scheduled. A member of the Laboratory Safety Committee may also attend to offer advice and counsel. At this meeting, the Authoree will be required to discuss the corrective actions to be implemented to avoid a recurrence of any future violations.

When *multiple* “CLASS I” violations are incurred during a single inspection, or when *multiple and/or repeated* “CLASS II” violations are incurred within twelve months, a *Management Meeting* may be scheduled at the discretion of the RSO, the Associate Dean for Research, or the Laboratory Safety Committee. At this meeting, the Authoree will be required to discuss corrective actions as above.

NOTE: The delivery of licensed materials may be suspended from the date of the violation until the Management Meeting is completed and corrective actions are implemented.

SANCTIONS

A. Suspension of Delivery of Licensed Materials

The suspension of the delivery of materials will also be considered for the following:

1. Failure to attend the Management Meeting within four weeks of notification;

2. During an "incident" and until the incident has been fully investigated, root causes identified, and corrective actions implemented.

3. At the discretion of the Radiation Safety Officer or the Associate Dean for Research.

B. Suspension of Authorization To Use Radioactive Materials

A suspension of the authorization to use any radioactive materials will occur when **three** “CLASS I” violations are incurred within a **15 month** period. The duration of the suspension of authorization will be a minimum of **two weeks**. The suspension will be lifted when the Associate Dean for Research and the Radiation Safety Officer are satisfied that the authoree has taken measures to assure that use of radioactive materials in his/her laboratory will be in complete and consistent compliance with the RWJMS policies.

Further violations by the authoree's laboratory will result in escalating suspensions of authorization to use radioactive materials.

CLASSIFICATIONS OF RADIATION SAFETY VIOLATIONS

1. The following are examples of CLASS I violations:

- Failure to perform and document contamination surveys
- Failure to use gloves or other personal protective equipment
- Failure to meet the training requirements
- Significant undetected contamination in the lab
- Eating, drinking or smoking in the lab (or evidence of such)
- Failure to notify in the event of a major emergency
- Improper waste disposal or loss of material
- Failure to maintain a functional survey meter
- Failure to secure licensed source material (i.e. a source vial)

2. The following examples would be considered as CLASS II violations:

- Failure to secure other licensed material
- Lack of secondary containment for liquid waste
- Failure to maintain an adequate inventory
- No MDA or efficiency calculations for monthly wipe sample

XIV. PRACTICAL RADIATION PROTECTION

There are two potential primary exposure types of concern with work involving radioisotopes: external and internal exposure to radiation. Each must be carefully evaluated prior to working with radioactive materials, and precautions must be taken to prevent these exposures.

A. Routes of Exposure

External Radiation Exposure

External hazards arise when radiation from a source external to the body penetrates the body and causes a dose of ionizing radiation. These exposures can be from gamma or x-rays, neutrons, alpha particles, beta particles; and they are dependent upon both the type and energy of the radiation.

Most beta particles do not normally penetrate beyond the skin, but when sufficiently intense, can cause skin and/or eye damage. Very energetic beta particles, such as those emitted by P32, can penetrate several millimeters into the skin. Shielding is needed in order to reduce the external radiation exposure. Typically, a maximum of ½inch thick sheet of Plexiglass or acrylic is an effective shield for most beta particles.

Alpha particles, because of higher mass, slower velocity and greater electrical charge compared to beta particles, are capable of traveling a few inches in air and rarely penetrate the outer dead layer of skin. Therefore, alpha particles are typically not an external radiation hazard.

X and gamma rays, along with neutron radiation, are very penetrating, and are of primary importance when evaluating external radiation exposure and usually must be shielded. The onset of first observable effects of acute radiation exposure, diminished red blood cell count, may occur at a dose of approximately 100 rads of acute whole body radiation exposure. The LD_{50} for humans is about 500 rads, assuming no medical intervention.

Exposure to external radiation may be controlled by limiting the working time in the radiation field, working at a distance from the source of radiation, using shielding between the worker and the source, and by using no more radioactive material than is necessary.

Internal Radiation Exposure

Internal exposures arise radiation is emitted from radioactive materials present within the body. Although external hazards are primarily caused by photons, high energy betas and neutrons, all forms of radiation can cause internal radiation exposures. Alpha particles create a high concentration of ions along their path, and can cause severe damage to internal organs and tissues when they are inhaled, ingested or are present on the skin. Once these particles get into the body, damage can occur since there is no protective dead skin layer to shield the organs and tissues. Internal exposures are not limited to the intake of large amounts at one time, i.e. acute exposure. Chronic exposure may arise from an accumulation of small amounts of radioactive materials over a long period of time.

Routes of Exposure

Radioactive materials may be internally deposited in the body when an uptake occurs through one of four routes of entry: inhalation, ingestion, skin contact (absorption). and injection. Precautions should be taken to avoid each of these means of internal exposure to radiation. These exposures can occur when radioactive material is airborne; is inhaled and absorbed by the lungs and deposited in the body; is present in contaminated food or other consumable items and ingested; or is spilled or aerosolizes onto the skin and absorbed. Internal deposition may also result from contaminated hands, with subsequent eating or rubbing of eyes.

B. Time, Distance and Shielding

External radiation exposures can be reduced using three basic tools: **time, distance** and **shielding.**

Time

Radiation dose is directly proportional to exposure time, therefore, one of the simplest methods of reducing exposure is to limit the time spent exposed to the radiation. Below are a few suggestions to help reduce exposure time:

1. Preplanning - Conduct ‘dry runs’ of the experiment without using radioactive materials, gather all equipment and supplies needed to perform the experiment, and conduct the work quickly and efficiently.

2. Postings - Signs posted in radioactive materials work areas will help to keep non-essential personnel away from the radiation field and remind researches to avoid the area except when absolutely necessary.

Distance

The intensity of a point source of gamma radiation is inversely proportional to the distance (Inverse Square Law), therefore, greater distance means less dose. Do not increase the distance to the point where dexterity or control of the material is compromised. The use of remote handing tools and the storage of radioactive material in a remote area are extremely effective in reducing radiation exposure.

Shielding

1. Gamma radiation- Gamma radiation is diminished in intensity by any given absorber, but not completely stopped. Materials having a high atomic number (Z) can absorb more gamma radiation than lighter elements. Lead is a frequently used shielding material. A convenient way to calculate the thickness of shielding necessary is to use the concept of Half Value Layer (HVL) which is the amount of shielding which reduces the incident radiation by one-half.

2. Alpha and Beta particles- Due to the fact that alpha and beta particles deposit so much energy over such a short distance they are easy to shield. Alpha particles require little or no shielding as they travel only very short distances in air. Low density (Z) materials, such as Plexiglas or acrylic, make excellent shielding for bea particles. High density materials such as lead must be avoided when possible as they cause the production of Bremsstrahlung (x-ray) radiation.

C. Personal Protective Equipment

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

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

Individuals using radioactive materials must wear lab coats, eye protection and double pairs of gloves. Additional protective equipment may be deemed necessary by REHS.

D. Airborne Radioactive Material

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

a. Use of volatile forms of radionuclides, such as I-125 for iodinations or H-3 sodium borohydride may generate airborne radioactivity. Any chemical or physical form which readily volatilizes or evaporates into the air must be considered a potential airborne risk. Use of I-125 in radioiodinations requires that the procedure be performed in a fume hood. Other work practices might include maintaining iodine solutions at a pH or 9 or greater or using non-oxidative processes when possible. Where H-3 sodium borohydride is used, care should be taken to perform all work iun a suitable fume hood, covering containers tightly and acidifying wastes.

b. Chemical reactions may generate radioactive gases or other airborne contaminants. An example is the labeling reaction for S-35 methionine, which generates a methyl mercaptan reaction which liberates HCL and $^{35}SO_2$. Care should be taken to absorb or exhaust volatile radioactive compounds released during radiolytic decay otherwise contamination of incubators and other equipment may result.

As mentioned above, fume hoods are essential to minimizing airborne contamination, however, the use of fume hoods shall be limited to units with a demonstrated face velocity of 80 -100 linear feet per minute at a sash height of no less than 18 inches. The face velocity shall be determined annually and documented on the stickers affixed to each hood.

XV. MACHINE SOURCES OF RADIATION

A. Registration Requirements

For the purpose of this Guide, the term “x-ray producing machine” refers to x-ray machines of both the standard diagnostic and therapeutic types, x-ray diffraction units, electron microscopes, particle accelerators, and high voltage rectifiers with voltages exceeding 20 keV. All x-ray producing devices are regulated by the Machine Source Bureau of the New Jersey Departmental of Environmental Protection.

The use of each x-ray machine is covered by an authorization. An application form can be obtained by calling REHS at 445-2550. The acquisition of an x-ray machine must have prior approval of REHS to assure that adequate facilities are available for its use.

After the receipt of an x-ray machine and prior to its use, a Health Physicist will make an appointment to discuss its use with the applicant. The applicant must also complete a registration form to be submitted to the State. A radiation survey will be made when the machine is operable. Only after the determination that the x-ray machine can be used safely is an authorization issued. The authorization permits only the use of the specific machine identified in the application, and only in the location for which an evaluation was made. No changes in locations may be made until a specific amendment to the authorization is requested and received from REHS. Disposal or transfer of an x-ray machine must have prior approval of REHS.

B. Safe Use of Machine Sources

An x-ray producing machine authoree has the following responsibilities to assure that state regulations and University policy are being followed:

1. Assure that the x-ray device meets all the requirements of the NJ DEP regulations. REHS will help to interpret these regulations and provide assistance in implementing them.

2. Provide written, detailed instruction for the safe operation of the device to each user and to ascertain that all users are properly trained in its use.

3. Ensure the proper use (and return) of personal monitoring equipment, *i.e.*, whole body and extremity TLD badges, assigned to those under his/her authorization.

4. Make arrangements with REHS to conduct a biannual inspection of x-ray producing machines under his/her authorization.

5. Notify REHS immediately in the following circumstances:

   a. when an over-exposure to radiation is indicated or suspected.
   b. upon failure of an interlock or “fail-safe” device.
   c. when change in experimental design could result in significant hazard.
   d. before shielding is changed or the machine relocated.
   e. before an x-ray machine is moved, disposed of or transferred.

XVI. SEALED SOURCES

A. Procedures for Use

Authorees must have the appropriate authorization to possess and use sealed radioactive sources. Users must attend training, sources must be labeled, and security must be in place. It is the authorees responsibility to assure that the sources are used according to the regulations pertaining to the use. REHS must be notified whenever a sealed source is purchased, transferred, moved or disposed of.

B. Semi-Annual Wipe Tests

Sealed sources at RWJMS must be inspected and tested for leakage under the supervision of REHS at six month intervals or as specified in the NRC license under which they were acquired. If any leak test reveals the presence of 0.005 microCuries or greater of contamination, the sources must be removed from use, decontaminated and repaired, or disposed of. Any leak test greater than 0.005 microCuries must be reported to the NRC Division of Nuclear Materials Safety.

APPENDIX A

CHARACTERISTICS OF COMMONLY USED RADIOISOTOPES

ISOTOPE	PRINCIPAL EMISSION	ENERGY	PHYSICAL HALF-LIFE	GAMMA RAY CONSTANT	CRITICAL ORGAN
H-3	*β-	19 keV	12.3 yr	N/A	BODY WATER, TISSUE
C-14	*β-	156 keV	5,730 yr	N/A	FATTY TISSUE
S-35	*β-	167 keV	87.4 days	N/A	TESTIS
P-32	*β-	1.710 keV	14.3 days	N/A	BONE
P-33	*β-	249 keV	25.4 days	N/A	BONE
I-125	gamma	35 keV	60.2 days	1.4 R/hr	THYROID
Ca-45	*β-	257 keV	163 days	N/A	BONE
Cr-51	gamma	320 keV	27.7 days	0.18 R/hr	LOWER LARGE INTESTINE

It requires a β- particle of at least 70 keV to penetrate the protective layer of skin (0.07 mm thick)

* Dose rate (in rad/hr) at one centimeter from a β- point source (neglecting self and air absorption) equals approximately 300 rad/hr per millicurie. The dose rate varies only slightly with β- energy.

APPENDIX B

Carbon -14 (^{14}C)

Physical Data:

Beta Energy	156 keV (maximum)
Physical Half Life	5730 years
Biological Half Life	12 days
Effective Half Life	25 days
Maximum Beta Range in Air	24 cm (10 inches)
Maximum Beta Range in Tissue	0.28 mm (0.012 inches)

Radiological Data:

Critical Organ	Fatty tissue
Routes of Intake	Ingestion, inhalation, skin absorption
External Exposure	Deep dose is not a radiological concern
Annual Limit on Intake	2 mCi (ingestion) 200 mCi (inhalation of CO_2) 2000 mCi (inhalation of CO)
Dose Rate to basal cells from skin contamination1 uCi/cm^2	1400 mrad/hour
Shielding	None required
Survey Instrumentation	Can detect ^{14}C using a G-M pancake probe, however, the counting efficiency is very low (5%). Liquid scintillation counting of wipes may be used to detect removable ^{14}C.
Radiation Monitoring Badges	None needed; beta energy is too low.

Chromium-51 (^{51}Cr)

Physical data:

Gamma Energy	320 keV
X-ray Energy	5 keV
Specific Gamma Ray Constant	0.017 mR/hr /mCi at 1 meter
Physical Half Life	27.8 days
Biological Half Life	616 days
Effective Half Life	26.5 days

Radiological Data:

Critical Organ	Lower large intestine
Routes of Intake	Ingestion, inhalation, skin absorption
Radiological Concerns	Internal and external exposure
Annual Limit on Intake	20 mCi inhalation 40 mCi ingestion
Half Value Layer	0.07 inches of lead
Shielding	Use 1/4 to 1/2 inch of lead shielding
Survey Instrumentation	A survey instrument with a NaI scintillation probe is recommended. A G-M pancake probe has a low counting efficiency for the detection of ^{51}Cr. Wipes counted in a liquid scintillation counter is best for the detection of removable ^{51}Cr surface contamination.
Radiation Monitoring Badges	Whole body and extremity badges are required.

Hydrogen -3 (^3H)

Physical Data:

Beta Energy	18.6 keV (maximum)
Physical Half Life	12.3 years
Biological Half Life	10 - 12 days
Effective Half Life	10 days
Maximum Beta Range in Air	6 mm (0.25 inch)
Maximum. Beta Range in Water	0.006 mm
Permeability in Matter	Insignificant

Radiological Data:

Critical Organ	Body water or tissue Least radiotoxic of all radionuclides
Routes of Intake	Ingestion, inhalation, skin absorption
External Exposure	Not a radiological concern
Radiological Concerns	Internal exposure and contamination are concerns
Annual Limit on Intake	80 mCi
Dose Rate to basal cells from skin contamination 1 uCi/cm^2	0 mrad/hr
Shielding	None required
Survey Instrumentation	^{3}H **cannot** be detected with a G-M or NaI survey meter. Monitor for ^{3}H contamination using wipe tests only.
Radiation Monitoring Badges	None needed

Iodine-125 (^{125}I)

Physical Data:

Gamma Energies	35.5 keV 27 - 31 keV x-rays
Specific Gamma Ray Constant	0.27 mR/hr/mCi at 1 meter
Physical Half Life	60.1 days
Biological Half Life	138 days
Effective Half Life	42 days

Radiological Data:

Critical Organ	Thyroid gland
Routes of Intake	Ingestion, inhalation (most probable), skin absorption
Annual Limit on Intake	60 uCi
Radiological Concerns	External and Internal exposures and contamination are concerns when using ^{125}I
Shielding	Lead foil or sheets 1/32 to 1/16 inches thick
Half Value Layer	0.02 mm (0.008 inches)
Survey Instrumentation	A survey instrument equipped with a NaI probe (not a Geiger-Mueller probe) is necessary.
Radiation Monitoring Badges	A whole body and extremity badge is required when performing iodinations

Calcium- 45 (^{45}Ca)

Physical Data:

Beta Energies	257 keV (maximum)
Physical Half Life	163 days
Biological Half Life	138 days
Effective Half Life	75 days
Maximum beta range in air	52 cm
Maximum beta range in tissue	0.62 mm

Radiological Data:

Critical Organ	Bone
Routes of Intake	Ingestion, inhalation (most probable), skin absorption
Annual Limit on Intake	800 uCi
Dose rate to basal cells from Skin contamination 1mCi/cm^2	4,000 mrad/hr
Radiological Concerns	Internal exposures and contamination are concerns when using ^{45}Ca.
Shielding	Plexiglass or acrylic recommended
Survey Instrumentation	A survey instrument equipped with a Geiger-Mueller probemay be used to detect ^{45}Ca. LSC wipes will detect removable contamination
Radiation Monitoring Badges	A whole body and extremity badge may be used when working with Ca^{45}

Phosphorus - 32 (^{32}P)

Physical Data:

Beta Energy	1.71 MeV (maximum)
Physical Half Life	14.3 days
Biological Half Life	1155 days
Effective Half Life	14 days
Maximum Range in Air	610 cm (20 feet)
Maximum Range in Tissue	0.76 cm (1/3 inch)

Radiological Data:

Critical Organ	Bone
Routes of Intake	Ingestion, inhalation, skin absorption
Annual Limit on Intake	400 uCi
Dose Rate to basal cells from skin contamination of 1 uCi/cm^2	9200 mrad/hr
Shielding	1/2 inch Plexiglas, lucite or acrylic DO NOT use lead foil or sheets.
Survey Instrumentation	A GM survey meter with a pancake probe is recommended. LSC may be used to detect removable surface contamination on wipes.
Radiation Monitoring Badges	Whole body and extremity dosimeters are required when handling greater than 1 mCi at any one time.

Phosphorus - 33 (^{33}P)

Physical Data:

Beta Energy	0.249 keV (maximum)
Physical Half Life	25.4 days
Biological half Life	19 days
Effective half Life	11 days
Maximum beta range in air	89 cm (3 feet)
Maximum range in tissue	0.22 cm (0.04 inch)
Half Value layer	0.3 mm (tissue)

Radiological Data:

Critical Organ	Bone marrow
Routes of Intake	Ingestion, inhalation, skin absorption
Annual Limit on Intake	800 uCi
Dose rate to basal cells from skin contamination of 1 uCi/cm^2	2910 mrad/hr
Shielding	Not required; however, Plexiglas or acrylic is recommended
Survey Instrumentation	A GM survey meter with a pancake probe is required. LSC of wipes may be used to detect removable contamination.
Radiation Monitoring Badges	None required

Sulfur -35 (^{35}S)

Physical Data:

Beta Energy	167 keV (maximum)
Physical Half Life	87.4 days
Biological Half Life	623 days
Effective Half Life	44-76 days
Maximum beta range in air	26 cm (10.2 inches)
Maximum beta range in tissue	0.32 mm (0.015 inch)

Radiological Data:

Critical organ	Testis
Routes of Intake	Ingestion, inhalation, skin absorption
Annual Limit on Intake	2 mCi
Dose rate to basal cells from skin contamination 1uCi/cm^2	1,200 mrad/hr
Shielding	None required; Plexiglas optional
Survey Instrumentation	Can detect ^{35}S with a G-M survey meter with a pancake probe; the efficiency is approximately 5 %. LSC of wipes will also detect removable contamination.
Radiation Monitoring Badges	None needed; the energy of ^{35}S is too low to be detected by a TLD

APPENDIX C

IODINATION SAFETY RULES

Iodine labeling can create potential exposures to the thyroid in workers performing iodinations if proper safety precautions are not followed. Radioiodinations are commonly performed at RWJMS; however, with safe practices exposures do not occur. The following list of safety precautions will assist workers in preventing unnecessary exposures to ^{125}I during iodinations. If you have any questions, please call REHS at 445-2550.

1. Individuals who will be using ^{125}I for radioiodinations in the form of NaI are required to obtain a baseline thyroid scan at REHS, Building 4127 Livingston Campus, prior to the first procedure.

2. Whole body and extremity dosimeters must be worn while iodinating.

3. All iodination protocols (and changes to existing protocols) must be approved in advance by REHS.

4. Individuals who are iodinating for the first time must have their experiment observed by the University Health Physicist or equivalent.

5. All iodinations must be conducted in a fume hood certified for radioisotope work. Preferably, the hood should be dedicated to experiments using ^{125}I. The sash of the fume hood should be brought down to the lowest possible operating height.

6. The fume hood should be covered with absorbent paper to absorb possible spills or drips.

7. Double gloves and a lab coat must be worn during the procedure.

8. Individuals who wish to iodinate must be in compliance with Rutgers' radiation training requirements.

9. An air sampling pump supplied by REHS must be set up in the fume hood and utilized while iodinating.

10. A ratemeter with a low energy gamma probe must be available during and after the procedure to survey for potential ^{125}I contamination.

11. Thyroid bioassays must be performed on workers after each iodination. Post-iodination thyroid scans are done no less than 24 hours after each iodination, and no longer than 72 hours after each iodination.

APPENDIX D

Iodination Survey Form

NRC license conditions require that a contamination survey be conducted immediately after an iodination is performed. This survey could be performed using a calibrated low energy NaI probe or by wipe tests. Areas to be surveyed include: bench tops, floors, instruments, lab coats, shoes, hands, face and anything else that could have been contaminated during this procedure.

A. If you are fulfilling this requirement by wipe tests, please provide the highest results in the spaces below:

Background in DPM: _______________ MDA in DPM: _______________

Efficiency: _______________

Benchtop in DPM: _______________ Floor in DPM: _______________

Hood Sash in DPM: _______________ Instruments in DPM: _______________

Labcoat in DPM: _______________ Shoes in DPM: _______________

B. If you are fulfilling this requirement by using a NaI survey meter, please provide the highest results in the spaces below:

Background:__________________ Efficiency:________________________

LOCATION:	CPM ABOVE BACKGROUND:	DPM (CPM / Efficiency):
Benchtop		
Hood Sash		
Instruments		
Floor		
Labcoat		
Shoes/Clothing		

By signing below, you are confirming that you have performed the above survey and that any contamination found has been cleaned below applicable limits. When you have your thyroid bioassay, please give this completed form to the REHS representative.

____

Signature and date

APPENDIX E

Post-Experiment Contamination Survey Form

Date	Personal Survey	Equipment Survey	Bench Survey	Floor Survey	Trash Survey	RAM Secure

By initialing the boxes above I certify the areas have been surveyed and are free of contamination. If contamination is found, the area(s) or item should be decontaminated and surveyed again, or they should be suitably labeled and stored.

APPENDIX F

Efficiency/MDA Calculations

RWJMS is required to determine the counting efficiency and minimal detectable activity (MDA) of liquid scintillation and gamma counters in order to properly evaluate wipe test results. Monthly laboratory wipe tests must be recorded in units of disintegrations per minute (dpm) as per NRC regulations. To ensure compliance, the following procedures must be performed monthly for, at a minimum, the least efficient isotope that is used in the lab.

A. Determination of Efficiency (E):

a. Use a standard of known activity. Remember that 1 uCi = 2.2×10^6 dpm.
b. Set the gain and discriminator levels (windows) according to the manufacturer's recommendation for the isotope to be counted.
c. Count a blank (background) and the standard for one minute to obtain counts per minute (cpm) for both.
d. Determine the net cpm of the standard by subtracting the background cpm from the standard cpm.
e. Calculate the efficiency (E):
E = net standard cpm/activity of standard in dpm
f. Divide cpm of wipe samples by the efficiency to convert to dpm.

B. Determination of the Minimal Detectable Activity (MDA):

a. Count the blank (background) for one minute.
b. Calculate the MDA:

$$\text{MDA} = 4.653 \sqrt{\text{background cpm}} = (\text{background cpm})^{1/2}$$

c. To obtain results in dpm, divide the MDA by the efficiency.

d. Record all calculations and results in the lab notebook with the monthly lab wipes. The MDA of the counting instrument should be less than 100 dpm. If not, please notify REHS.

APPENDIX G

RADIOLOGICAL UNITS

UNIT	SYMBOL	DESCRIPTION	USE
Curie	Ci	3.7×10^{10} dps 2.22×10^{12} dpm	Special unit of activity
Becquerel	Bq	1 dps	SI unit of activity
Roentgen	R	2.58×10^{-4} C/kg	Special unit of exposure, applies to photons
Rad	rad	0.01 J/kg	Special dose unit
Gray	Gy	1 J/kg	SI unit of dose
Dose Equivalent	H	Dose x Q	Radiation Protection
Quality Factor	Q	Biological effectiveness	Radiation Protection
Rem	rem	Rad dose x Q	Special unit of dose equivalent
Sievert	Sv	Gy x Q	SI unit of dose equvalent

RELATIONSHIP BETWEEN SPECIAL AND SI UNITS

QUANTITY	NAME	SYMBOL	UNITS
Activity	Becquerel	Bq	1 dps
	Curie	Ci	3.7×10^{10} Bq
Absorbed Dose	Gray	Gy	Joule/kg
	rad	rad	10^{-2} Gy
Dose Equivalent	Sievert	Sv	Joule/kg
	rem	rem	10^{-2} Sv
Exposure	coulomb/kg		C/kg
	Roentgen	R	2.58×10^{-4} C/kg

PREFIXES COMMONLY USED WITH RADIOLOGICAL UNITS

PREFIX	FACTOR	SYMBOL
milli	10^{-3}	m
micro	10^{-6}	u
nano	10^{-9}	n
pico	10^{-12}	p

APPENDIX H

IONIZING RADIATION THEORY

All of the known nuclides can be classified as either stable or unstable. If a given nuclide is not stable it will be radioactive with its own unique half-life and decay products. A radionuclide is any unstable nuclide that emits radiation in the process of seeking stability. We define radiation as:

The emission and propagation of energy through space or through a medium in the form of particulate emissions or electromagnetic waves.

One of the principal characteristics of radiation is its energy. A radiation's energy is a measure of its kinetic energy or energy due to motion. The kinetic energy of a particle is proportional to the mass of the particle and the square of its velocity. In general, the higher the energy of a particular radiation the more penetrating it is and the potential risk will be associated with it.

Ionizing radiation has the ability to remove electrons from atoms, creating ions; hence the term "ionizing radiation." The result of ionization is the production of negatively charged free electrons and positively charged ionized atoms. There are four types of ionizing radiation that can be classified into two groups:

1.) photons, such as **gamma** and **x-rays**, and

2.) particles, such as **beta particles** (electrons and positrons), **alpha particles**, and **neutrons**

Photons are electromagnetic radiation having energy, but no mass or charge; whereas particles have typically both mass and charge as well as energy. Neutrons have mass and energy, but no charge, and are typically produced by man with machines, such as cyclotrons. All types of ionizing radiation can remove electrons, but they interact with matter in different ways.

Particles are more highly ionizing; excitation and ionization are the primary interaction with matter, and the potential for ionization increases as mass and charge increases. The range in tissue for particles decreases as mass and charge increase. Photons, because they have no mass or charge, are less ionizing but more penetrating in matter. Gammas and x-rays will primarily interact with matter through direct collisions with orbital electrons, therefore, the probability of interaction is much higher with very dense materials

Ionized atoms (free radicals), regardless of how they are formed, are much more active chemically than neutral atoms. These chemically active ions can form compounds that interfere with the process of cell division and metabolism. Also, reactive ions can cause a cascade of chemical changes in tissue. The degree of damage suffered by an individual exposed to ionizing radiation is a function of several factors: type of radiation involved, chemical form of the radiation, intensity of the radiation flux, energy, and duration of exposure.

Radioactive Decay

Radioactive materials have an associated half-life, or decay time characteristic of that isotope. As radiation is emitted, the material becomes less radioactive over time, decaying exponentially. Since it is impossible or impractical to measure how long one atom takes to decay, the amount of time it takes for half of the original amount of radioactive material to decay is used to calculate half-life. Some radionuclides have long half-lives; for example Carbon-14 takes 5,730 years for any given quantity to decay to half of the original amount. Others have short half-lives, such as Phosphorus-32 which has a half-life of 14 days.

Knowing the half-life of a radioisotope, and understanding the concept, is important for many reasons. When deposited in the human body, the half-life of the radioactive material present in the body affects the amount of exposure. If the radioactive material contaminates a workbench or piece of equipment, and is not removable, the amount of time before the contaminated item may be used again is determined by the half-life. Radioisotope decay using half-life also minimizes the costs and concerns of radioactive waste management.

How to calculate decay

The instantaneous rate of change in the number of atoms decaying over time is directly proportional to the number of atoms present in the sample The constant of proportionality is known as the **decay constant.** Mathematically this is represented by :

$- dN/dt = \lambda N$

where:

$-dN/dt$ = the instantaneous rate of change of the number of atoms over time.

λ = the decay constant

N = the number of atoms in the sample at a given time.

Equation (1) can be solved and rewritten as:

$N = N_0 e^{-kt}$

where:

N = the number of atoms remaining after time t

N_o = the number of atoms at t_0

e = the base of the natural logarithm

k = 0.693

t = the time between N_0 and N

Since the activity of a sample was previously defined as the number of radioactive nuclei decaying per unit time, activity may be mathematically defined as:

$$\mathbf{A = -dN/dt = \lambda N} \quad \text{or} \quad \mathbf{A = A_0 e^{-kt}}$$

Biological Effects of Ionizing Radiation

Injury due to irradiation is caused mainly by ionization within the tissues of the body. When radiation interacts with a cell, ionizations and excitations are produced in either biological macromolecules or in the medium in which the cellular organelles are suspended, predominantly water. Based on the site of interaction, the radiation-cellular interactions may be termed as either direct or indirect.

- **Direct action** occurs when an ionizing particle interacts with and is absorbed by a macromolecule in a cell (DNA, RNA, protein, enzymes, etc.). These macromolecules become abnormal structures that initiate the events that lead to biological changes.
- **Indirect action** involves the absorption of ionizing radiation in the medium in which the molecules are suspended. The molecule that most commonly mediates this action is water. Through a complex set of reactions the ionized water molecules form free radicals that can cause damage to macromolecules. Indirect effects are probably more important than direct effects.

The most important target for radiation in the cell is DNA in the nucleus. Biological effects result when DNA damage is not repaired or is improperly repaired. Extensive damage to DNA can lead to cell death. Cell death implies the inability of individual cells to reproduce. Large numbers of cells dying can lead to organ failure and death for the individual. Damaged or improperly repaired DNA may develop into lymphoma and cancers in somatic cells. Two kinds of effects may result.

- **Acute, or nonstochastic**, effects are health effects the severity of which varies with the dose and for which a threshold is believed to exist. Radiation-induced cataract formation or skin erythema are examples of a nonstochastic effect, also known as a deterministic effect.
- **Delayed, or stochastic** effects, are health effects that occur randomly and for which the probability of the effect occurring, rather than the severity, is assumed to be a linear function of the dose without threshold. Genetic effects and cancer incidence are example of stochastic effects.

TISSUE AND CELL SENSITIVITY TO RADIATION

Various degrees of sensitivity to radiation exist due to the type of tissue which receives the exposure and are shown below.

RADIOSENSITIVE	RADIORESISTANT
breast tissue	heart tissue
bone marrow cells	large arteries
mucosal lining of sm. intestine	large veins
sebaceous glands of skin	mature blood cells
immune response cells	neurons
all stem cell populations	muscle cells
lymphocytes	bone

It is important, when considering the real versus the perceived risk of radiation exposures, to be aware of the acute effects of large radiation exposures. Without this information, one has no comparison to determine whether the radiation one is handling presents an actual risk or not. Often fears exist that because the radiation is present and is measurable, a serious risk is present. The fact that we can not see, smell, or feel the radiation sometimes magnifies the fears. The table below shows the effect of various types of high radiation exposures.

Effects of Acute Radiation Exposures in Humans

Radiation Exposure	Effects
1000 R; single dose, whole body	death occurs in a few hours from neurological and cardiovascular breakdown
500-1200 R; single dose; whole body	death occurs within days and is associated with bloody diarrhea (GI syndrome)
250-500 R; single dose, whole body LD_{50} ~ 450 R	death occurs after several weeks due to damage to bone marrow
50-350 R and higher; single dose; whole body	various degrees of nausea, vomiting, diarrhea, reddening of skin, hair loss, blisters
100 R; single dose, whole body	mild radiation sickness, depressed lymphocyte count
25 R; single dose; whole body	lymphocytes temporarily disappear from circulating blood
10 R; single dose; whole body	elevated number of chromosomal aberrations in peripheral blood
400-500 R; localized; low energy x-ray	temporary hair loss
600-900 R; localized to eye	cataracts
500-600 R to skin; localized single dose, 200 keV	erythema in 7-10 days, followed by gradual repair and dull tanning
1500-2500 R to skin; localized single dose, 200 keV	erythema, blistering, residual smooth,soft, depressed scar

GLOSSARY

Absorbed Dose- the amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material. The International unit of absorbed dose is the Gray, which is 1 joule/kg.

Absorption- The process by which the number or energy of particles (or photons) moving through a materiel is reduced by interaction with it.

Activity- The decay rate of a radioactive sample, normally expressed in disintegrations per second or minute. Activity is the product of the number of atoms of the radioactive isotope in the sample and the decay constant of that isotope.

Acute exposure- A short (< 24 hours) radiation exposure of an individual to a relatively high radiation level.

Airborne radioactivity- Any radioactive material dispersed in the air in the form of dusts, fumes, mists, vapors, or gases.

ALARA- an acronym for As Low As Reasonably Achievable; making every reasonable effort to maintain exposures to radiation as far below the dose limits as is practical.

Alpha particle- A positively charged particle emitted by certain radioactive materials. It is made up of two neutrons and two protons bound together and is identical to the nucleus of a helium atom.

Annual Limit of Intake (ALI)- the derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year.

Attenuation- The combination of absorption and scattering processes by which the intensity or flux density of a beam of radiation is reduced in intensity when passing through some material.

Background radiation, natural- The radiation in man's natural environment, including cosmic rays and radiation from naturally radioactive elements.

Becquerel- the international (SI) unit for radioactivity in which the number of disintegrations is equal to one disintegration per second (dps).

Beta particle- A particle emitted by certain radioactive particles. A negatively charged beta is identical to an electron. A positively charged beta is called a positron.

Bioassay- the determination of kinds, quantities or concentrations, of radioactive materials in the human body, whether by direct measurement (in vivo counting) or by analysis and evaluation of materials excreted or removed from the body.

Bremsstrahlung- secondary photon radiation produced by the deceleration of charged particles through matter. Usually associated with energetic beta emitters, e.g., ^{32}P.

Chronic exposure- Radiation exposure, usually to low-level radiation, taking place over a long period of time.

Contamination, radioactive- particles of radioactive materials in an undesired location or in any location where it may be harmful to personnel, equipment or facilities.

Coulomb- the meter-kilogram-second unit of electrical charge, equal to the quantity of charge transferred in one second by a constant current of one ampere.

Cpm – counts per minute – pulses that have been detected (in a time period of one minute) corresponding to an ionizing event or to an extraneous disturbance.

Critical organ- The body organ receiving the greatest dose from a particular radioactive species relative to the permissible dose during internal exposure. Usually it is the organ receiving the greatest concentration.

Curie- The original unit of measure of radioactivity. That amount of any radionuclide in which the number of distintegrations per second is 3.7×10^{10}. Several standard metric prefixes are commonly used, such as the millicurie, microcurie and nanocurie.

Declared pregnant worker- a woman who has voluntarily declared, in writing, her pregnancy and the estimated date of conception.

Derived air concentration- 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.

Disintegration – a spontaneous nuclear transformation characterized by the emission of energy and / or mass from the nucleus.

Dose Equivalent – the product of the absorbed dose in tissue, quality factor, and other modifying factors at the location of interest. The international unit of dose equivalent is the Sievert (Sv).

Dosimeter- a device worn by personnel on their bodies to measure the amount of accumulated dose received from external sources of radiation.

Efficiency – A measure of the probability that a count will be recorded when radiation is incident on a detector.

Electromagnetic radiation- A traveling wave consisting of oscillating electric and magnetic fields. Familiar types of EM radiation range from gamma and x-rays of short wavelength, through the ultraviolet, visible light and infrared regions, to radar and radio waves of relatively long wavelength. All EM radiation travels at the speed of light in a vacuum.

Electron- a negatively charged elementary particle which is a constituent of every neutral atom. Its unit of negative electricity equals 4.8×10^{-19} coulombs. Its mass is 0.000549 amu.

Electron volt- A unit of energy equivalent to the energy gained by an electron passing through a potential difference of one volt. Larger multiple unit of the electron volt are frequently used: keV for thousand or kilo electron volts; MeV for million or mega electron volts.

Erg- the amount of energy required to move a mass of 1/980 gram though one centimeter. One erg equals 6.25×10^{5} MeV.

Exposure- the amount of radiation to which an individual is exposed.

Extremity- the hand, elbow, arm below the elbow, foot, knee, or leg below the knee.

Gamma ray- penetrating EM radiation having wavelengths much shorter than those of visible light. Gamma rays accompany many nuclear reactions; e.g., radioactive decay, fission, and neutron capture.

Gray- the international (SI) unit of absorbed dose in which the energy deposited is equal to one joule per kilogram.

Half-life, radioactive- the time required for the activity of a given radioactive element to decrease by one-half due to radioactive decay. The half-life is a characteristic property of each radioactive nuclide and is independent of its amount.

Half-life, biological- the time required for the body to eliminate half of the material taken into by natural biological processes.

Half-life, effective- the time required for a radioactive element in the body to be diminished by one-half as a result of the combined action of radioactive decay and biological elimination. May depend on the chemical form of the radioactive material.

Half value layer- the thickness of any specified material necessary to reduce the intensity of an x-ray or gamma ray beam to one-half its original value.

Intake- the quantity of material introduced into the body by inhalation, ingestion or through the skin.

Inverse Square Law- the intensity of radiation at any distance from a point source varies inversely as the square of that distance.

Ion- an atom or molecule in which the number of electrons and the number of protons differ. An ion with an excess of electrons has a net negative charge. One with a deficiency of electrons has a net positive charge.

Ionization- the process of changing an atom or molecule into an ion. Generally this involves the removal of an electron form the atom or molecule, either directly or indirectly, leaving a positively charged ion. The separated electron and ion are referred to as an ion pair.

Ionizing radiation- any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, by its passage through matter. Ionizing radiation includes gamma and x-rays, alpha and beta particles, high speed electrons, neutrons, and other nuclear particles.

Licensed material- source material, special nuclear material, or byproduct material received, possessed, used, transferred or disposed of under a general or specific license issued by the Nuclear Regulatory Commission.

Molecule- a group of atoms held together by chemical forces. A molecule is the smallest unit of a compound that can exist by itself and retain all its chemical properties.

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

Natural radioactivity- radioactivity of naturally-occurring nuclides whose location and chemical and physical form have not been altered.

Nuclear Regulatory Commission- an independent Federal regulatory agency responsible for licensing and inspecting nuclear power plants, universities, hospitals and other facilities using radioactive materials.

Nucleus- the small, positively charged core of an atom. The nucleus spans only about 1/10,000 the diameter of the atom, but contains nearly all of the atom's mass. All nuclei contain both protons and neutrons, except the nucleus of ordinary hydrogen.

Neutron- an uncharged particle with a mass slightly greater than that of the proton, and found in the nucleus of every atom heavier than ordinary hydrogen.

Photon- a quantum of energy emitted in the form of EM radiation. Gamma and x-rays are examples of photons.

Proton- a positively charged particle always found in the nucleus of all atoms.

Quality factor- a proportionality factor that relates the biological effects, as measured in rem, to the actual radiation energy absorbed, as expressed in rad, taking into consideration the type and energy of the radiation involved.

Rad- the special unit of absorbed dose. It is that amount of any type of radiation which will deposit 100 ergs of energy per gram of material.

Radioactivity- the spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nucleus of an unstable isotope. As a result of this emission, the radioactive isotope decays into the isotope of a different element which may also be radioactive. Ultimately as a result of one or more stages of radioactive decay, a stable end product is formed.

Radioactive decay- the decrease in the amount of any radioactive material with the passage of time due to the spontaneous emission from the atomic nuclei of either alpha or beta particles, or gamma rays.

Radioactive material- any material (solid, liquid, or gas) which spontaneously emits ionizing radiation.

Relative Biological Effectiveness- for a particular living organism or part of an organism, the ratio of the absorbed dose of a reference radiation (typically –rays) that produces a specified biological effect to the absorbed dose of the radiation of interest that produces the same biological effect.

Rem- the special unit of dose equivalent, defined as the amount of any type of radiation which will cause damage to human body tissue equivalent to the damage that would be caused by absorbing 100 ergs of gamma radiation per gram of body tissue.

Roentgen (R)- the special unit of exposure, defined as the amount of gamma or x-rays required to produce ions carrying one electrostatic unit of electrical charge in one cubic centimeter of dry air under standard conditions. One roentgen will deposit 83 ergs of energy per gram of dry air. One roentgen equals 2.58×10^{-4} coulombs/kg of air.

Sealed source- radioactive material that is permanently bonded or fixed in a capsule or matrix designed to prevent release and dispersal of the radioactive material.

Sievert- the international (SI) unit of dose equivalent, which is equal to 100 rem.

Specific activity- the total radioactivity of a given nuclide per gram of a compound, element or radioactive nuclide.

TLD – thermoluminescent dosimeter – a dosimeter made of certain crystalline material which is capable of both storing a fraction of absorbed ionizing radiation and releasing this energy in the form of visible photons when heated. The amount of light released can be used as a measure of radiation exposure to these crystals.

Whole body- (for purposes of external exposure) the head, trunk, arms above the elbow, gonads, or legs above the knee.

Wipe- a procedure in which a moistened filter paper or cotton swab is rubbed on a surface and its radioactivity measured to determine if the surface is contaminated with removable radioactive material.

X-rays- penetrating EM radiation (photons) having wavelengths much shorter than those of visible light. X-rays are most commonly produced by the excitation of the electron field around certain atomic nuclei. X-rays are very similar to gamma rays, but are slightly less energetic due to their longer wavelength.

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