

Radiation Safety Manual



TABLE of CONTENTS

Introduction3

Chapter 1 Radiation Safety Organization4

Chapter 2 Principles of Radiation Safety14

Chapter 3 Radiation Exposure Limits22

Chapter 4 Facilities and Equipment Considerations.....27

Chapter 5 Radioisotope Laboratory Setup Guide.....32

Chapter 6 Procurement and Transfer of Radioactive Materials.....39

Chapter 7 Radiological Surveys.....49

Chapter 8 Radiological Postings.....65

Chapter 9 Response to Radiological Incidents70

Chapter 10 Laboratory Procedures.....77

Chapter 11 Radioactive Waste Handling and Disposal.....93

Chapter 12 Radiological Improvement Program.....115

Chapter 13 Radiation Producing Equipment119

Mark Hatcher, Radiation Safety Officer

Alan Parker, Director, Environmental Health and Safety Services

Dr. Bud Fischer, Dean, Basic and Applied Science

Dr. David Butler, Vice Provost, Office of Research

Jeffry Porter, Director Office of Research and Sponsored Programs



DATE: 11/18/19

INTRODUCTION

Radiation Safety Mission Statement

The goal of the Radiation Safety Program of Middle Tennessee State University (MTSU) is to keep radiation exposure to University personnel, members of the public, and the environment As Low As Reasonably Achievable (ALARA) and in compliance with state and federal regulations.

The ALARA concept dictates that we implement safety measures that are commensurate with the level of risk presented by the radiation hazard. This risk may be minimized by education and the application of appropriate radiological controls.

The Radiation Safety Officer has the responsibility and authority to establish radiation safety policies. These policies must achieve adequate safety, satisfy regulatory requirements, and should maintain harmonious support of the teaching, research, and service missions of the University. Each radiation worker has the responsibility for compliance with the policies provided in order to keep his or her own radiation exposure ALARA.

Acknowledgement

This manual was written by Jody Jacobs, Radiation Safety Manager, Environmental Safety Division, University of Georgia. It was adapted with permission for use by Middle Tennessee State University.



1.0 RESPONSIBILITY AND AUTHORITY OF THE RADIATION SAFETY COMMITTEE**1.1 Appointment of the Committee**

- 1) The Committee is appointed by the Radiation Safety Officer.
- 2) The Committee will include:
 - faculty members who are knowledgeable in the use of ionizing radiation
 - the Radiation Safety Officer
 - other safety professionals at the discretion of the Vice Provost Office of Research

1.2 Establishment of Radiation Safety Policy

- 1) The Committee will establish radiation safety policy. The policy will be designed to:
 - protect faculty, staff, students, visitors and the public from hazardous radiological conditions
 - keep the University in compliance with state and federal regulations and the conditions of the University's license
 - maintain radiation exposure as low as reasonably achievable (ALARA)
- 2) The Committee will review policies and modify them as appropriate.

1.3 Committee Meetings

- 1) The Committee will meet as necessary to conduct its business, but not less than quarterly.
- 2) One half of the membership of the Committee will constitute a quorum.
- 3) A Committee member who cannot attend a meeting may send a qualified representative to represent him/her. The representative is not a voting representative and does not contribute to the quorum.
- 4) A Committee member who does not attend at least two quarterly meetings in an academic year may be removed from the Committee and replaced on recommendation of the Committee Chairman to the Vice Provost Office of Research. A representative does not count as an attendee for purposes of this rule.
- 5) Minutes of meetings will be maintained. The minutes will be distributed to Committee members. Minutes will also be available to other interested persons upon request and payment of the cost of reproduction.

1.4 Authorized Users

- 1) The Committee will authorize faculty members for the use of radioactive materials after submission of a written application if it is determined that safety requirements will be met. The Committee may also selectively authorize other individuals, including tenants in space leased from the University, whom the committee determines to be qualified. Faculty members and other individuals so authorized shall be referred to as “Authorized Users” throughout the remainder of this document.
- 2) The applicant must have adequate training and experience to safely handle the types and quantities of radioactive materials requested.
- 3) The applicant must have adequate space, facilities, and equipment to safely use and possess the radioactive materials requested.
- 4) The applicant must agree to comply with guidelines stipulated in the MTSU Radiation Safety Manual and with any other written directives authorized by the Radiation Safety Committee.
- 5) Tenants in space leased by the University additionally must agree to comply with terms and restrictions stipulated in the lease. Throughout this document, references to the Authorized User’s department will be taken to mean the Office of Research for Authorized Users who are tenants in leased space at the University.
- 6) The Committee may deny or rescind the permit of a prospective or Authorized User who:
 - Does not, in the opinion of the Committee, have the experience or facilities to safely possess the radioactive materials requested.
 - Demonstrates a serious or chronic disregard for safety regulations or radiation safety policy.
- 7) The Committee may delegate to the Chairman the authority to approve routine authorized use permit or amendment requests with the concurrence of a member of the Radiation Safety staff. Non-routine matters will be addressed by the entire committee. Non-routine matters include, but are not limited to:
 - The initial authorization of tenants in space leased from the University.
 - Authorizations or amendments which would require the filing of a Radioactive Materials License Amendment with the State of Tennessee.
 - Any other authorizations or amendments that the Radiation Safety Officer, Radiation Safety Chairman, or Radiation Safety Committee members consider to be non-routine, in accordance with their professional training and experience.
- 8) No person may bring radioactive materials onto University property or remove radioactive materials from University property without prior approval of the University Radiation Safety Officer or designee.

1.5 Oversight of the Radiation Safety Program

- 1) The Committee will review and advise on corrective actions recommended by the Radiation Safety staff.



- Authorized Users may appeal decisions made by the Radiation Safety staff in the implementation of the radiation safety program.
 - The Radiation Safety staff may bring to the Committee for resolution problems with Authorized Users whom they feel are not in compliance with radiation safety procedures.
- 2) **The Committee will periodically review the radiation safety program to ensure its effective operation.**
 - 3) **The Committee will bring to the attention of the MTSU administration issues that need to be addressed by administrative procedures and advise the administration on options available and desirability of various options.**

1.6 Investigation of Incidents

- 1) An incident that causes an excessive radiation exposure, or a potentially excessive exposure, will be investigated by the Radiation Safety Officer to determine the cause and necessary corrective action.
- 2) At the discretion of the Committee, another Committee member may be appointed to conduct the investigation in conjunction with the Radiation Safety Officer.
- 3) When appropriate, corrective action will be initiated by the Committee to reduce the potential for future incidents.
- 4) In the event of a serious disagreement between the Radiation Safety staff and an Authorized User over the causes or circumstances of an incident, the Committee may designate one or more Committee members to conduct an investigation.

2.0 RESPONSIBILITY AND AUTHORITY OF THE RADIATION SAFETY OFFICER AND RADIATION SAFETY STAFF

2.1 Appointment of the Radiation Safety Officer

- 1) The Radiation Safety Officer shall be a person qualified by training and experience to give guidance and assistance in the safe use of ionizing radiation.
- 2) The Radiation Safety Officer is designated by the President of the University to carry out the policies of the Radiation Safety Committee, ensure that federal and state laws and regulations as well as University regulations are complied with, and to advise the Committee in matters of radiation safety.

2.2 Duties of the Radiation Safety Officer and Staff

- 1) The Radiation Safety Officer and staff are available to assist and advise Authorized Users of ionizing radiation on the University campus, and to ensure that all ionizing radiation is used in accordance with the policies approved by the Radiation Safety Committee.
- 2) The Radiation Safety Officer shall ensure that proper surveys are carried out in all authorized locations where ionizing radiation is used, and that appropriate records are kept.



- 3) Radiation Safety maintains all records required by state and federal regulations and rules of good practice including, but not limited to, the following:
 - personnel dosimetry records
 - radioactive waste disposal
 - radioactive materials inventory
 - radiological instrument calibration
 - leak tests on sealed sources
 - radiation safety surveys
- 4) The Radiation Safety Officer may require Authorized Users to keep such records as may be necessary to assist in maintaining the above records.
- 5) The Radiation Safety Officer or designee shall provide an individual radiation exposure record within 30 days of request from any individual whose exposure was monitored under the MTSU radiation safety program.
- 6) The Radiation Safety staff offers courses of instruction for users and potential users of ionizing radiation.
- 7) The Radiation Safety Officer and staff assist faculty members who offer formal courses in the use of ionizing radiation.
- 8) The Radiation Safety Officer or designee shall suspend as rapidly as possible any operation causing an excessive radiological hazard.

2.3 Authority of the Radiation Safety Officer and Staff

- 1) **State and federal codes require that radioactive materials are regulated to ensure that radiation exposure to employees or the public do not exceed specified levels.**
 - The University receives its radioactive materials license from the State of Tennessee Department of Environment and Conservation Division of Radiological Health with appropriate regulations to ensure that safety requirements are met.
 - The Middle Tennessee State University Environmental Health and Safety Services (EHS) administers the radiation safety program under the authority and within policies established by the President of the University.
- 2) The Radiation Safety Officer shall implement the federal, state and university radiation safety policies through the guidelines established by the Radiation Safety Committee.
- 3) The Radiation Safety Officer shall work directly under the supervision of the Associate Vice Provost, Office of Research Services, Environmental Health and Safety Services. In extreme cases where a serious radiation hazard threatens, the Radiation Safety Officer may and should report immediately and directly to the President of the University.
- 4) The Radiation Safety Officer shall suspend any operation that violates, or that may result in the violation of, the policies set forth in this manual.
- 5) An Authorized User whose operation is suspended by the Radiation Safety Officer may appeal to the Radiation Safety Committee for a formal ruling.



3.0 RESPONSIBILITIES OF THE AUTHORIZED USER

3.1 Requests for Radioactive Materials Use

Any person who wishes to use radioactive materials on University property must submit an application to the Radiation Safety Committee via the Radiation Safety Office. Application forms and instructions for completing an application are available from Radiation Safety.

The application may be approved, provided that the prospective user furnishes evidence of training, experience, facilities and equipment necessary to possess the radioactive materials in such a manner that:

- Personnel exposure to ionizing radiation will be kept As Low As Reasonably Achievable (ALARA).
- The Authorized User will be in compliance with the policies set forth in this manual and the radiation safety program.
- No state or federal regulations will be violated.

When a radioactive materials use application has been approved, the Radiation Safety Officer or designee will provide the applicant with a written authorization. This written authorization will normally be in the form of a radioactive materials permit (formerly known as a license). Specific terms, conditions, and limitations associated with the possession and use of radioactive materials will be described in the permit.

3.2 Requests for Changes to Radioactive Materials Permits

An Authorized User that desires to make a change to their radioactive materials permit must submit a written request to the Radiation Safety Office. Requests for changes to radioactive materials permits are typically processed as permit amendments. Some examples of changes that may be authorized through the use of an amendment include, but are not limited to the following:

- adding or deleting radioisotopes
- increasing or decreasing possession limits for authorized radioisotopes
- adding or deleting approval for sewer disposal
- changing authorized use locations
- requesting inactive status
- requesting permit termination.

3.3 Duties of the Authorized User

It is the responsibility of the Authorized User:



- 1) To ensure that the policies in this manual are observed by all personnel under their direction.
- 2) To properly train new personnel before allowing them to work with, or be exposed to ionizing radiation from authorized sources. Training shall include:
 - Reading of this manual.
 - General rules of radiation safety.
 - Specific rules for the authorized uses and use locations.
 - Directions for contacting the Radiation Safety Officer and Radiation Safety staff for assistance.
 - Directions for notifying the proper authorities in the event of an emergency or accident.
 - Certification of at least one worker in the authorized use location as an Advanced Radiation Worker by successful completion of required training as provided by Radiation Safety.
- 3) To make available appropriate radiation safety procedures and policies to be observed in the authorized use location.
- 4) To see that radiological surveys are made and records kept as required by the Radiation Safety Officer and this manual.
- 5) To keep an up-to-date inventory of all radioactive materials in their possession.
- 6) To ensure that security of radioactive materials is adequate to prevent unauthorized access.
- 7) To properly prepare and store radioactive waste material for disposal as described in this manual.
- 8) To post proper radiation signs and labels as described in this manual.
- 9) To provide Radiation Safety with all required radiological records prior to:
 - terminating employment with the University
 - terminating lease of space from the University
 - terminating radioisotope usage.
- 10) To treat all authorized use locations as radioactive materials areas and comply with the associated safety requirements.
- 11) To ensure that neither radioactive materials nor contaminated equipment is removed from the radioactive materials area, unless proper procedures are followed as described in this manual.
- 12) To ensure that no furniture or equipment is removed from an authorized use location to an unrestricted area until the materials have been surveyed, found to be free of contamination, and all radioactive warning labels removed.



3.4 Absences of the Authorized User

An Authorized User on sabbatical leave or absent for a period greater than 60 days may assign responsibility for his/her program to another Authorized User who will be in charge of the laboratory in his/her absence.

- 1) The person who accepts this responsibility shall be:
 - another Authorized User who agrees in writing to accept responsibility for the laboratory, or
 - a resident post-doctoral researcher.
- 2) This alternative may be utilized for a period not exceeding 12 months.
- 3) The Authorized User will leave suitable contact information (preferably a phone number and electronic mail address) with the Radiation Safety staff and with the department office so that he/she can be reached.
- 4) The post-doctoral researcher must be approved by the department head who will notify Radiation Safety, in writing, of the arrangement and assume overall responsibility for the laboratory.
- 5) The arrangement must be approved by the Chairman of the Radiation Safety Committee and by a representative of Radiation Safety.
- 6) If the Authorized User does not choose one of the options listed above, the Chairman of the Radiation Safety Committee should be notified. If approved by the Chairman, the absent Authorized User's radioactive materials will be transferred directly to one of the following:
 - another Authorized User who is willing to accept the materials, or
 - Radiation Safety for disposition.
- 7) If cleanup and disposal costs are accrued, charges may be billed for these services. If the material was the property of a faculty member, the faculty member's department will be charged for this service. If the material was the property of a tenant, the tenant will be charged for this service. If the tenant does not pay for this service, the Office of Research will be charged for this service.

3.5 Inactive Status

An Authorized User who does not possess any radioactive materials or radioactive waste may have his/her permit placed on inactive status for a period not exceeding 12 months by notifying Radiation Safety in writing. The permit may be reactivated following Radiation Safety approval of a written request submitted by the Authorized User.

An Authorized User who does not reactivate their permit during the 12 month period will be subject to having their permit terminated as described in section 3.8. If the permit is terminated the faculty



member may re-apply by filling out a standard radioactive materials permit application and obtaining approval from the Radiation Safety Committee.

3.6 Special Authorizations

Graduate students, post-doctoral associates and non-tenure track faculty members will not be authorized except under special circumstances at the discretion of the Radiation Safety Committee. These researchers may work under the direction of an Authorized User. Under special circumstances at the discretion of the Radiation Safety Committee, tenants in space leased from the University may be authorized.

3.7 Individual Permit Requirements

Each full or tenure track faculty member (assistant professor, associate professor or professor) who works with radioactive materials must obtain an individual permit. A faculty member may not work under the permit of another faculty member unless specifically approved by the Radiation Safety Committee.

3.8 Termination of Permits

An Authorized User who plans to leave the University, or terminate his/her permit for any reason, must notify Radiation Safety and arrange for the disposition of their radioactive materials by proper disposal or by transfer to another Authorized User. Authorized users who are tenants in space leased from the University may be subject to additional binding restrictions specified in the lease.

- 1) To dispose of the material:
 - Properly package and label the materials as described in this manual and notify Radiation Safety of the need for a waste pickup.
 - Disposal of large sealed sources or other radioactive materials requiring special handling and extra expense must be funded by the researcher or his department.
- 2) To transfer the material to another Authorized User:
 - Follow the requirements for radioactive materials transfers as described in this manual.
 - If the radioactivity is in such a quantity or form so as to require special funding for disposal, a letter from the department head must be enclosed specifying that such funding will be made available when the source is no longer needed.
- 3) A member of the Radiation Safety staff will inspect the laboratory to determine if it is free of radioactive materials and/or contamination.
- 4) In the event that an Authorized User abandons radioactive material upon leaving the University and fails to arrange for proper disposal or transfer, the radioactive materials become the responsibility of his/her department. The course of action for abandonment shall be as follows:
 - The Radiation Safety staff will clean up and dispose of the abandoned radioactive materials and remediate contaminated areas.



- The Environmental Health and Safety Services will submit an itemized list of expenses to the researcher's department for payment. The bill will include charges for the time, equipment, and supplies used in the cleanup and disposal, plus overhead.
- If an outside contractor is required for cleanup and/or disposal, the charges will be paid by the researcher's department.
- If the department desires to arrange for the outside contractor directly, it may do so by going through the Procurement Office and obtaining a qualified contractor for the job. The contractor must meet all applicable state and federal regulations and University policies.
- In the event that an Authorized User who is a tenant in space leased from the University abandons radioactive material upon leaving the University space and fails to arrange for proper disposal, the Authorized User will be subject to the penalties and remedial procedures specified in the written lease. Disposal and cleanup charges will be the responsibility of the Office of Research.

3.9 Retirement of Authorized Users

The radioactive materials permit ordinarily will be terminated upon retirement of an authorized faculty member, at which time the inventory of radioactive materials must be cleared. A retiring individual (e.g. faculty granted emeritus status) continuing to use a laboratory on University property may apply annually for one-year extensions of the radioactive materials permit. For favorable consideration, the Committee requires verification that the Authorized User will have continuing access to adequate facilities to store and handle radioactive materials safely and that funds will be available, if needed, for disposal. Verification ordinarily involves written assurance from the head of the applicant's department or equivalent unit.

3.10 Financial Assurance

When an authorized faculty member wishes to obtain radioactive materials that will require special funding for disposal, he/she must submit a letter from the department head stating that the department will accept financial responsibility for funding of disposal.

4.0 RESPONSIBILITIES OF THE RADIATION WORKER

Individual radiation workers shall:

- 1) Comply with all University radiation safety policies as described in this manual and any other radiation safety documents authorized by the Radiation Safety Committee, Radiation Safety Officer, or the Authorized User.
- 2) Observe, understand, and obey radiological postings, signs, tags, and boundaries.
- 3) Communicate honestly and effectively with the Authorized User, Radiation Safety staff, Radiation Safety Committee, and any state or federal regulatory personnel regarding any radiological conditions, compliance issues, or concerns.
- 4) Have the responsibility to maintain his or her own exposure to radiation and radioactive



materials ALARA. This should include, but is not limited to:

- being aware of the radiation hazards in their work area
- properly handling and storing radioactive materials
- using appropriate personal protective equipment
- performing any required radiological monitoring.



1.0 UNITS OF RADIATION DOSE

1.1 Roentgen

In 1896, x-rays were discovered by Roentgen and radioactivity by Becquerel. For some time, no one realized that radiation could cause harmful effects. It was recognized very soon that x-rays could be used in medical diagnosis, and early radiologists received large doses of radiation. Many of these radiologists later suffered severe injuries due to overexposure (radiation effects may appear years after exposure). The first unit of dose was the erythema dose. This was the amount of x-radiation which would barely cause reddening of the skin. It was not a very satisfactory unit of dose, but indicates the early recognition by some scientists that radiation exposure can be harmful and should be limited. One erythema dose consisted of about 270 to 1,000 roentgens, depending upon the energy of the x-rays. The recommended limit was 1/1000 of an erythema dose per day (about 0.27 to 1.0 roentgen per day).

Madame Curie, in her work with radium, received radiation exposure which eventually proved fatal. It should be noted that Madame Curie received what would now be considered extremely high doses of radiation exposure and that she lived to be 67, a long lifetime for the period. Radium-containing "tonics" were sold by unscrupulous persons as health aids and some of the persons taking these "tonics" died of radiation poisoning. Probably the most widely known example of radiation poisoning is the case of the watch dial painters who used radium to paint luminous dials. These workers ingested radium by using their lips to make a pointed tip on their brushes. Many of them died later of bone cancer. It should be emphasized that the persons noted above who suffered radiation damage received very large doses of radiation and followed no standards of exposure limitation.

In 1928, the International Commission on Radiation Protection (ICRP) was established. This group defined the roentgen as the unit of radiation dose. In 1934, a "tolerance dose" of 0.2 roentgens per day (60 roentgens per year) was agreed upon as the recommended limit for radiation exposure.

In 1936, the recommended limit was reduced to 0.1 roentgen per day (30 roentgens per year). In 1950, the National Council on Radiation Protection and Measurement (NCRP) and the ICRP introduced the concept of "permissible dose" and set the permissible exposure at 0.3 roentgen per week (15 roentgens per year). In 1956, the permissible dose was reduced to 0.1 roentgen per week (5 roentgens per year). This was not due to any observed ill effects at previous limits, but was based on the desire to be conservative and reduce the possibility of any long-range effects. At the present time, the limit for occupational exposure remains 5 roentgens per year or the equivalent. No ill effects have been noted at this exposure level.

1.2 Rad

The roentgen was not an ideal unit of radiation dose. It was defined as the amount of x or gamma radiation which produces ions carrying one electrostatic unit of charge of either sign in one cubic centimeter of dry air at standard temperature and pressure. Thus, the roentgen was defined as a given



amount of ionization in air and applied only to x and gamma radiation. It did not indicate directly the damage within a biological system. It was soon realized that a given amount of ionization in air could result in different amounts of damage in an object being irradiated. Results of experiments using low energy x-rays could not be compared with those using high energy x-rays or gamma rays. This led to much confusion in the literature on radiation effects.

This resulted in establishment of the rad. A rad is 100 ergs of energy per gram, absorbed by any material from any type of ionizing radiation.

1.3 Rem

By this time it had also been established that radiation effects depended not only upon the number of ions being formed, but also upon their distribution within living tissue. Dense trails of ions cause more damage than the same number of ions spread widely apart. Thus, the specific ionization (ions per unit distance) must be taken into consideration. X and gamma radiation and beta particles tend to produce ions spread relatively far apart, while alpha particles and neutrons tend to cause dense trails of ions. The x-ray, beta, and gamma radiation is referred to as low Linear Energy Transfer (low LET) radiation, while alpha particles and neutrons are called high LET radiation. One explanation for the difference in effect between high and low LET radiation is that the cells within a living organism can repair small amounts of damage caused by radiation. However, if there is too much damage within one cell, the repair mechanism may be overwhelmed and the cell may die or be irreparably damaged.

To correct for differences in LET the Quality Factor (QF) was invented. Radiation with higher LET is given a higher Quality Factor. The rad (unit of absorbed dose) is multiplied by the Quality Factor to obtain the rem.

The rem is a unit of damage to a biological system. It is equivalent to the damage done by exposure to one roentgen of 250 keV x-radiation and is called the equivalent dose. Effects from any type of ionizing radiation may be compared using the rem.

We now have the:

- roentgen - **exposure dose** based on ionization in air
- rad - **absorbed dose** based on absorption of energy
- rem - **equivalent dose** based on biological effects

1.4 Quality Factors

For x-rays of 250 KeV, the roentgen, rad and rem are approximately equal. For practical purposes it is usually assumed that all x and gamma radiation from about 100 KeV to 3 MeV have a quality factor of 1 and that the roentgen, rad, and rem are equivalent in this range.

Below are some examples of Quality Factors for different types of radiation.

Radiation

Q. F.



x-ray	1
gamma ray	1
beta particle	1
alpha particle	20
slow neutron	2.5
fast neutron	20
heavy ions	20

1.5 International Units

It should be mentioned here that there are also international (SI) units of dose. Applied health physicists in general feel that these new units are unnecessary and will cause much confusion, especially in record keeping. The new units have not, at this time, been widely accepted for use in the United States. While we will continue to use the roentgen, the rad, and the rem, the following conversions can be made if desired:

$$\begin{aligned} \text{Gray} &= 100 \text{ rad} \\ \text{Sievert} &= 100 \text{ rem} \end{aligned}$$

2.0 EFFECTS OF RADIATION EXPOSURE

2.1 Acute Exposure Effects

Radiation in large doses causes observable damage. The following list gives some typical effects of radiation exposure by X or gamma rays given to the total body at a high dose rate over a short period of time.

0 - 25 rem	-	No observable effects on the health of the individual. At 25 rem, a physician could probably see some changes in blood cells.
50-100 rem	-	Possible nausea and blood count depression. Recovery within days to weeks with no lasting ill effects.
500 rem	-	Nausea, weakness, anemia, internal bleeding, temporary sterility, susceptibility to infection, loss of hair. This is the LD ⁵⁰⁻³⁰ . Half of the persons so exposed die within 30 days (without medical treatment). The other 50% recover with few lasting ill effects. Recovery takes months to years. Death is usually due to damage to the blood-forming stem cells in bone marrow.
1000 rem	-	Death within days to weeks, usually from damage to the gastrointestinal system.
10,000 rem	-	Death within hours to days from damage to the nervous system.
100,000 rem	-	Essentially instantaneous death from damage to the nervous system.



The above effects are observable within a short time after the exposure. They have been observed in persons exposed before the harmful effects of radiation were known, in persons exposed for medical treatment, in the watch dial painters, the atomic bomb survivors and a few persons suffering accidental occupational overexposures.

In addition to the effects listed above, persons who are exposed to large amounts of radiation and recover have an increased incidence of some types of cancer, leukemia being the most readily observed. For the atomic bomb survivors who received 200 rem or more of gamma radiation, the incidence of cancer was approximately doubled over the following 25 years.

2.2 Genetic Effects

There is also the possibility of increased genetic damage in persons who recover from high doses. This is theoretically possible and has been observed in lower animals. However, there has been no observable increase in genetic defects among the atomic bomb survivors. Genetic effects have not been observed in humans.

2.3 Chronic Exposure Effects

The effects from radiation exposure decrease as the dose rate is lowered. Spreading the dose over a longer period reduces the effects. Much of the controversy over radiation exposure centers on the question of how much damage is done by radiation delivered at low doses or low dose rates. It has been assumed that one could predict the maximum amount of damage that might be expected from low doses of radiation by extrapolating from the effects at high doses. Some persons have claimed that there is no damage at very low doses. This is called the threshold model. Since cancers caused by radiation do not generally appear until years after the exposure and are of the same types as naturally occurring cancers, it has been impossible to show any effects for exposure below about 100 rem. While there may be some increase in cancer from exposures below 100 rem, the number is too small to measure statistically.

It has been popular to assume that the straight line model is fact and that the number of cancers depends strictly upon the number of person-rem of exposure to the population. If 10,000 persons are exposed to 100 rem each:

$$\begin{aligned} \text{persons} \times \text{rem} &= \text{person-rem} \\ 10,000 \times 100 &= 1,000,000 \end{aligned}$$

Using this formula and data from persons exposed to high doses (such as the atomic bomb survivors) the report of the National Academy of Sciences Committee on the Biological Effects of Ionizing Radiation (BEIR Report) predicts that there will be approximately 200-400 fatal cancers for each 1,000,000 person-rem of exposure. This estimate has varied from 100 to 400 over the years, as new estimates were made based on revised data. The estimate is probably reasonably accurate for exposures above 50 rem. The value may even be zero for individual exposures much below 50 rem. One may take the straight-line model and apply it to low-level radiation exposure. For instance:

$$\begin{aligned} \text{persons} \times \text{rem} &= \text{person-rem} \\ 1,000,000,000 \times 0.001 &= 1,000,000 \end{aligned}$$



This implies that one billion persons exposed to one-thousandth of a rem each (one millirem) would develop 200-400 fatal cancers. Since 400 cancers among one billion persons would be impossible to detect among the millions of cancers naturally occurring, it has been impossible to prove or disprove the straight-line model for low-level radiation. However, some persons have pointed out that if the straight-line model were correct for low-level radiation, background radiation would cause more cancers than those which are actually observed. A few persons have claimed that low-level radiation causes up to 10 times the number of cancers predicted by the straight-line model. However, in view of the above observation concerning background radiation, little credence is given to these claims by most scientists.

In Report No. 64 issued in April 1980, the NCRP set forth evidence indicating that the straight-line model overestimates the effects of low-level radiation. According to this report, the response to radiation exposure by biological systems follows a curve composed of at least two parts: a linear component due to low-level radiation and a quadratic component due to high dose and high dose rate. The curve is described by the formula:

$$I = \alpha D + \beta D^2$$

I is the effectiveness per unit dose.

D is the total dose given.

α and β are constants which depend upon the particular effect being studied and experimental conditions.

The NCRP estimated that the straight-line model overestimates the effects of low-dose radiation by a factor of 2 to 10. This is called the Dose Rate Effectiveness Factor (DREF). The DREF may vary somewhat with the particular effect being studied. The most accurate data were obtained from plants and lower animals, but the same type of curves are presumed to apply to human beings. The above applies to low LET radiations. High LET radiations appear to follow the straight-line curve. Most occupational exposure is low LET radiation.

3.0 ESTABLISHED DOSE LIMITS

3.1 Occupational Exposure

Exposure to ionizing radiation through occupational exposure is limited by law to 5 rem per year. In accordance with the observation that the effects are less if the dose is spread over a longer period, the dose should be spread out as much as possible.

3.2 Medical Exposure

There is no limit to medical exposure. The medical doctor should ensure that no patient is exposed to more radiation than is necessary to achieve the required medical diagnosis or treatment. Medical x-rays may be considered as part of the background exposure and cause an average of about 50 to 100 millirem each year to persons in the U.S.

3.3 Background Exposure

Natural background gives one good reference which can be used in setting radiation limits. Human beings have been exposed to background radiation since the origins of mankind and it can probably be



assumed that this amount is not very harmful. It may even be beneficial. Increased average lifespans have been observed in rats exposed to 100 millirads per day of x-radiation. In fact, some minimum level of background radiation may be essential to life on earth.

A typical background exposure might be as follows:

<u>Radiation</u>	<u>Millirem/Year</u>
Cosmic	40
Terrestrial	60
Potassium-40	20
Other	5
Total	125

Background radiation varies with location. Cosmic radiation increases with altitude, and terrestrial radiation varies with the types and quantities of minerals in the soil. Background in the United States may vary from approximately 90 millirem per year to more than 250 millirem per year. In some areas of Brazil and India, background may reach 3,000 millirem (3 rem) per year because of radioactive minerals in the soil. It has been impossible to show any ill effects, such as increase in cancer rate, among persons who live in these areas of high natural radioactivity. Therefore, it is believed that the exposure of a few people to occupational exposures of 5 rem per year is unlikely to cause any significant effects. The limit set for the general population is 100 millirem per year in addition to background.

3.4 As Low As Reasonably Achievable

In addition to the specific limits set above, U.S. law requires that no one be unnecessarily exposed to ionizing radiation. Exposure must be kept As Low As Reasonably Achievable (ALARA) in order to minimize any possible ill effects.

4.0 RISKS OF IONIZING RADIATION

4.1 Risk Comparison

Since many persons are particularly fearful of radiation, it may be helpful to compare the risk from radiation exposure to some other risks encountered in everyday life. Based on the straight-line model, a worker exposed to 1,000 millirem (one rem) per year for 30 years would lose about 30 days of life expectancy due to increased risk of cancer. This is comparable to other "safe" jobs. For comparison, the loss of life expectancy for some other risks is given below.

<u>Job or Other Risk</u>	<u>Days of Life Expectancy Lost</u>
Manufacturing	43
Agriculture	277
Construction	302
Coal Mining	1100
Being 30% overweight	1300
Being President of the U.S.	1861
Being an average male smoker	2153



To put it another way, statistically the risk from one millirem of exposure is approximately equal to the risk from taking one puff on a cigarette or driving a car 0.15 miles on the highway. Many persons do not approach radiation risk rationally. Some tend to ignore the risk because they cannot see any immediate ill effects. Others have an irrational fear of radiation entirely out of proportion to the actual risk (Radiophobia).

It should be noted that no ill effects have ever been observed in persons whose exposure remained within the limits recommended by the NCRP, and incorporated into current government regulations and University policy.

4.2 What levels of Radiation are dangerous?

1000 rem

- Fatal to all exposed persons if received as total body exposure over a short period.
- Terminal case of radiation syndrome.

500 rem

- Fatal to approximately one-half the exposed persons if received as total-body exposure over a short period.
- Severe case of radiation syndrome.
- Increased risk of cancer in survivors.

100 rem

- Smallest dose that can definitely be shown to cause ill effects to adults.
- May cause mild symptoms of radiation syndrome.
- Slightly increased risk of cancer.

25 rem

- Smallest dose that will cause effects that can be detected by a physician.
- No readily detectable signs of illness.
- No long-range ill effects can be demonstrated.

5 rem (5000 mrem)

- Limit for one year of occupational exposure.
- Not expected to cause any ill effects over a lifetime.
- Epidemiological studies cannot detect any harmful effects at this level.

3 rem (3000 mrem)

- Maximum received in one year by the general population from natural radiation in the most radioactive areas of earth.
- No demonstrated ill effects.



1 rem (1000 mrem)

- Effective dose equivalent from living for one year in a house with 4 picocuries per liter of radon in the air (the EPA limit).
- This value may vary considerably depending upon assumptions made in the calculations.
- No demonstrated ill effects.

0.3 rem (300 mrem)

- Approximate effective dose equivalent from living in a house with 1 picocurie per liter of radon in the air.
- May be near the average for U.S. homes.
- No demonstrated ill effects.

0.125 rem (125 mrem)

- Average dose received in one year from background radiation (not including radon) in Athens, Ga.
- No demonstrated ill effects.

0.1 rem (100 mrem)

- Annual limit for non-occupational exposure (general public).
- Dose received each year by the average person from medical x-rays.
- Approximate dose received from background (excluding radon).
- No demonstrated ill effects.

4.3 Additional Information

For additional information on the risks associated with radiation exposure you should read the U.S. Nuclear Regulatory Commission (NRC) document entitled *Regulatory Guide 8.29, Instruction Concerning Risks from Occupational Radiation Exposure*.



1.0. ALARA POLICY

It is the policy of Middle Tennessee State University that exposure to ionizing radiation will be as low as reasonably achievable, consistent with the teaching, research, and service missions of the institution.

2.0 MONITORING OF EXTERNAL RADIATION EXPOSURE

Each radiation worker at Middle Tennessee State University with the potential to exceed 10% of any annual exposure limit due to external radiation detectable by industry standard dosimetry will have that exposure monitored by the use of personnel dosimetry.

3.0 RADIATION EXPOSURE ALARA ACTION LEVELS

3.1 The radiation exposure ALARA Action Level 1, as described in Table 3.0, will apply to all MTSU radiation workers, except as specified in section 3.2 (below).

3.2 Personnel in the Department of Anatomy and Radiology at the College of Veterinary Medicine and the Veterinary Teaching Hospital, and any other exposure groups approved by the RSC, will use the ALARA Action Level 2 as described in Table 3.0.

**Table 3.0
Radiation Exposure ALARA Action Levels**

Exposure Measurement	ALARA Action Level 1 mrem/calendar quarter	ALARA Action Level 2 mrem/calendar quarter
Total Effective Dose Equivalent (TEDE)	125	375
The sum of the deep dose equivalent and the committed dose equivalent to any individual organ or tissue other than the lens of the eye	1875	5625
Shallow Dose Equivalent (SDE) to the skin or any Monitored Extremity (SDEME)	1875	5625
Lens of the eye Dose Equivalent (LDE)	750	2250

3.3 If any individual exceeds an ALARA action level, Radiation Safety will report the exposure to the appropriate Authorized User and the Radiation Safety Committee.



- 1) The Authorized User, with assistance from Radiation Safety, will be responsible for performing an investigation of the radiation exposure.
- 2) A written summary of the investigation results, including potential corrective actions, should be provided to the Radiation Safety Committee.
- 3) Persons who turn in two consecutive monitoring badges that are over the ALARA action level will be individually counseled by a member of the Radiation Safety staff.
 - The person will be informed of the risk from radiation exposure.
 - The reason for the exposure will be determined, if possible.
 - Changes in work habits, procedures, and equipment will be recommended as appropriate.

4.0 INTERNAL EXPOSURE MONITORING AND ACTION LEVELS

4.1 Radioactive Iodine Monitoring and Action Levels

- 1) Individuals should receive a thyroid bioassay after completion of operations involving, at any one time, direct handling or use of unsealed radioiodine in individual quantities in excess of the quantities specified in Table 4.1.
- 2) Persons routinely working with individual quantities of radioiodine in excess of these amounts should have monthly bioassays.
- 3) Scheduling of routine bioassays is the responsibility of the individual radiation worker.

Table 4.1
Radioiodine Bioassay Requirements

Type of Operation or Procedure Conducted	Quantity Requiring a Bioassay	
	volatile form*	bound to non-volatile agent*
Operations performed in an open room or bench.	>0.1 mCi	>1 mCi
Operations performed in a fume hood.	>1 mCi	>10 mCi

*Volatile forms include, but are not limited to, unlabeled sodium iodide (NaI) or operations involving acids or chlorine. Non-volatile forms are those that are chemically bound and used in such a manner that the radioiodine will remain nonvolatile and are diluted to concentrations less than 0.1 mCi/mg of non-volatile agent. Radioimmunoassay (RIA) kits are considered non-volatile.

- 4) If historical data indicates that exposures are consistently minimal and personnel/procedures are uniform in nature, the RSO may reduce the frequency of routine thyroid bioassays to a quarterly, bi-annual, or annual schedule.
- 5) The optimum schedule for a thyroid bioassay is within the time period of 8 to 72 hours of exposure. No more than a two week delay is considered acceptable.



- 6) Persons with internal radioiodine exposures in excess of 10% of the applicable limit will be counseled by a Radiation Safety staff member.
- 7) The Authorized User and Radiation Safety will evaluate the probable causes of the exposure and changes in procedures, work habits, or equipment will be recommended as appropriate.
- 8) A written summary of the investigation results, including potential corrective actions, should be provided to the Radiation Safety Committee.

4.2 Tritium Monitoring and Action Levels

- 1) Individuals involved in operations which utilize, at any one time, more than 100 millicuries of tritium in a non-contained form, other than metallic foil, shall have a bioassay performed within one week following a single operation, and at weekly intervals for continuing operations.
 - Tritium shall not be used in such a manner as to cause any individual to receive a radiation exposure such that urinary excretion rates exceed 28 microcuries of tritium per liter when averaged over a calendar quarter.
 - If the average concentration of tritium in urine for an individual during a calendar quarter is less than 10 microcuries per liter, urinalysis may be performed on that individual at monthly intervals for the following calendar quarter and may continue at monthly intervals so long as the average concentration in a calendar quarter remains below 10 microcuries per liter.
 - The urine specimen should be collected on the same day of the week, whenever practical.
 - Scheduling of routine bioassays is the responsibility of the individual radiation worker.
- 2) Persons with more than 10% of the applicable limit for internal exposure of tritium will be counseled by a Radiation Safety staff member.
- 3) The Authorized User and Radiation Safety will evaluate the probable causes of the exposure and changes in procedures, work habits, or equipment will be recommended as appropriate.
- 4) A written summary of the investigation results, including potential corrective actions, should be provided to the Radiation Safety Committee.

4.3 Non-routine Bioassay Requirements

- 1) If ingestion, inhalation, or absorption of any radioactive material is suspected, a bioassay or dose calculation will be performed by the RSO or designee.
- 2) Any individual, whose internal exposure exceeds 10% of the applicable limit for the radioisotope, or sum of the radioisotopes, will be counseled by a Radiation Safety staff member.



- 3) The Authorized User and Radiation Safety will evaluate the probable causes of the exposure and changes in procedures, work habits or equipment will be recommended as appropriate.
- 4) A written summary of the investigation results, including potential corrective actions, should be provided to the Radiation Safety Committee.

4.4 Airborne Radioactivity Exposure

Any intentional exposure of individuals to airborne radioactive materials or conduct of a project which will require the use of radiological respiratory protective equipment is highly restricted. Such actions will require the development of procedures, plans, and/or protocols for the proposed activity by the Authorized User and Radiation Safety. A complete review and approval of the proposed project and associated documentation by the Radiation Safety Committee will be required prior to the initiation of any such activity.

5.0 PERSONNEL EXPOSURE LIMITS

5.1 Occupationally Exposed Adults

The occupational dose to individual adults (radiation workers) shall not exceed the following annual dose limits:

- 1) A total effective dose equivalent (TEDE) of 5 rem; or,
- 2) The sum of the deep-dose equivalent and the committed dose equivalent to any individual organ or tissue, other than the lens of the eye, being equal to 50 rem.
- 3) A dose equivalent of 15 rem to the lens of the eye.
- 4) A shallow-dose equivalent of 50 rem to the skin or any extremity.

5.2 Planned Special Exposures

In keeping with the research and teaching missions of Middle Tennessee State University, use of the Planned Special Exposure as defined in Rule .03(5)(e)6.(i) of Chapter 391-3-17 *Rules and Regulations for Radioactive Materials* shall not be authorized.

5.3 Occupationally Exposed Minors

The annual dose limits for occupationally exposed minors (any individual less than 18 years of age) shall not exceed 10 percent of the annual dose limits specified above for adult workers.

5.4 Occupational Exposure to Pregnant Women

The U.S. Nuclear Regulatory Commission's Regulatory Guide 8.13 and its Appendix are required reading for all MTSU radiation workers, including all Authorized Users. Obviously, not all radiation workers may become pregnant. However, any radiation worker may have the opportunity to work with a radiation worker who is, or has the potential to, become pregnant. Authorized Users or Advanced Radworker personnel may be required to supervise the activities of occupationally exposed pregnant women.



Therefore, all radiation workers should be instructed in regard to the hazards of radiation exposure to unborn children. In addition to Regulatory Guide 8.13, the following MTSU policies apply:

- 1) A pregnant radiation worker must make her own decision regarding whether or not to declare her pregnancy in accordance with Regulatory Guide 8.13.
- 2) The declaration of pregnancy must be submitted in writing to the appropriate Authorized User (or work group supervisor) and to Radiation Safety.
- 3) Once pregnancy is declared in writing, the declaration will remain in effect for a period of one year from the date of submission, unless it is revoked in writing.
- 4) The radiation exposure to the embryo/fetus of a declared pregnant woman shall not exceed 500 mrem during the entire term of the pregnancy.
- 5) The radiation exposure to the embryo/fetus of a declared pregnant woman should not exceed an ALARA action level of 50 mrem per month. Any monthly exposure in excess of this value will be evaluated by Radiation Safety and the responsible Authorized User (or supervisor). When appropriate, corrective actions will be taken to prevent future monthly exposures from exceeding this ALARA action level.
- 6) If a pregnant woman has already received ≥ 450 mrem during the term of pregnancy by the time she declares, the limit for the remainder of the entire term of declared pregnancy shall be 50 mrem.
- 7) If a declared pregnant woman has already received a radiation exposure of < 450 mrem by the time she declares, the monthly ALARA action level may be reduced by the RSO to a level that will ensure that the dose to the embryo/fetus will not exceed 500 mrem for the term of the pregnancy.
- 8) Exposure to the embryo/fetus of a declared pregnant woman shall be maintained as low as reasonably achievable, consistent with the right-to-work prerogative of the employee and/or student.

5.5 Exposure to Members of the Public

The total effective dose equivalent to individual members of the public due to MTSU licensed radioactive material or radiation producing devices, will not exceed 100 mrem in a year exclusive of the dose contribution from background, medical treatments, or radioactive material disposed of via sanitary sewerage performed in accordance with state and federal regulations



1.0 PURPOSE AND SCOPE

The purpose of this chapter is to describe the criteria for radiological use facilities and equipment in all areas controlled under Middle Tennessee State University's radioactive materials license. This chapter provides guidance to the Radiation Safety Committee, Radiation Safety staff, and to prospective and Authorized Users in evaluating the adequacy of radiological use facilities and equipment.

2.0 PRECAUTIONS

Proper facilities and equipment are an essential component of a good radiation safety program. Facilities and equipment that are inadequate or are improperly used or maintained may cause unsafe conditions with the potential to result in excessive personnel exposure or a loss of radiological controls.

3.0 LABORATORY CLASSIFICATION SCHEME

Middle Tennessee State University laboratory facilities shall be evaluated for suitability for use with unsealed radioactive materials in accordance with the guidelines of the following classification scheme. In the event that a deviation from this classification scheme is approved by the RSC, appropriate documented justification will be maintained. This classification scheme is referenced in *NUREG-1556, Vol. 11, Consolidated Guidance about Materials Licenses: Program-Specific Guidance about Licenses of Broad Scope*. Additional information about laboratory classifications is referenced from *The Health Physics and Radiological Health Handbook, Revised Edition, 1992*.

- 1) Table 3.1 describes the relative radiotoxicity of various radionuclides.
- 2) Table 3.2 describes the laboratory classification scheme. Basic chemical laboratories are considered class C. Class B is a specifically designed radioisotope laboratory. The class B designation includes a certified fume hood, appropriate radiological waste containers, dedicated radioactive material storage enclosures, and washing facilities suitable for decontamination use. As described in *Appendix K of NUREG 1556*, "In the case of a conventional modern chemical laboratory with adequate ventilation and non-porous work surfaces, it may be possible to increase the upper limits of activity for type C laboratories toward the limits for type B for toxicity groups 3 and 4."
- 3) The criteria describing the modifying factors as listed in Table 3.3 is also used in the consideration of appropriate facilities for radioisotope use. Modifying factors take into consideration the type of operations performed or planned.

Table 3.1
Radiotoxicity Table of Representative Radioisotopes

**Radiotoxicity
Group**

Radioisotopes



Very High (group 1)	Pb-210, Po-210, Ra-223, Ra-226, Ra-228, Ac-227, Th-227, Th-228, Th-230, Pa-231, U-230, U-232, U-233, U-234, Np-237, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Am-241, Am-243, Cm-242, Cm-243, Cm-244, Cm-245, Cm-246, Cf-249, Cf-250, Cf-252
High (group 2)	Na-22, Cl-36, Ca-45, Sc-46, Mn-54, Co-56, Co-60, Sr-89, Sr-90, Y-91, Zr-95, Ru-106, Ag-110m, Cd-115m, In-114m, Sb-124, Sb-125, Te-127m, Te-129m, I-124, I-125, I-126, I-131, Cs-134, Cs-137, Ba-140, Ce-144, Eu-152, Eu-154, Tb-160, Tm-170, Hf-181, Ta-182, Ir-192, Tl-204, Bi-207, Bi-210, At-211, Pb-212, Ra-224, Ac-228, Pa-230, Th-234, U-236, Bk-249
Moderate (group 3)	Be-7, C-14, F-18, Na-24, C1-38, Si-31, P-32, P-33, S-35, Ar-41, K-42, K-43, Ca-47, Sc-47, Sc-48, V-48, Cr-51, Mn-52, Mn-56, Fe-52, Fe-55, Fe-59, Co-57, Co-58, Ni-63, Ni-65, Cu-64, Zn-65, Zn-69m, Ga-72, As-73, As-74, As-76, As-77, Se-75, Br-82, Kr-85m, Kr-87, Rb-86, Sr-85, Sr-91, Y-90, Y-92, Y-93, Zr-97, Nb-93m, Nb-95, Mo-99, Tc-96, Tc-97m, Tc-97, Tc-99, Ru-97, Ru-103, Ru-105, Rh-105, Pd-103, Pd-109, Ag-105, Ag-111, Cd-109, Cd-115, In-115m, Sn-113, Sn-125, Sb-122, Te-125m, Te-127, Te-129, Te-131m, Te-132, I-130, I-132, I-133, I-134, I-135, Xe-135, Cs-131, Cs-136, Ba-131, La-140, Ce-141, Ce-143, Pr-142, Pr-143, Nd-147, Nd-149, Pm-147, Pm-149, Sm-151, Sm-153, Eu-152, Eu-155, Gd-153, Gd-159, Dy-165, Dy-166, Ho-166, Er-169, Er-171 (9.2 hr), Tm-171, Yb-175, Lu-177, W-181, W-185, W-187, Re-183, Re-186, Re-188, Os-185, Os-191, Os-193, Ir-190, Ir-194, Pt-191, Pt-193, Pt-197, Au-196, Au-198, Au-199, Hg-197, Hg-197m, Hg-203, Tl-200, Tl-201, Tl-202, Pb-203, Bi-206, Bi-212, Rn-220, Rn-222, Th-231, Pa-233, Np-239
Low (group 4)	H-3, O-15, Ar-37, Co-58m, Ni-59, Zn-69, Ge-71, Kr-85, Sr-85m, Rb-87, Y-91m, Zr-93, Nb-97, Tc-96m Tc-99m, Rh-103m, In-113m, I-129, Xe-131m, Xe-133, Cs-134m, Cs-135, Sm-147, Re-187, Os-191m, Pt-193m, Pt-197m, Th-232, Th-Nat, U-235, U-238, U-Nat

Table 3.2
Laboratory Classification Scheme

Radiotoxicity Group	Class C Laboratory Quantity	Class B Laboratory Quantity
Very High	< 10 μ Ci	10 μ Ci to 10 mCi
High	< 100 μ Ci	100 μ Ci to 100 mCi
Moderate	< 1 mCi	1 mCi to 1 Ci
Low	< 10 mCi	10 mCi to 10 Ci

Table 3.3
Modifying Factors

Operation Description	Modifying Factor
Storage (stock solutions)	X 100
Simple wet operations	X 10
Normal operations	X 1
Complex wet operations with risk of spills and simple dry operations	X 0.1



4.0 FUME HOOD CRITERIA

Chemical type fume hoods provide a working area with a controlled inward airflow from the room to the hood exhaust system. Hoods should be used for gases, for unsealed volatile radioisotopes, and for processes such as evaporation that may release gases and vapors. Fume hoods provide emergency ventilation and exhaust for accidental spills, as well as routine exhaust of effluents. The criteria for radiological use of fume hoods is provided below.

- 1) Up to 1 millicurie of non-volatile*, non-dust generating, not highly toxic radioisotopes may be used without a fume hood, if the materials and protocols are deemed acceptable by the RSC.
- 2) Up to 10 millicuries may be approved for use in a standard fume hood, if the materials and protocols are deemed acceptable by the RSC.
- 3) Up to 50 millicuries may be approved for use in a radioisotope fume hood with stainless steel lining and HEPA filtration, if the materials and protocols are deemed acceptable by the RSC.

***Note:** Volatile radioisotopes include, but are not limited to, the following: H-3 as tritiated water, NaBH₄, or acetic anhydride; C-14 as carbon dioxide gas; S-35 as cysteine or methionine compounds, I-125 or I-131 as unlabeled NaI or if combined with chlorine or in an acidic solution.

5.0 PORTABLE SURVEY INSTRUMENT REQUIREMENTS

- A radiological use laboratory must have a portable survey instrument suitable for detecting the radiation produced by the radioactive materials to be used. A borrowed instrument is only acceptable as a backup.
- This requirement does not apply to laboratories using exclusively H-3 or in other limited use situations that may be approved by Radiation Safety on a case by case basis.
- A suitable instrument typically has a thin window detector, calibration adjustment mechanism, and a display in units of millirem per hour. Instruments that display results exclusively in counts per minute are suitable for contamination (not radiation) monitoring only.
- Instruments must be calibrated on an annual basis. Calibration of portable radiation monitoring instruments is provided by the Radiation Safety staff.

6.0 COUNTING INSTRUMENTATION REQUIREMENTS

- A counting instrument suitable for determining the quantity of radioactive material present in a given sample media must be available to all Authorized Users of unsealed radioactive materials.
- A shared counter is considered appropriate, but the room where the counter is located should be listed on each user's radioactive materials permit, unless otherwise approved by the RSO.



- A liquid scintillation counter is recommended for use with isotopes that primarily emit beta radiation.
- Other counters such as gas proportional counters, gamma well counters, etc. may be more suitable for counting specific isotopes, such as low energy gamma emitters.
- Counting instruments should only be used in accordance with the manufacturers design criteria.
- Instrument performance checks including the measurement of radioactive standards should be conducted at a frequency adequate to ensure proper operation of counting instrumentation.

7.0 RADIATION SHIELDING AND DOSE RATE EVALUATIONS

- Radiation shielding in the form of bricks, panels, storage containers, and other shapes should be used when appropriate to keep exposure rates ALARA.
- Plexiglas, Lucite, or other high-density plastic shielding is recommended when using milliCi quantities of P-32.
- Lead shielding is recommended for use with milliCi quantities of I-125/131, or with other gamma emitting isotopes with potential exposure rates of ≥ 1 mrem/hr @ 1 foot.
- Shielded shipping containers should be used for storage of radioactive materials after receipt, unless other containers having equivalent or better shielding is used.
- Radioactive materials that have the potential to generate significant dose rates, especially in the form of sealed source irradiators, should be evaluated by dose rate calculations in addition to any vendor supplied data. Formulas for use in dose rate calculations are available in Chapter 10, *Laboratory Procedures*.
- Upon initial setup of a sealed source irradiation device that has the potential to generate a dose rate in excess of 5 mrem/hr @ 30 cm, surveys by the Radiation Safety staff should be used to establish operational parameters and verify dose rates for restricted and unrestricted areas.

8.0 GENERAL CONSIDERATIONS

- Bench top or open work areas may be used for handling small quantities of solid materials in a form not likely to become airborne or dispersed, and for small quantities of liquids of such low volatility as not to cause airborne contamination or toxicity problems.
- Trays and/or absorbent surface covers (secondary containment) to catch and retain spilled liquids should be used in all appropriate radioisotope work locations.
- Radioactive materials that are handled or used in unsealed forms should be confined to control the release of materials and to prevent the spread of contamination. Gaseous, volatile, and fine particulate solid materials should be handled in fume hoods as described in section 4.0 of this procedure.
- Sinks used for sewer disposal of radioisotopes must be properly monitored and maintained. Prior to maintenance or repair of discharge plumbing, the piping should be flushed with water and surveyed for the presence of radioactivity.
- Containers for radioactive waste should be placed near the waste-generating areas and away from frequently occupied areas, when practical. Secondary containment should be used for



liquid waste containers. Waste containers should be shielded as needed to keep dose rates ALARA.

- Radioactive materials security devices must be adequate to prevent unauthorized access and should be commensurate with the relative hazard of the radioisotopes involved (i.e. large quantity sources may require additional security).
- A physical barrier is required between radioactive material areas and areas used for eating, drinking, food storage, etc. There should be walls and doors separating these areas.
- Proper lighting, good housekeeping, and appropriate laboratory safety equipment must be maintained.
- Additional information about personnel protective equipment (PPE), personnel dosimetry, and safe work practices are discussed in Chapter 10, *Laboratory Procedures*.



1.0 PURPOSE AND SCOPE

The purpose of this chapter is to assist the Authorized User (AU) in properly setting up a laboratory for the use of unsealed radioactive materials. This guide is intended to be used in the initial setup of a laboratory and is also a useful reference for existing facilities or for persons relocating their laboratories.

1.1 Precautions and Limitations

Prospective users should plan their setup procedures but may not want to begin procurement of materials (i.e. waste containers) until they have been notified that their radioactive materials use has been approved by the Radiation Safety Committee. Prior to setting up a laboratory for radioisotope use ensure that all general lab safety equipment is in place and suitable for use. The lab safety representatives of the Environmental Health Safety Services should be consulted for specific requirements. Some recommendations of this guide are mandated by regulatory requirements established by state or federal agencies and are described in the MTSU Radiation Safety Manual. The information in this guide should be used as a supplement and not a replacement to those regulations and documents.

1.2 Instructions for the Use of this Guide

This guide is provided primarily as a tool for your use. For new Authorized Users, access to procurement of radioactive materials will not be granted until the required laboratory setup has been verified as complete by the Radiation Safety staff.

Contact Information for the MTSU Radiation Safety Staff

Name, Primary Responsibilities, E-mail Address, Telephone Number

Mark Hatcher
Radiation Safety Officer
mark.hatcher@mtsu.edu
615-898-5831

Alan Parker
Director
Environmental Health and Safety Services
alan.parker@mtsu.edu
615-898-2392

1.3 Planning

- Plan your radiological work in relation to the layout of the laboratory.



- Consider the locations of storage freezers, fume hoods, work benches, sinks, counting equipment, waste receptacles, etc. When practical, it is better to keep your radiological use components in close proximity to each other to reduce the likelihood of spreading contamination. The exception to this is to allow an appropriate distance between personnel and sources of radiation likely to result in personnel exposure. If you want to relocate any large equipment, it is generally easier to do so before you begin radiological work than after.
- If your planned use of radioactive materials is anticipated to produce radiation levels of > 0.05 mrem/hr at 30 cm (1 foot) from the source, consider the potential impact on nearby non-radiological use areas. Radiation sources placed against the exterior walls of your laboratory could result in unacceptable radiation levels in adjacent rooms.
- A physical barrier is required between radioactive material areas and areas used for eating, drinking, food storage, etc. There should be walls and doors separating these areas.
- Look under sinks for evidence of water leaks; it is better to have them fixed now than to find leaks after you begin use of radioisotopes.
- Verify that laboratory equipment planned for use with radioactive materials is properly functioning (centrifuge, freezers, incubators, etc.) prior to radiological use.
- It is recommended that a radiation survey be performed in the laboratory prior to the start of radioisotope use. To perform this task, slowly walk through the laboratory taking radiation readings with a portable survey instrument and record the results.
- These readings indicate the background radiation levels for your location. The average background levels on the Athens campus vary, but are generally < 0.02 mr/hr. Levels in excess of 0.05 mr/hr should be investigated.

1.4 Radioactive Materials Security

Federal and state regulations require that radioactive material be kept secure from unauthorized use. To facilitate this, MTSU requires that radioactive materials laboratories be locked, or that radioactive materials within laboratories be kept in locked enclosures, or that the lab be continuously occupied by individuals with training in radiation safety that are willing to challenge other personnel who might be attempting unauthorized access. As a part of laboratory setup, you should:

- Ensure that locks are properly working and keys are available for appropriate Radiation Workers to laboratory doors.
- Provide for additional locking devices on storage cabinets, freezers, waste containers, and the like as needed to control access.

1.5 Protective Coverings and Secondary Containment

- Areas with the potential for becoming contaminated should be evaluated before applying protective coverings. The first step is to ensure, whenever practical, that underlying surfaces are made of non-porous materials.
- Consider the use of trays or bins which can catch small spills and are easily decontaminated.



- Remember that radioisotope work areas are not the only sources of contamination. Consider where you will store lab equipment used with radioisotopes, such as glassware and other small items. If these items are stored in drawers or cabinets, use removable trays or coverings to protect underlying surfaces from contamination.
- Apply protective coverings which have an absorbent work surface and waterproof backing when appropriate. However, excessive use of such materials can contribute to unnecessary generation of radioactive waste.
- Use secondary containment devices for any bulk storage of liquid radioisotopes. This should include the use of trays or bins under your liquid waste carboys to contain spills or leakage.

1.6 Fume Hoods

- The use of an approved fume hood is required for any activity likely to generate dust, fumes, or vapors containing radioactive materials.
- Fume hoods should be used when working with volatile radioactive materials, and when initially opening vials containing millicuries quantities of radioisotopes.
- Fume hoods are checked on an annual basis by the lab safety staff of the Environmental Health and Safety Services. If your fume hood does not have a current certification label, contact EHS at 615-494-7725 to have it checked.

1.7 Spill Kits

- All radioisotope use locations should have a spill kit appropriate for the intended use, such as the “Attack Pak” brand name spill kit.
- Spill kit locations should be easily accessible and not blocked by other items.
- When training laboratory workers, remember to inform them of the locations of spill kits and how to use the equipment.
- Spill kits can also be prepared from readily available supplies. A spill kit should include absorbent materials (vermiculite, “kitty litter”, sorbent pillows or pads), PPE (gloves), and items to be used in cleanup of the absorbent material (bags, a dustpan or scoop, etc.).

1.8 Personal Protective Equipment (PPE)

- Lab coats and disposable gloves should be procured and available for use. This is considered the minimum acceptable PPE for handling unsealed radioactive materials.
- Eye protection in the form of safety glasses or face shields should be available for use by persons handling unshielded or millicuries quantities of P-32, or when performing operations with the potential for liquid splash.

1.9 Radiation Shielding

- Plexiglas or Lucite shielding is recommended for laboratories using milliCi quantities of P-32. Self-supporting shields and blocks designed to hold glassware are commercially available from



lab safety supply companies.

- Lead shielding is recommended for use with milliCi quantities of I-125/131, or with other gamma emitting isotopes with potential exposure rates of >1 mrem/hr @ 1 foot.
- Spare shielding materials are sometimes available from Radiation Safety; call for details.

1.10 Portable Survey Instruments

- A radiological use laboratory must have a portable survey instrument suitable for the radioactive materials planned to be used. A borrowed instrument is only acceptable as a backup.
- This requirement does not apply to laboratories using exclusively H-3. The exclusive use of I-125 immunoassay kits with <10 microCi per kit is also exempted.
- A suitable instrument typically has a thin window detector, a calibration adjustment mechanism, and a readout in units of millirem. One recommended example of a general purpose instrument suitable for radioisotope laboratory use is the Ludlum Model 3 with 44-9 probe. Information on the Ludlum brand of monitoring instruments is available on their website at <http://www.ludlums.com/>.
- Instruments must be calibrated on an annual basis. Calibration of portable radiation monitoring instruments is a service provided by the Radiation Safety staff.

1.11 Counting Instrumentation

- A liquid scintillation counter is the standard instrument recommended for counting of wipe tests and for liquid analysis for sewer disposal.
- A shared LSC is considered appropriate, but the room where the LSC is located must be listed on your permit.
- Biodegradable scintillation fluids must be used in order to avoid the generation of mixed radioactive waste. One recommended biodegradable scintillation fluid for general purpose counting is Ecoscint from National Diagnostics. The Fisher products Cytoscint and Scintisafe are also good biodegradable LSC fluids.
- Other counters such as gas proportional counters, gamma well counters, etc. may be suitable for wipe test counting and analysis of liquid samples for sewer discharge. If you need additional information about a particular instrument refer to the manufacturer's technical manual or contact the Radiation Safety staff.

1.12 Personnel Dosimetry

- Dosimetry is required for all individuals working with gamma and high energy beta emitting isotopes (P-32, I-125, I-131, Na-22, Tc-99m, Cr-51, etc.) except as noted below.
- Radiation Workers without dosimetry may perform limited tasks approved and supervised by the AU or Advanced Radiation Worker. Individuals without dosimetry shall not be exposed to dose rates >2 mr/hr and should not be allowed to frequent areas with dose rates > 0.2 mr/hr.



These radiation exposure levels are for whole body dose rates as measured at 30 cm (approximately 1 foot) from the radiation source.

- Extremity monitoring (finger rings) is required for all individuals performing operations that involve direct handling of un-shielded containers of individual quantities of >1millicurie of P-32 or other gamma and high energy beta emitting isotopes.
- Dosimetry is not required for personnel working in laboratories permitted only for milliCi quantities of isotopes which emit primarily beta radiation with energies below 250keV (H-3, C-14, S-35, and P-33). The exclusive use of I-125 immunoassay kits with < 10microCi per kit is also exempted.
- Individuals required to have dosimetry must make a request for a dosimetry badge from the Radiation Safety Office. Allow a minimum of two weeks for procurement of dosimetry. Dosimetry is a service provided by Environmental Health and Safety Services.
- Dosimetry may be discontinued for individual workers on a case by case basis if historical data indicates that exposures are consistently minimal. This determination will be made by the radiation safety staff. In most cases a representative individual in the laboratory who performs the majority of the radiological work will continue to be monitored with dosimetry.

1.13 Radioactive Waste Containers for Dry Materials

- The currently approved container for dry, solid radioactive waste is a 30 gallon fiber drum with lid and locking band.
- Alternative containers that may be used include 5 gallon plastic pails with secure screw top lids and 10 to 20 gallon capacity all fiber drums. The all fiber drums are recommended for incinerable H-3/C-14 dry waste. Plastic pails are appropriate for small quantity generators and provide additional shielding for high energy beta emitters such as P-32.
- Separate containers must be provided for each of the following materials:
 1. Short lived radioactive materials (half-life < 120 days)
 2. Long lived radioactive materials (half-life > 120 days)
 3. Mixed radioactive waste (contact the Radiation Safety staff for details)
- Ensure that each waste container has a "Caution, Radioactive Materials" labels on it prior to use. Radiation Safety can provide these labels and a minimum of 2 labels should be put on opposite sides of the container.
- The form "DAW Container Log" should be used to document the contents of each waste container.
- Users of P-32, radioiodine, and other gamma emitters should consider the need for shielding waste drums. Commercially made shield boxes are available through lab safety suppliers.
- A sufficient quantity of radioactive waste containers and liner bags (> 6 mil thickness) should be procured by the AU to allow for the anticipated volume of waste generated. After decay in storage for 10 half-lives, short lived waste containers will be returned to the AU.

1.14 Radioactive Waste Containers for Liquid Waste

- The currently approved container for liquid radioactive waste is a 2.5 gallon polycarboy.



- Separate containers must be provided for each of the following materials:
 1. Short lived radioactive materials (half-life < 120 days)
 2. Long lived radioactive materials (half-life > 120 days)
 3. Mixed radioactive waste (contact Radiation Safety for details)
- Ensure that each waste container has a “Caution, Radioactive Materials” label on it prior to use. Radiation Safety can provide these labels and a minimum of 2 labels should be put on opposite sides of the container.
- The form “Liquid Radioactivity Analysis Form” should be used to determine the activity of each waste container prior to pick up.
- Other forms may be used for analysis of low level liquids for release or for sewer disposal. See the Radiation Safety Manual for details or contact the Radiation Safety staff for assistance.
- Liquid waste carboys should be stored in trays or bins which provide secondary containment for preventing spills.
- A sufficient quantity of liquid radioactive waste containers should be procured by the AU to allow for the anticipated volume of waste generated. After decay in storage and/or sewer disposal by Radiation Safety, liquid waste containers will be returned to the AU.

1.15 Radioactive Material Signs and Labels

- Doors to radioactive material areas must be posted with a radioactive materials sticker on the standard laboratory hazard door sign. In addition the posting “Notice to Employees” is required. The Radiation Safety staff will provide these postings. Other labeling materials should be procured by the AU and are generally available through commercial lab safety suppliers.
- All enclosed containers, freezers, refrigerators, equipment, or cabinets where radioactive materials or contaminated items are used or stored must be labeled with the standard radiation symbol and the words “Caution, Radioactive Material.”
- Radioactive waste containers must be labeled as previously discussed.
- Tape bearing the standard radiation symbol and the words “Caution, Radioactive Material” should be used to post the boundaries of all countertops and similar locations routinely used for radioisotope work.
- Containers of radioisotopes should be marked with the standard radioactive material markings and should additionally be labeled with the isotope, quantity (mCi or microCi), and date.
- Instruments that contain radioactive sources such as GC’s and LSC’s should be labeled with a “Caution, this instrument contains radioactive material” sign or approved equivalent. These instrument labels are available from Radiation Safety.

1.16 Initial Radiation Safety Training

- Any individual that wants to use radioisotopes must receive training by the Radiation Safety Officer
- At least one person in an authorized use laboratory is required to successfully complete Advanced Radworker training. Advanced Radworker training is provided and documented by Radiation Safety. Six months will be allowed for completion of all modules of this training.



1.17 Radiation Safety Records

Records in support of the requirements described in the MTSU Radiation Safety Manual must be maintained in the laboratory. Copies of blank forms are available in the radiation safety section of the ESD website. It is recommended that records be organized in binders for easy access and to facilitate the review process. These records should include:

- Radioactive materials permit application
- Radioactive materials permit
- Radioactive materials permit sign-in sheets
- Radioactive materials permit amendments
- Monthly survey records
- Sewer disposal records
- Radioactive materials inventory sheets
- Summary of isotopes inventory forms
- Copies of radioactive materials forms used to record waste disposal
- Training records



1.0 PROCUREMENT POLICY

The University policy is that all orders for radioactive materials must be placed through the Procurement Office. Direct purchases from suppliers are prohibited, regardless of the amount to be expended. Radioisotope deliveries will be made to Radiation Safety, unless a written exception is granted by the Radiation Safety Committee.

2.0 PRECAUTIONS / PREREQUISITES

- Prior to ordering radioactive materials, Authorized Users must be approved by the RSC for the type and quantity of radioactive materials desired.
- Individuals performing transportation, shipment, or receipt of radioactive materials must have training in the requirements of this procedure and in the proper performance of radiological surveys. Advanced Radiation Worker training and DOT Basic Awareness training or an RSO approved equivalent is considered appropriate.
- Personnel opening radioactive material packages or working with radioactive materials shall wear personnel protective equipment (PPE) and dosimetry as required by this manual.

3.0 ORDERING PROCEDURE

To place an order for radioactive materials, Authorized Users must first be granted access to an electronic database system. This database is maintained by the Radiation Safety staff. After an AU has been approved for radioactive materials use by the RSC, their permit information is set-up in the database system by the Radiation Safety staff. The isotope and quantity limits that have been approved by the RSC are entered in the database. This database serves to control access and to track radioactive materials inventory. In the event of a malfunction of the electronic database system, the RSO may approve the use of an alternate system of inventory verification and tracking.

The following steps may be used to place an order for radioactive materials via the electronic database system.

- 1) The Authorized User or designee will log onto the database and input information in support of the radioactive materials order. If the isotope and quantity requested are within the prescribed limits for the Authorized User, the information is accepted into the system and an authorization tracking number (referred to as a "B number") is issued for the order. An authorization tracking number is a unique identifier for an individual order and is not reusable.
- 2) The Authorized User should prepare and route a purchase request form in accordance with the instructions of the Administrative Policies and Procedures Manual. The authorization number (B number) must be typed as part of the item description on the purchase request form. The "Deliver To" space of the purchase request form should be completed as provided in the Administrative Policies and Procedures Manual, with the Authorized Users desired final delivery point. MTSU Radiation Safety Office should be final delivery point. The Procurement Office will then request that the vendor route the



delivery to the Radiation Safety Office where the package will be received and in-processed by Radiation Safety personnel as described in section 4.0 of this procedure.

- 3) The exception to this is when isotopes are ordered by an AU approved for direct delivery. In this case the AU should place a statement on the face of the purchase request to the effect that delivery is to go directly to the authorized use location. In such instances, the delivery information described above should not be typed in the comments area. In order for these purchase orders to be processed, the procurement office must be notified that the RSC has approved the Authorized User for direct delivery. This notification will be provided by the RSO.
- 4) The Procurement Office will issue a Field Purchase Order to the supplier and copies of the purchase order will be distributed to MTSU personnel in accordance with standard operating procedures.

4.0 RECEIPT AND INVENTORY TRACKING OF RADIOACTIVE MATERIALS

Radiation Safety will receive and in-process all shipments of radioactive materials directed to them and will re-deliver the shipments to the final delivery point designated on the purchase request form. The Central Receiving Section will not be involved with such deliveries and, therefore, will not perform any automatic follow-up function on outstanding isotope orders. The Authorized User or their designee will be responsible for routine follow-ups. If a significant problem with a given shipment or continued problems with a supplier is encountered in follow-up activity, the Procurement Office should be notified.

Note: Radiological surveys of the exterior surfaces of radioactive material shipments shall be performed as soon as practicable after receipt of the package, but not later than three hours after the package is received if receipt occurs during normal working hours. Packages that are not received during normal working hours are required to be surveyed within three hours of the next normal workday following receipt.

4.1 Inspection and Redelivery

- 1) For deliveries directed to EHS, Radiation Safety will perform a receipt inspection of each package and evaluate compliance with the requirements of this procedure. If no discrepancies are noted, re-delivery will be made by the Radiation Safety staff to the Authorized User, usually on the same day. An *Inventory of Radioisotopes* form will be prepared and delivered with each shipment. The *Inventory of Radioisotopes* form must be returned to Radiation Safety when the radioactive material has been used up and disposed of.
- 2) Any shipment of radioactive material with more than 1000 dpm/100cm² of removable contamination on either the outside package or the inside container will not be delivered to the Authorized User. The vendor should be contacted and arrangements made for a replacement shipment. The shipment may be returned to the vendor or disposed of as waste. The Authorized User will be notified that the shipment has arrived, that it is contaminated and that a replacement should be ordered. Vendor notification for replacement shipments is the responsibility of the Authorized User. The



Procurement Department should be made aware of this notification.

- 3) In the case of an AU approved for direct delivery, an individual trained in the requirements of this procedure will be responsible for performing the receipt inspection.
 - A *Package Receipt Record* documenting the shipment receipt and radiological survey data must be completed by the individual performing the receipt inspection and forwarded to Radiation Safety.
 - Laboratory personnel will log in the shipment on an *Inventory of Radioisotopes* form upon arrival. A copy of the *Inventory of Radioisotopes* form must be returned to Radiation Safety when the shipment has been used up or disposed of as waste. The radioactive materials inventory database will be updated (radioisotope removed from AU's inventory) when the *Inventory of Radioisotopes* form is returned to Radiation Safety.

4.2 Receipt Inspection Procedure

- 1) Precautions/prerequisites:
 - Individuals performing receipt inspections of radioactive materials must be trained to the level of Advanced Radiation Worker, or an RSO approved equivalent.
 - Personnel opening radioactive material packages shall wear a minimum PPE of gloves to prevent hand contamination.
 - Wear personnel dosimetry in accordance with the requirements of this manual when working with radioactive materials.
- 2) Visually inspect the package for any signs of damage, including crushed or punctured containers or signs of leakage. If any signs of damage are noted, store the package within a secondary containment and notify the RSO. Also, request that the person responsible for delivery of the package remain in the area until they can be monitored for contamination. If removable contamination on the outside of the package is confirmed to be in excess of the limits specified below, request that the delivery vehicle remain in place until released by the RSO.
- 3) Check the packing slip for a description of the contents and verify that the isotope and activity of the shipment does not exceed license (or permit) limits.
- 4) Survey the exterior of the package for radiation dose rates. Measure and record the maximum reading at contact on the package and the reading at 1 meter from the package. Compare the results to table 4.2 of this chapter. If the dose rate values are not in compliance with the labeling of the package, notify the RSO or designee. Do not proceed with opening the package.
- 5) Survey the exterior of the package for transferable contamination by performing a wipe test of an area of approximately 300 cm². Count the wipe in an appropriate counting instrument. Results should not exceed 200 dpm/100cm² and shall not exceed 1000 dpm/100cm². If results exceed 1000 dpm/100cm² notify the RSO or designee. Do not proceed with opening the package.



- 6) If no external contamination is indicated, open the package and carefully remove the packing material until the final source container is reached. Again, check for any obvious signs of leakage and take appropriate precautions.
- 7) Packages that contain volatile radioactive materials (I-125/131, S-35, H-3, etc.) in quantities greater than limited quantity shipments should be opened in a fume hood, if available. When appropriate, use shielding to reduce personnel exposure.
- 8) Perform a wipe test of the exterior of the inner-most radioactive materials container. Results shall not exceed 1000 dpm/100cm². If results exceed 1000 dpm/100cm² notify the RSO or designee. Do not proceed with use or delivery of the package unless approved by the RSO.
- 9) Verify that the inner container labeling is correct with the packing slip. Again, this should be done to confirm that the isotope and activity of the shipment does not exceed license (or permit) limits.
- 10) Re-package the inner container into the original shipping package for delivery to the final destination.

Table 4.2
Shipping Label Requirements and Dose Rate Limits

Label Category	Maximum External Contact Dose Rate	Transport Index (TI)*
Limited Quantity	≤0.5 mrem/hr	0
White I**	≤0.5 mrem/hr	0
Yellow II	>0.5 to 50 mrem/hr	0 to 1
Yellow III	>50 to 200 mrem/hr	1 to 10

*The TI is determined by the dose rate at 1 meter (3.3 feet) from the external surface of the package. TI values should be rounded up to the next tenth. The TI value is considered to be zero if the 1 meter dose rate is <0.05 mrem/hr.

**The White I category differs from the Limited Quantity category in that the Curie content exceeds the criteria for a limited quantity of material. Limited quantity values are shown in Table 6.4 of this procedure.

4.3 Inventory Record Keeping

- The Authorized User has the responsibility to keep accurate and up-to-date records of all radioactive materials in their possession. The first step in this process is to use the *Inventory of Radioisotopes* form. It is strongly recommended that copies of this form be kept in a dedicated location, preferably in some type of binder, for easy access and organization.
- The second inventory control tool is the *Radioactive Material Inventory Summary* form. If desired, an electronic equivalent of this form may be maintained. If kept electronically, printed copies may be requested by Radiation Safety for inventory verification purposes.
- The University's radioactive materials license with the State of Tennessee requires the performance of a physical verification of radioactive material inventory every six months.



Records in support of this inventory verification will be requested by Radiation Safety on a biannual basis.

4.4 Removal of Radioactive Materials from the Inventory of Authorized Users

- When all of the radioactive material assigned to an authorization tracking number (B number) has been used up or disposed of as waste, the *Inventory of Radioisotopes* form (or approved equivalent) must be completed and returned to Radiation Safety. The radioactive materials tracked by the B number on the returned *Inventory of Radioisotopes* form will be removed from the inventory of the respective AU in the database system by the Radiation Safety staff.
- *Inventory of Radioisotopes* forms must be returned promptly in order for the inventory database to be accurate. Additional radioactive materials orders will not be processed (B numbers will not be issued) if the inventory database indicates that a requested order would result in the AU's radioactive material inventory exceeding their possession limit.
- Authorized Users should be aware that radioactive materials are not removed from the inventory database as a result of radioactive decay. Inventory paperwork must be processed as described in this chapter in order for the database to be accurate.
- In the event that a B number is obtained for an order and the order is not completed (not purchased), Radiation Safety should be contacted. After verification that the order has not been procured, the radioactive materials tracked by that B number will be removed from the Authorized Users inventory.
- AU's are encouraged to dispose of radioisotopes that have exceeded a reasonable shelf life as recommended by the manufacturer. Ionization due to radioactivity can cause the production of free radicals, resulting in accelerated chemical decomposition and increasing the possibility of ruined experiments.

4.5 Receipt of Devices Possessed Under a General License

Individuals who are already in possession of items received under a general license must inform Radiation Safety of the radioactive materials in their possession when they begin working at MTSU. Individuals planning to acquire these items should contact Radiation Safety to arrange a transfer. These items must be tracked and controlled in accordance with the University's broad scope radioactive materials license. Some examples of items typically controlled under a general license include the Nickel-63 sources in electron capture detectors as found in certain gas chromatographs and the calibration sources in some liquid scintillation counters. Gas chromatographs and similar measuring and gauging devices that contain sealed radioactive sources may be procured and used by personnel other than Authorized Users if appropriate controls are met. Procurement, transfer, monitoring, training, and registration for these devices must be coordinated with Radiation Safety.

5.0 TRANSFER OF RADIOACTIVE MATERIALS

5.1 External Transfers

Licensed radioactive materials shall not be transferred from one institution to another without the approval of the RSO. The RSO of the institution desiring to make the transfer must contact the RSO of the receiving institution prior to making the transfer. Any individual wishing to initiate or receive an



external transfer must notify the RSO well in advance of the transfer. The requirements for labeling, shipping, and receiving of radioactive materials as described in this manual and 49 CFR 173 must be complied with.

5.2 Internal Transfers

Radioactive materials may be transferred from one Authorized User to another by the internal transfer process. These transfers must be coordinated through the Radiation Safety Office and approved before the transfer takes place. The inventory records for both AU's will have to be updated by the Radiation Safety staff. The AU receiving the radioactive materials must be approved for the quantity and type of materials to be transferred and the transfer must not cause their possession limits to be exceeded. The *Internal Transfer of Radioactive Materials* form must be completed and signed by both AU's involved in the transfer. In addition, the requirements of section 6.0 of this procedure must be complied with.

5.3 Gifts and Donations

Gifts and donations of radioactive materials must be controlled in the same manner as for internal and external transfers.

5.4 General Transfer Requirements

- Radioactive materials may only be transferred from an Authorized User's approved location or from one AU to another after receiving approval from Radiation Safety.
- A University researcher who desires to use radioactive materials off campus must contact Radiation Safety well in advance of the proposed time of use.
 - (1) If the proposed site is a University-affiliated experiment station which is licensed to use the isotope in question, a few days' notice should be sufficient.
 - (2) If the proposed site is another institution, not affiliated with Middle Tennessee State University, but licensed to use the isotope in question, approximately two weeks should be allowed for arrangements to be made. The name and phone number of the RSO (or equivalent) at the other institution should be provided to MTSU Radiation Safety to facilitate this process.
 - (3) If no license exists for use of radioactive materials at the desired site, then a license amendment must be obtained from the State of Tennessee Department of Environment and Conservation Division of Radiological Health. A minimum of one month and possibly longer may be required. If the site is out-of-state, requiring coordination with other state regulatory agencies, the required time may be even longer.

6.0 TRANSPORTING RADIOACTIVE MATERIALS

- Transport of radioactive materials in private vehicles is not permitted. The use of University vehicles or common carriers is required, except as noted below.



- An exception to the prohibition regarding transporting radioactive materials in private vehicles is radioactive materials in exempt quantities or concentrations.
- Isotopes destined for common carrier must be checked by Radiation Safety before shipment to assure that they are properly packaged and all shipping papers are completed.
- Other materials exempt from the shipping requirements of this procedure include any radioactive materials in concentrations less than the amounts specified in 10 CFR 20 Appendix B, Table 2, any quantity or concentration of a radioisotope less than the exempt quantities or concentrations specified in 49 CFR 173.436, or any package containing radioactive material having a specific activity not greater than 0.002 microcuries/gram.

6.1 Transportation on University Property

If transportation of radioactive materials is to occur exclusively on University property and no public highways are to be traveled, the following method may be used.

- Ensure that Radiation Safety has approved the transfer.
- Individuals packaging and transporting the radioactive materials should be trained to the level of Advanced Radiation Worker, or an RSO approved equivalent.
- Package the radioactive materials in a secure container with adequate resistance to breakage. A secondary container should be used for liquids to prevent leakage.
- Label the radioactive materials with the isotope, quantity, and date.
- Ensure that contamination on the exterior of the outermost container does not exceed 200 dpm/100cm².
- Survey the exterior of the container for radiation dose rates. If the dose rates exceed 2 mrem/hr at 30 cm or 0.2 mrem/hr at 1 meter, contact the Radiation Safety staff for assistance prior to transporting the material.
- During transport it is considered a good practice to avoid high traffic areas and eating, drinking, and smoking areas. Otherwise, the most practical and direct route should be taken.
- The radioactive materials must be under continuous control of a trained Radiation Worker during transport.

6.2 Transportation by Common Carrier

Radioactive material shipments that are to be shipped by common carrier (Fed-Ex, UPS, etc.) must be approved by the Radiation Safety staff. The packaging and labeling information of this chapter must be followed, except as otherwise directed by the Radiation Safety staff.

6.3 Transportation on Public Roadways

- Radioactive materials must be properly packaged and labeled prior to transport on public highways. This requirement applies to all public highway transportation regardless of whether it is on or off campus.



- Any individual responsible for transporting or packaging radioactive materials for transport over public highways must be trained to the level of Advanced Radiation Worker, or an RSO approved equivalent.
- A "Letter of Intent" must be carried in the vehicle at all times when radioactive material is being transported. Copies of this letter may be obtained from the Radiation Safety Office.
- Whenever practical, the original shipping containers that radioactive materials are received in should be reused. These containers should meet or exceed DOT requirements for packaging of radioactive materials.

6.4 Limited Quantity Shipments of Radioactive Materials

Radioactive material packages in quantities that do not exceed the values shown in Table 6.4 may be shipped as a limited quantity if the dose rate at contact on the exterior of the shipping container does not exceed 0.5 mrem/hr.

In the case of individual packages that contain multiple radioisotopes, the sum of the ratios of the quantity of each isotope in the package to the limit value for that isotope must be <1 to be in compliance with the quantity limits.

Table 6.4
Limited Quantity Values for Typically Used Radioisotopes

Isotope	Limited Quantity Value for Liquids	Limited Quantity Value for Solids
³ H	110 mCi	1100 mCi
¹⁴ C	8.1 mCi	81 mCi
³⁵ S	8.1 mCi	81 mCi
³² P	1.4 mCi	14 mCi
³³ P	2.7 mCi	27 mCi
¹²⁵ I	8.1 mCi	81 mCi
¹²⁹ I	unlimited	unlimited
¹³¹ I	1.9 mCi	19 mCi
¹³³ Ba	8.1 mCi	81 mCi
⁶⁷ Ga	8.1 mCi	81 mCi
⁶³ Ni	81 mCi	810 mCi
⁴⁵ Ca	2.7 mCi	27 mCi
²¹⁰ Po	0.054 mCi	0.54 mCi
¹³⁷ Cs	1.6 mCi	16 mCi
⁵⁷ Co	27 mCi	270 mCi
⁶⁰ Co	1.1 mCi	11 mCi
^{99m} Tc	11 mCi	110 mCi
²⁰³ Hg	2.7 mCi	27 mCi



Instructions for Packaging Limited Quantities of Radioactive Materials

- 1) Package the materials in a suitable container with enough packing material or a secondary containment to contain any spillage in case of breakage. This is the inside container.
- 2) The inside container of radioactive materials must be labeled "Caution, Radioactive Materials" and should describe the isotope, quantity, and assay date.
- 3) Place the inside container in a strong tight outer container. Add packing materials suitable to keep the inside container from moving within the outer container.
- 4) Survey the exterior surface of the package (outer container) with a portable instrument. If the dose rate exceeds 0.5 mrem/hr, repackage the container to reduce the dose rate. If this is not practical contact the Radiation Safety staff for assistance.
- 5) Survey the exterior of the package for transferable contamination by performing a wipe test covering an area of approximately 300 cm². Count the wipe in an appropriate counting instrument. Results should not exceed 200 dpm/100cm² and shall not exceed 1000 dpm/100cm².
- 6) Document the shipment survey on the *Limited Quantity Shipment Form*. Alternatively, a Radiological Survey Form (RSF) or equivalent may be used to document the survey if approved by the RSO or designee.
- 7) The designation "UN 2910" must be marked on at least one side or one end of the outside of the package in a manner that it is durable, legible, and readily visible.
- 8) The following statement must appear on a label placed on the outside of the package or on a packing slip, or equivalent, located inside the package:
"This package conforms to the conditions and limitations specified in 49 CFR 173.421 for radioactive material, excepted package-limited quantity of material, UN 2910."
- 9) Do not place any other radioactive material labels on the exterior of the shipping container.
- 10) All outgoing shipments must be approved by the Radiation Safety staff prior to transport.

6.5 Limited Quantity Shipments of Instruments and Articles

A commercially manufactured instrument or article that contains radioactive material may be shipped as a Limited Quantity if the following conditions are met:

- 1) The quantity of radioactive material must not exceed 10 times the value for solids shown in Table 6.4.
- 2) The radiation level at 10 cm from any point on the external surface of the unpackaged item must not exceed 10 mrem/hr.
- 3) The radiation level on the exterior surface of the shipping container must not exceed 0.5 mrem/hr.



- 4) The transferable contamination levels on the exterior surface must be in compliance with item 5 of section 6.4.
- 5) Radiological surveys of the item should be documented on a RSF or an RSO approved equivalent. .
- 6) The designation “UN 2911” must be marked on at least one side or one end of the outside of the shipping container in a manner that it is durable, legible, and readily visible.
- 7) The following statement must appear on a label placed on the outside of the package or on a packing slip, or equivalent, located inside the package:
“This package conforms to the conditions and limitations specified in 49 CFR 173.424 for radioactive material, excepted package-instruments or articles, UN 2911.”
- 8) All outgoing shipments must be approved by the Radiation Safety staff prior to transport.

6.6 Shipments of Radioactive Material in Quantities Exceeding Limited Quantities

Packages of radioactive materials which exceed the criteria described in section 6.4 or 6.5 for limited quantity shipments must be inspected, surveyed, and have shipping papers completed by the Radiation Safety staff prior to transport by either University vehicle or common carrier.

7.0 EXEMPT ITEMS

The items described below are exempt from the procurement and transfer requirements of this procedure. However, a manufactured product containing radioactive materials must not be used in any manner that is not approved by the manufacturer. These items should not be disassembled, altered, modified, or repaired; unless the items are returned to the manufacturer or their authorized representative, except as approved by the RSO. Naturally occurring radioactive materials shall not be used in any manner which could cause the concentration, extraction, or dispersal of the radioactive materials. The Radiation Safety Office must also be contacted regarding proper disposal of such items.

Items that are exempt from the procurement and transfer requirements of this procedure include the following:

- Industrial products that contain exempt quantities or concentrations of radioactive materials, including; smoke detectors, self illuminated signs, etc.
- Manufactured products, radioactive standards, or sealed sources containing exempt radioactive materials as defined by the Nuclear Regulatory Commission in 10 CFR 30.
- Naturally occurring radioactive material (NORM) in exempt quantities or concentrations.
- X-ray, imaging devices, and radioactive materials controlled under medical (human) use protocols or that are controlled in accordance with Chapter 290-5-22, *Rules and Regulations for X-Rays*.
- Any radioactive materials in quantities less than the amounts specified in 10 CFR 20 Appendix B, Table 2



1.0 INTRODUCTION

1.1 Purpose and Scope

This chapter describes the methodology for performance of radiation and contamination surveys of areas where radioactive materials are used, stored, or suspected to be present. Specific survey requirements for radioactive materials shipments, leak rate testing of radioactive sources, and x-ray equipment are not described in this chapter.

The primary purpose of radiation surveys is to identify the magnitude (or verify the absence) of dose rates so that personnel exposure to radiation is maintained As Low As Reasonably Achievable (ALARA).

The primary purpose of contamination surveys is to identify the quantity (or verify the absence) of radioactive contamination on surfaces. The objective is to prevent the inhalation, ingestion, or absorption of radioactive contamination by personnel and to ensure that contamination is not spread to the surrounding environment.

The documented performance of radiological surveys is required by *Title 10, Part 20 of the Code of Federal Regulations* and by the State of Tennessee *Rules and Regulations for Radioactive Materials*.

1.2 Precautions and Limitations

Wear appropriate personnel protective equipment (i.e. lab coat & gloves) during the performance of activities with unsealed radioactive materials or the potential to encounter radioactive contamination.

Use the ALARA principles of time, distance, and shielding to reduce your exposure to radiation during the conduct of radiological surveys.

2.0 TERMS / DEFINITIONS

radiological survey – an evaluation of radiological conditions by testing, measurement, or calculation.

contamination – radioactive material in an undesirable location, or transferable contamination in excess of the limits specified in Table 5.1 of this chapter.

radiation – energy in the form of particles or waves emitted from a radiation source.

direct scan survey – use of the direct scan technique to measure the activity emitted from a surface. The radiation detected is the total result of any fixed and transferable contamination on the surface, and of any radiation that may be penetrating through the surface or emanating from another source.

transferable contamination survey – An assessment of the amount of readily removable contamination present on a surface. A collection medium is used to wipe a surface while applying moderate pressure.



The amount of activity detected on the collection medium is then determined using radiological instrumentation.

wipe survey – the use of a collection medium (paper disc or equivalent) to cover approximately 100 square centimeters of surface area in the assessment of transferable contamination.

large area wipe survey – the use of a collection medium (paper towel, disposable wipe, or equivalent) to perform a transferable contamination survey of a surface area significantly larger than 100 square centimeters.

cpm – counts per minute; the observed count rate determined from the use of a counting instrument.

dpm – disintegrations per minute; the rate of emission of radioactive material as determined by correcting the counts per minute for background, efficiency, and geometry factors.

contact dose rate – the radiation dose rate at (or near) contact with the radiation source. This value may be used to determine the extremity dose rate.

30 cm dose rate – the radiation dose rate measured 30cm (approximately 1 foot) from the radiation source, this value may be used to determine the whole body dose rate, skin/lens of eye dose rate, and deep dose equivalent exposure rate.

general area dose rate – the dose rate at approximately 1 meter from the radiation source, or the generally occupied area dose rate, as measured at approximately waist level by the survey technician.

mrem/hr – the unit of dose equivalent rate.

unrestricted area – an area or location that is not controlled for the purpose of limiting exposure to radiation or radioactive materials. Controls include physical boundaries and radiological postings, signs, and labels.

restricted area – an area or location that is controlled for the purpose of limiting exposure to radiation or radioactive materials. A posted Radioactive Materials Area is an example of a restricted area.

ND - a notation used to describe the survey result when no detectable radiation or contamination above instrument background level was found.

3.0 MONITORING INSTRUMENTATION

3.1 Portable Instrumentation

Radiation Safety should be contacted for training in the use of monitoring instrumentation. Refer to the vendor provided instrument technical manual for specific operating information. The following general information is applicable to most types of portable radiation monitoring instrumentation used in MTSU laboratories.

- 1) Pre-operational checks:



- Verify that the instrument has a current and up to date calibration label (instrument calibration services are available from Radiation Safety).
 - Inspect the instrument for physical damage.
 - Check the batteries, for instruments equipped with a battery test function.
 - Verify that the instrument is operational by checking for detection of normal background radiation. This should be done in a low background area away from sources of radiation. If routinely performed in the same location, consistent, reproducible results are an indication of a properly performing instrument.
 - Instruments which are not capable of detecting background levels should be response tested with a radiation source of known quantity. Response check sources may be available from Radiation Safety for this purpose.
- 2) Selection of audible and response settings on portable instruments is left up to the discretion of the surveyor, however, the following settings are recommended:
- Audible on - Normally used.
 - Audible Off - Recommended when the instrument higher scales are used, and at the discretion of the survey technician.
 - Fast Response - Recommended when surveying with audible off, using the instrument high range scales, or for contamination surveys.
 - Slow response - Normally used for dose rate readings on the low scales.

3.2 Wipe Test Counting Equipment

The type of laboratory equipment selected for counting wipe test samples is dependent on the radioisotope(s) to be detected and equipment availability. Typical instruments include a counter/scaler, gamma counter, or a liquid scintillation counter (LSC). The following general information is applicable to the counting instruments typically used at MTSU.

- 1) Refer to the vendor provided instrument technical manual for specific operating and counting information.
- 2) Whenever practical utilize known radioactive standards to conduct functional tests and verify instrument efficiencies (instrument cpm/actual source dpm = counter efficiency).
- 3) Determine the minimum detectable activity (MDA) for the counting instrument prior to counting samples where a minimum activity threshold value is required. MDA varies with changes in counter background and counting times. Lower background levels and longer counting times enable a lower MDA value to be reached. Calculate the MDA by use of the formula:

$$\text{MDA in dpm} = \frac{2.71 + 4.66 \sqrt{\text{bkg cpm} \times \text{count time}}}{(\text{efficiency}) (\text{count time})}$$

Example: a 1 minute counting time, 50 cpm background (bkg), and LSC efficiency for H-3 of 0.33 would give a MDA of 96 dpm. Therefore it would be appropriate to count a wipe



sample for 1 minute for H-3 at this background level because the most restrictive limit is 200 dpm.

- 4) Run background samples to calculate net counts per minute (gross cpm – bkg = net cpm).
- 5) Use instrument efficiencies to convert net cpm to dpm (net cpm / instrument efficiency = dpm).
- 6) A simpler way to convert net cpm to dpm is to use a correction factor (CF). A correction factor is determined by the following method: $CF = 1/\text{efficiency}$. When using a correction factor to convert cpm to dpm use the following formula: $\text{cpm} \times CF = \text{dpm}$
- 7) The standard efficiency to be used when counting wipe samples with a LSC is 33%, which provides a correction factor (CF) value of 3. When counting wipe samples in a LSC, simply multiply the net cpm value by 3 to convert the results to dpm.
- 8) The standard efficiency is based on the lowest counting efficiency (highest CF) for the radioisotopes typically used at MTSU. This provides a uniform standard and eliminates the need for spectral analysis of wipe samples when the probability of multiple unidentified isotopes exists.
- 9) The standard efficiency is appropriate for use when counting wipes in commercially available scintillation fluid, or for counting exclusively P-32 wipes using water (Cerenkov counting). In Cerenkov counting, water is used instead of liquid scintillation fluid. The Cerenkov effect occurs when visible light in the blue spectrum is produced when a beta particle travels through a transparent medium faster than the speed of light in that medium. Counting wipes in water with an LSC is only approved for P-32, wipes for no other isotopes may be counted by this method.
- 10) Table 3.2 provides the net cpm value that will equal 200 dpm and 1000 dpm when using the standard efficiency of 33%.

Table 3.2
CPM to DPM Conversion Using the Standard LSC Wipe Counting Efficiency

LSC standard wipe counting efficiency	Correction Factor	Net cpm to equal 200 dpm	Net cpm to equal 1000 dpm
0.33	3	67 cpm	333 cpm

- 11) The net cpm values provided in the table above may be used as a wipe test counting guideline in meeting the criteria of restricted and unrestricted areas for transferable contamination.
- 12) When using a counter other than a LSC for analysis of wipe samples, you should use the actual efficiency for the instrument and isotope being surveyed for. An exception to this occurs if the efficiency exceeds 33%, in this case you should use the 33% value to ensure consistency in analysis of wipe samples.

4.0 DIRECT SCANNING FOR CONTAMINATION



Direct scans of material/equipment/surfaces are performed to identify the amount of contamination (fixed and transferable) present on an accessible surface. It is important to understand that direct scans may also identify the presence of radiation from another source, such as radiation penetrating through the surface of a container. Direct scan surveys may be used to provide an initial assessment of the amount of total surface contamination. The contamination detected by direct scans may be fixed (non-transferable) or transferable. Transferable contamination survey techniques are described later in this procedure.

- Direct scan surveys for contamination are not required to be performed and documented during a routine monthly survey.
- Direct scan surveys are required to be performed and documented when surveying an item or component for release to unrestricted use.
- Direct scan surveys are a primary tool for contamination monitoring during and after the performance of radioisotope work.

4.1 Direct Scan Technique

- 1) A pancake type GM thin window detector is the recommended instrument to perform direct scan surveys. Even with thin window detectors, these portable instruments will not detect H-3 and have a low efficiency for detecting low energy beta/gamma emitters.
- 2) Perform direct scan surveys in a low background area. If it is necessary to transport an item to a lower background location, take appropriate steps to prevent the possible spread of contamination (i.e. survey for transferable contamination first).
- 3) When scanning for contamination, position the detector approximately ½ inch above the surface being surveyed; slowly scan the surface at an approximate rate of 1 to 2 inches per second. Observe closely for increases on the meter display or in the audible signal.
- 4) If contamination is known to be present on the surface, the scan speed may be adjusted to an appropriate speed for locating the maximum contamination level, as desired.
- 5) If activity is detected, then hold the probe stationary until the meter stabilizes to obtain a reading.
- 6) Any activity equal to or greater than 2 times background is a positive indication of contamination. The ALARA action level of <2 times background not to exceed <0.05 mr/hr is the appropriate limit for unrestricted areas, or for items to be released for unrestricted use.
- 7) If high levels of contamination are detected take appropriate precautions to control or prevent the spread of contamination. Notify the Authorized User and/or Radiation Safety for assistance.
- 8) Direct scan surveys are not required to be documented as a part of your monthly radiological survey. Direct scan surveys for release of potentially contaminated items or components to unrestricted use (see section 7.2) do require documentation. When appropriate, direct scan surveys may be documented on a Radiological Survey Form (RSF) by identifying the items or locations surveyed and recording the results. “ND” may



be used to indicate no detectable contamination. If contamination is identified, the levels found and units measured must be recorded. Refer to the RSF and the instructions provided by Radiation Safety for additional information.

5.0 TRANSFERABLE CONTAMINATION SURVEYS (WIPE TESTS)

Transferable contamination surveys are performed by wiping a known surface area (typically 100 cm²) with a collection medium. The concentration of radioactivity on the collection medium is then analyzed. This is an important survey technique because transferable contamination can be spread from one location to another and is a potential inhalation, ingestion, or absorption hazard. Also, transferable contamination measurements are required to be performed and documented to maintain compliance with state and federal regulations.

In addition to the standard wipe testing technique described in section 5.1, there are two optional techniques that may be used for special applications as described in sections 5.2 and 5.3. If you do not fully understand the limitations of these optional survey techniques, contact Radiation Safety for assistance.

5.1 Survey Technique - 100 cm² Wipe Tests

- 1) 100 cm² wipe tests may be performed using filter papers or commercially available wipes or smears with an approximate diameter of 1" as the collection medium.
- 2) Wipe the collection medium over the surface of the area being surveyed using moderate pressure such that 100 cm² is wiped (typically a 16"-18" lazy S pattern).
- 3) Analyze the wipes using counting equipment as described in your laboratory standard protocols and section 3.2 of this chapter.
 - If using a LSC, add an appropriate amount of biodegradable scintillation fluid and count the sample for a minimum of 1 minute (see sections 3.2 and 5.2 for special counting considerations if analyzing exclusively for P-32)
 - If using a gamma counter or counter scaler, follow the standard counting protocol for the instrument
- 4) Subtract the background count rate (cpm) from the gross count rate (cpm) to obtain a result in net cpm. Multiply the net cpm by the conversion factor of 3 to convert the result to dpm/100 cm².
- 5) Wipe test results should be documented in units of dpm/100 cm² in the space provided on the radiological survey form (RSF).
- 6) If wipe test results are <200 dpm (<66 cpm), the counting media should be disposed of as "clean" waste. Biodegradable liquid scintillation fluid may be disposed of via sink drains, empty vials and non-contaminated wipes should be discarded in regular trash.
- 7) Compare the wipe test results to Table 5.1 (below) and take appropriate actions.

Table 5.1
Transferable Contamination ALARA Action Levels

Description	Action Level for
-------------	------------------



Transferable Contamination (beta-gamma*)

Unrestricted Area

200 dpm/100cm² (<66 cpm/wipe)

Restricted Area

1000 dpm/100cm² (<333 cpm/wipe)

*Alpha contamination surveys will not be required unless work is performed with unsealed isotopes that primarily or exclusively decay by emission of alpha radiation. If alpha contamination surveys are required, transferable contamination limits will comply with regulatory guidance.

Note: The ALARA goal is to maintain all normally occupied routinely accessible areas at the unrestricted area transferable contamination action level.

5.2 Optional Survey Technique – Portable Instrument Counting of P-32 Wipes

Transferable contamination surveys that are performed exclusively to monitor for P-32 in restricted areas (Radioactive Material Areas) may use the following technique. This technique is suitable for meeting the restricted area limit of 1000 dpm/100 cm², but is not to be used to meet the unrestricted area limit of 200 dpm/100 cm². In other words this method of counting wipes may be used for monthly surveys and routine monitoring inside of Radioactive Material Areas, but may not be used for surveys for release of items or equipment to unrestricted use, or for out-going radioactive materials shipments.

- 1) Collect wipes by using 1.5" diameter paper or cloth disc smears (commercially available).
- 2) Using a pancake GM detector (Ludlum 44-9 probe or equivalent), hold the detector approximately 1/4 inch above the collection surface of the wipe for approximately 5 seconds.
- 3) Perform this check in a low background area only (<0.05 mr/hr). The instrument must be on a scale suitable to read <0.05 mr/hr (the x 0.1 scale for a Ludlum Model 3). Use of the audible response is recommended.
- 4) If no increase is noted (listen for audible response) in the count rate, the results are equivalent to <1000 dpm/100 cm². The results should be recorded as ND in the cpm space provided for wipe test results on the Radiological Survey Form.
- 5) If activity is indicated by use of the portable instrument, or if a more accurate count is desired, count the wipe in a LSC. Deposit the wipe in a scintillation vial and add an appropriate volume of water to fill the vial. Count the vial in the LSC for a minimum of 1 minute (Cerenkov counting). Subtract the background count rate and use the correction factor of 3 to convert the net counting results from cpm to dpm.

5.3 Optional Survey Technique - Large Area Wipes

Large area wipes are useful for routine monitoring of work areas. Large area wipes are not required to be performed and documented during routine monthly surveys. However, for specific situations approved by the RSO, large area wipes may be substituted for 100cm² wipe testing on a limited basis.

Large area wipes are only to be used as a positive/negative test for the presence of contamination. Due to the potential to spread contamination when wiping a large area, the primary use for large area wipes is to verify that normally "clean" areas have not become contaminated. Since large area wipes are read



with a portable survey instrument, they will not detect H-3 and may not be suitable for detecting small quantities (i.e. 200 dpm) of low energy beta/gamma emitters.

Perform large area wipes in accordance with the following instructions.

- 1) Large area wipes can be performed using paper towels, disposable wipes, disc smears or equivalent as the collection medium. Floors may also be surveyed by the use of dust mops that utilize treated cloths. If disc smears are used for large area wipe testing, a minimum disc diameter of 1.5" is preferred for optimum collection and counting results.
- 2) Wipe the collection medium over the surface using moderate pressure. You should wipe an area at least 500 cm², but not so large as to cause degradation of the collection medium. A recommended technique for large surfaces (desks, bench tops, etc) is to wipe in an "S" shaped pattern of approximately 6.5 feet in length. Use multiple wipes when checking large surfaces or different locations.
- 3) Perform a direct scan of the surface of the collection medium using a portable survey instrument, as detailed in section 4.1 of this chapter.
- 4) If contamination is detected take appropriate measures to control the potential spread of the contamination. A 100 cm² wipe test must be performed in order to quantify results. Compare the results to Table 5.1 for appropriate actions.
- 5) Large area wipe surveys are not required to be performed and documented as a part of your monthly radiological survey. However, large area wipes may be recorded on radiological surveys as a supplement to regular wipe testing. If large area wipes are performed and no contamination is detected, the results may be documented by identifying the items or locations surveyed and recording the results. "ND" may be used to indicate no detectable contamination. A large area wipe survey that indicates contamination should not be documented, but must be followed by a sufficient number of wipe test surveys to accurately determine the magnitude and extent of the contamination. Refer to the RSF and the instructions provided by Radiation Safety for additional information.

6.0 RADIATION SURVEYS

Radiation surveys are performed to measure the dose rates (radiation fields) produced by sources of radiation, or to confirm the absence of these dose rates. Unless specifically exempted, radiation dose rate measurements are required to be performed and documented to maintain compliance with state and federal regulations.

The performance of radiation dose rate surveys is not required in authorized use locations where the radioactive materials are limited exclusively to milliCi quantities of isotopes that emit primarily beta radiation with energies below 250 keV (H-3, C-14, S-35, and P-33). The exclusive use of I-125 immunoassay kits with <25 microCi per kit is also exempted.

Radiological surveys of all other authorized use locations must include radiation dose rate surveys. The minimum requirement is to measure the radiation levels at 30 cm (1 foot) from potential sources of radiation, including storage areas, waste containers, and isotope use locations. Even if no increase over



the background reading is noted, the survey must be documented as proof of compliance with the regulations.

During the performance of radiation surveys, remember to keep personnel exposure ALARA. In the event that significant radiation levels are detected, control access and notify Radiation Safety.

6.1 Radiation Survey Techniques

- 1) Survey the entire area concern, noting fluctuations in the meter or audible response. Investigate any increase to determine the magnitude and location of the highest reading.
- 2) Obtain 30 cm dose rate readings by measuring the radiation level at 30 cm (1 foot) from the radiation source or any surface from which the radiation emanates. 30 cm radiation levels may be used to establish whole body and skin/lens of eye exposure rates. These readings are also used in establishing radiological postings of areas.
- 3) General area dose rates should be measured at an approximate distance of 1 meter from the radiation source, or from any surface from which the radiation emanates. These dose rates are appropriate for estimating exposure to support personnel working in the vicinity of personnel whose exposure rates are determined by 30 cm dose rates.
- 4) General area dose rates are also useful in determining exposure rates for walkways and routinely occupied areas. General area dose rates taken for this purpose should consist of dose rate measurements taken at approximately waist level in normally occupied areas. If dose rates above area background are revealed by this method, additional surveys should be performed to determine the source of the radiation.
- 5) Contact dose rates shall be taken with the detector of the instrument at or near contact with the surface from which the radiation emanates. In addition to locating the source of radiation, contact dose rates provide useful information for estimating extremity exposure.

6.2 Radiation Dose Rate ALARA Action Levels

- 1) The ALARA action levels for radiation dose rates are shown in Table 6.2. Distances are measured from the source of the radiation, or from any surface from which the radiation is penetrating.

Table 6.2
Radiation Dose Rate ALARA Action Levels

Location	Dose Rate Action Level	Type of Measurement (source to detector distance)
Unrestricted Area	<0.05 mrem/hr	30 cm (whole body dose rate)
Restricted Area	<2 mrem/hr	30 cm (whole body dose rate)



- 2) If the dose rates exceed the criteria described in Table 6.2 take appropriate actions. Locate the radiation source and consider shielding or re-locating the radiation source to reduce the dose rates. Consult with a member of the Radiation Safety staff for additional assistance.
- 3) Dose rates in certain locations or situations are allowed to exceed the ALARA action levels of Table 6.2 if appropriate radiological controls are implemented. For example, these action levels may be exceeded during the conduct of procedures performed for a limited duration under the continuous control of trained Radiation Workers who ensure that no untrained personnel (members of the public) are exposed to radiation hazards. Contact Radiation Safety for evaluation of a specific situation.
- 4) Radiation dose rates due to radioactive material shipments that are appropriately packaged, labeled, and are in transport are exempt from the guidelines of Table 6.2.
- 5) Radiographic (x-ray) procedures are also exempt from the restricted area radiation dose rate ALARA action levels specified above.

7.0 RADIOLOGICAL SURVEY REQUIREMENTS

7.1 Documented Monthly Surveys of Authorized Use Locations

The AU is responsible to ensure that areas where unsealed radioactive materials are used or stored are surveyed on a minimum frequency of monthly, unless no use of unsealed radioactive materials occurred in that location during the month. This survey must be documented on the Radiological Survey Form (RSF), or an RSO approved equivalent.

Perform a monthly radiological survey as follows:

- 1) Prepare a diagram of the room or location to be surveyed on a RSF. At a minimum, the diagram should include the general layout of the room or location. Radiological work areas, fume hoods, storage areas, waste containers, etc. should be noted on the diagram. The building, room number, Authorized User, and Radioactive Materials Permit number must be listed on the form. It is recommended that a prepared form be maintained electronically, or be hand drawn once and photocopied for future use to promote efficiency.
- 2) Prepare instruments for use in accordance with section 3.0 of this procedure.

Note: The performance of radiation dose rate surveys is not required in authorized use locations where the radioactive materials are limited exclusively to milliCi quantities of isotopes that emit primarily beta radiation with energies below 250 keV (H-3, C-14, S-35, and P-33). The exclusive use of I-125 immunoassay kits with <25 microCi per kit is also exempted. Monthly radiological surveys of these locations are only required to include contamination surveys by wipe testing.

- 3) Measure the radiation levels at 30 cm (approximately 1 foot) from locations where radioactive materials are stored or typically used (waste containers, hoods, benchtops, freezers, etc.) throughout the survey location.



- 4) If all 30 cm radiation levels are <0.05 mr/hr, you may record this data on the RSF by using the statement "all dose rates are <0.05 mr/hr."
- 5) If the radiation levels at 30 cm are >0.05 mr/hr but <2 mr/hr, record the actual (as found) dose rate on the survey diagram in locations on the diagram that correspond to the survey points. Any individual survey points that are <0.05 mr/hr should be recorded as " <0.05 ."
- 6) If the radiation survey is performed in an unrestricted area and the 30 cm dose rates exceed 0.05 mr/hr, control access to the affected area and notify Radiation Safety for assistance.
- 7) In the event an instrument is used for a restricted area survey that will not detect 0.05 mr/hr, you should use the lowest value that the instrument will detect when recording dose rates in the manner listed above. For example, if the lowest range of an instrument is 0.2 mr/hr, and no increase is noted during the survey, record results as <0.2 mr/hr.
- 8) If the 30 cm dose rates are >2 mr/hr but <5 mr/hr, the surveyor should perform the following:
 - Locate the radiation source.
 - Determine the contact, 30 cm, and 1 meter dose rates of the primary radiation source that is producing the radiation levels. The results should be recorded on the RSF in the format: contact / 30 cm / 1 meter.
 - If appropriate, relocate the source to reduce the dose rates.
 - If appropriate, shield the source to reduce the dose rates.
 - Perform additional radiation surveys to verify that the dose rates have been reduced to <2 mr/hr at 30 cm and record the results on the survey form.
- 9) If the 30 cm dose rates cannot be reduced to <2 mr/hr or are ≥ 5 mr/hr, control access to the affected area and notify Radiation Safety for assistance.
- 10) Perform a representative number of wipe tests in accordance with your professional judgment with consideration given to the type, quantity, and locations of radioactive materials use that has occurred since the last survey. A total of 10 to 20 wipe test locations are generally appropriate for a typical radioisotope use laboratory. No more than 5 wipe test locations would be appropriate for a location used exclusively for sample counting, such as a LSC room where no other radioisotope work is performed. Recommended wipe test locations include the following:
 - areas normally used for radioisotope work (countertops, hoods, sinks, etc.)
 - adjacent areas with the potential to have become contaminated
 - floor locations in high traffic areas (hallways, doorways) and in areas adjacent to locations where radioisotopes are commonly handled (in front of hoods, sinks, benchtops, etc.)
 - items frequently handled when moving from radioisotope use/storage areas to unrestricted areas (doorknobs, freezer handles, etc.)
 - exterior surfaces of radioactive waste containers



- boundaries between restricted and unrestricted areas.
- 11) You may use large area wipes to supplement 100 cm² wipe tests during the performance of monthly surveys. To use this option you must follow the requirements of section 5.3 of this chapter.
 - 12) When performing wipe surveys, it is recommended that you survey areas with the least potential for contamination first and work your way to areas with the greatest potential for contamination last. This reduces the potential for cross contamination of wipes and survey locations.
 - 13) Wipe test locations may be identified on the map by using circled numbers, or as otherwise described on the RSF.
 - 14) Analyze the wipe samples in an appropriate counter, document the results, and compare the wipe test results to the ALARA action levels of Table 5.1 of this chapter.
 - 15) If the ALARA action levels for transferable contamination are exceeded, take the following actions:
 - If unrestricted area contamination levels exceed 200 dpm/100cm² but are less than 1000 dpm/100cm²; perform decontamination, re-survey, and document the results on the survey form. In the comments section of the survey form indicate that the affected areas were decontaminated and resurveyed.
 - If unrestricted area contamination levels exceed 1000 dpm/100cm²; prevent personnel access to the affected area and promptly contact Radiation Safety for assistance.
 - If restricted area contamination levels exceed 1000 dpm/100cm² but are less than 10,000 dpm/100cm²; perform decontamination, re-survey, and document the results on the survey form. In the comments section of the survey form indicate that the affected areas were decontaminated and resurveyed.
 - If restricted area contamination levels exceed 10,000 dpm/100cm²; prevent personnel access to the affected area and promptly contact Radiation Safety for assistance.
 - If decontamination is widespread or is not reduced after three decontamination attempts; prevent personnel access to the affected area and promptly contact Radiation Safety for assistance.
 - 16) Document results on the RSF. Keep a copy of the RSF for your records and submit the original to Radiation Safety to be maintained in project files.



Flow Chart for the Performance of a Monthly Radiological Survey in a Restricted Area

Prepare a Radiological Survey Form (RSF) with a diagram of the area and ensure that your radiation monitoring instruments are ready for use.

Are you exempted from performing radiation dose rate surveys as described in section 7.1 of this chapter?

Yes

No

Perform wipe tests of locations that have the potential for contamination. Record the wipe test locations on the survey diagram.

Measure the radiation dose rates at 30 cm (1 foot) from waste containers, radioactive materials storage areas, known radiation sources, and use locations.

Count the wipes with an appropriate instrument.

Are all 30 cm dose rates < 0.05 mr/hr?

Yes

No

Do any wipe results exceed 1000 dpm/100 cm²?

Record "all dose rates are < 0.05 mr/hr" on the survey diagram.

Do any dose rates exceed 2 mr/hr @ 30 cm?

Yes

No

If the dose rates are < 5 mr/hr, determine and record the contact/30 cm/1 meter dose rates. Take appropriate measures to reduce the dose rates to < 2 mr/hr @ 30 cm and record the results.

Yes

No

Decontaminate and re-survey the affected area. Contact Radiation Safety for assistance if needed.

Record the actual radiation dose rate readings in locations on the diagram corresponding to the survey points. Individual survey points that are < 0.05 mr/hr should be recorded as " < 0.05 " on the diagram.

Evaluate any areas < 1000 dpm/100 cm² but > 200 dpm/100cm², decontaminate as appropriate (ALARA).

If the dose rates cannot be reduced to acceptable levels or are ≥ 5 mr/hr @ 30 cm, control access and notify Radiation Safety.

Record all data on the RSF. Keep a copy of the RSF for your records and send a copy to Radiation Safety.



7.2 Surveys for Release to Unrestricted Use

- 1) Potentially contaminated items, components, or areas must be surveyed prior to being released for unrestricted use. This includes items which have been in contact with, or in the near proximity of unsealed radioactive materials. Small hand carried items that have the potential for contamination should be surveyed to the limits specified in this procedure for unrestricted use by the AU, Advanced Radworker, or designee. Routine checks of these small items are not required to be documented on a Radiological Survey Form.

Note: In most cases, a member of the Radiation Safety staff will perform surveys for release to unrestricted use for the items or locations listed below. However, a survey by any qualified AU or Advanced Radworker that is properly performed and documented may be approved by the RSO or designee as a suitable record of release to unrestricted use.

- 2) The following items, locations, or components must have a documented radiological survey performed and approved by the Radiation Safety Officer or designee prior to being released for unrestricted use:
 - Authorized use locations, radiological use laboratories, or posted radioactive material areas in radiological use laboratories (bench tops, hoods, sinks, etc.).
 - Large components or equipment that has been used with radioactive materials (freezers, refrigerators, centrifuges, etc.) and are potentially contaminated.
 - Furniture that has been used for radioisotope work, including desktops, cabinets or drawers used to stored radioactive materials or potentially contaminated laboratory items (glassware, pipettes, etc.).
- 3) Perform surveys for release to unrestricted use as follows:
 - Perform a direct scan survey of all accessible surfaces with the potential to be contaminated in accordance with section 4.1 of this procedure.
 - The use of a thin window GM pancake type detector and an instrument sensitivity and background of <0.05 mrem/hr is required for the performance of unrestricted release surveys, unless otherwise approved in writing by the RSO. The use of a low energy gamma detector may be needed if isotopes such as I-125 and Cr-51 are known to be present.
 - If contamination is detected via direct scans, determine the location of the contamination and evaluate the possibilities for decontamination.
 - Collect and analyze a representative number of wipe samples as described in section 5.0 of this procedure.
 - Document results on the Radiological Survey Form, if required per item 2 above.
 - Compare survey results to the unrestricted release values of the following table.



Table 7.2
Unrestricted Release Limits

Direct Scan Limit	Transferable Contamination Limit
<2 times background not to exceed 0.05 mrem/hr	<200 dpm/100cm ² (<66 cpm/wipe)

- If the survey results exceed the specified values; decontaminate in accordance with section 7.1, re-survey, and document results
 - If the results are below the limits specified in Table 7.2 the material is suitable for release to unrestricted use
 - If the material meets the criteria where a documented survey is required as described in item 2 above, provide a copy of the survey to the Radiation Safety Officer or designee for approval prior to release for unrestricted use. Keep a copy of the survey for your records.
 - Destroy or deface any radiological markings prior to releasing items for unrestricted use.
- 4) Liquids, bulk material, and components with inaccessible surfaces with the potential for contamination require special survey techniques or analysis. Contact the RSO or designee for release of these materials to unrestricted use.

7.3 Other Survey Requirements

The frequency of radiological surveys in the work place must be adequate to ensure that personnel exposure to radiation and radioactive materials is ALARA. Documentation of these surveys on a RSF is not required. Specific instances when monitoring is needed include, but are not limited to, the following:

- monitoring of conditions during work with radioisotopes
- surveys of work areas after handling radioisotopes
- personnel contamination monitoring (direct scans of hands, clothing, shoes) after working with any unsealed radioactive materials and prior to exiting the laboratory
- direct scans of lab coats, furniture, and other routinely used and potentially contaminated items
- surveys of laboratory equipment after being used with radioisotopes
- radiation surveys of storage areas and waste containers after adding radioactive materials to those locations, to verify that dose rates are within limits
- surveys to ensure that unrestricted areas (i.e. office or break areas) are free from radiological hazards
- surveys in support of radioactive material shipments or transfers
- surveys of waste containers prior to pick up by the Radiation Safety Staff
- monitoring in support of any suspected spill of radioactive materials



7.4 Use of the Radiological Survey Form

- Not all surveys have to be documented on a RSF. Examples of surveys that do not require documentation include routine work area surveys and personnel contamination monitoring. Also, surveys in support of radioactive material shipments or transfers may be documented on paperwork other than a RSF. Duplicate documentation of these surveys is not necessary.
- As a general rule, monthly surveys and surveys of potentially contaminated items for release to unrestricted use are the only surveys required to be documented by an AU (or their designee) on a RSF. When in doubt about the need to document a survey consult with the Radiation Safety staff.
- A radiological survey is not required if no use of radioactive materials in an unsealed form is performed in an authorized use location during a calendar month. This information should be reported to Radiation Safety by use of an RSO approved electronic reporting method or by sending in a *Radiological Survey Form* with a statement in the *Comments* section denoting that no radioactive materials use occurred. In the case of an Authorized User with multiple rooms approved for radioactive materials use, only those rooms where unsealed radioactive materials were used during the calendar month are required to be surveyed. Individual rooms that do not require a monthly survey should be noted on the RSF so that all approved rooms are accounted for.
- The *Radiological Survey Form* should be completed in an electronic format for increased efficiency. The electronic format must be approved by the RSO and obtained from Radiation Safety. After the electronic form is completed it must be printed and signed. The signed original copy must be sent to Radiation Safety to be reviewed and stored with project files. Laboratory copies may be maintained in either electronic or hard-copy format.
- If the electronic format *Radiological Survey Form* is un-available or is not being used for any reason, a radiological survey may still be documented on a paper copy of the form. Some calculations will have to be performed manually. Contact Radiation Safety for assistance if needed.



1.0 GENERAL POSTING INFORMATION

1.1 Regulatory Documents and Notices

- Current copies of the Middle Tennessee State University Radioactive Materials Licenses, Parts 19 and 20 of Title 10 of the Code of Federal Regulations, this Radiation Safety Manual, and other radiation safety program documents may be examined at the Radiation Safety Office, Environmental Health and Safety Services.
- In the event that the State of Tennessee Department of Environment and Conservation Division of Radiological Health issues a notice of violation involving radiation safety, it will be posted within two working days after receipt of the document from the Department. In addition, the response to any such notice shall be posted for a minimum of five working days or until corrective action has been completed, whichever is later. These notices and responses will be posted and available for examination at the Radiation Safety Office, Environmental Health and Safety Services.

1.2 Radiological Postings

- 1) Radiological postings shall be used to alert personnel to the presence of radiation and radioactive materials and to aid them in minimizing exposures and preventing the spread of contamination.
- 2) Signs shall contain the standard radiation symbol (trefoil) colored magenta or black on a yellow background. Lettering shall be either magenta or black. Magenta is the preferred color over black. All posting signs and labels should be of the same design and consistent with industry standard postings. Signs and labels should not be altered or defaced in any way to change their meaning. Inserts (on signs containing insert slots) may be changed, as appropriate.
- 3) Signs shall be conspicuously posted, clearly worded, and may include radiation safety instructions.
- 4) Radiological postings should be displayed only to signify actual or potential radiological conditions. Signs used for training should be clearly marked, such as "For Training Purposes Only."
- 5) Postings should not be positioned to obstruct other safety or security signs, markings, or equipment.
- 6) If more than one radiological condition (such as radioactive materials and radiation) exists in the same area, each condition should be identified. When appropriate, signs should be placed in order from greatest to least significant radiological hazard.
- 7) When required, boundaries for posted areas should consist of permanent structures (such as walls or fences) or specific radiological demarcations (such as yellow and magenta rope, chain, or tape). A continuous boundary (except for a designated entry/exit) is required for posting of High Radiation and Contamination Areas.



- 8) Posting of doors should be such that the postings remain visible when doors are open or closed.
- 9) A radiological posting that signifies the presence of an intermittent radiological condition should include a statement specifying when the condition is present, such as "Caution: Radiation Area When Red Light is On."
- 10) Trained or designated personnel may provide continuous coverage, in lieu of postings and barricades, for a limited duration (typically one business day) or until a barricade and postings can be established. In such instances designated personnel shall maintain control of entry into and exit from the affected area.

2.0 POSTING WITH SIGNS

2.1 Laboratory Door Signs

A caution sign shall be posted at each laboratory entrance door where radiological hazards are present. Standard placards are provided by the Environmental Health and Safety Services for all laboratory entrance ways. Radiological postings, as well as other hazard signs, should be affixed to the placards as appropriate for the individual laboratory.

The sign shall include, in addition to the standard radiation symbol and wording, any special precautions to be observed when entering the area and the name of a person to be contacted in case of emergency.

Signs of this type may be obtained from Radiation Safety Office.

2.2 Other Types of Signs

The following signs should be used at the entrance door, or within the laboratory, as appropriate for the locations and radiological hazards present or likely to be present in the affected area.

- 1) **Notice to Employees**

The State of Tennessee Department of Environment and Conservation Division of Radiological Health form "Notice to Employees", or an RSO approved equivalent shall be posted where licensed radioactive materials are used or stored.
- 2) **Caution-Radioactive Materials**

This sign shall be posted where licensed radioactive materials are used or stored.
- 3) **Caution-Radiation Area**

This sign shall be posted in any location, accessible to individuals, where the radiation levels could result in an individual receiving a radiation exposure in excess of 5 millirem in any one hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.
- 4) **Caution-High Radiation Area**
 - This sign shall be posted at the boundary to any location, accessible to individuals, in which the radiation levels could result in an individual receiving a radiation exposure in excess of 100 millirem in any one hour at 30 centimeters



from the radiation source or from any surface that the radiation penetrates.

- High radiation areas require specific controls such as physical boundaries, warning devices, interlocks, etc. or shall be locked or continuously guarded to prevent unauthorized entry.
- Signs for devices which emit ionizing radiation capable of producing a high radiation area only when turned on (x-ray devices, teletherapy units, etc.) should include an additional description such as “when unit is operating”, or an RSO approved equivalent.
- The Radiation Safety Officer, or designee, shall be notified prior to the conduct of any work activity that is planned or suspected to result in the production of any high radiation area that has not been previously approved.

5) **Caution-Contamination Area**

- This sign should be posted for areas accessible to personnel entry that exceed the ALARA action levels for transferable contamination as described in Chapter 7 of this manual.
- Refer to Chapter 7, section 7.1, for additional information regarding transferable contamination action levels and appropriate actions.
- This sign will normally be used only as a temporary measure, pending decontamination of the affected area.
- Contamination on the interior surfaces of closed containers or components should be posted with a radioactive materials tag or label instead of a contamination area sign.

6) **Caution-High Intensity X-Ray Beam**

- This sign shall be posted or adjacent to each x-ray tube housing so as to be clearly visible to any individual who may be working in close proximity to the beam path.
- This sign applies to non-medical open beam x-ray equipment.
- Additional information about postings for x-ray devices may be obtained from the State of Tennessee Department of Environment and Conservation Division of Radiological Health.

3.0 POSTING WITH TAGS, LABELS, AND TAPE

Radiological tags, labels, or tape shall be used when there is a need to caution personnel regarding radiation or contamination hazards from specific items and it would be impractical to use the larger signs normally used for radiological postings.

The following instructions apply to the use of tags, labels, and tape:

- 1) The most commonly needed tags and labels have the standard radiation symbol and the words “Caution, Radioactive Material.”
- 2) As a general rule, locations within posted laboratories that can be closed (freezers,



refrigerators, fume hoods, cabinets, etc.) require posting if radiological hazards lie within.

- 3) Radiological tags or labels should be used to label items with internal or potential internal contamination.
- 4) In addition to the standard radioactive material markings, labeling of containers of radioactive material should include the isotope, quantity, and assay date.
- 5) Items that do not contain radioactive material, are not contaminated, or are not likely to become contaminated or to contain radioactive material should not be posted with radiological markings even if they are used for radiological work. For example, a balance that is kept clean and free of contamination that is used to weigh radioactive materials contained in Petri dishes need not be labeled. A mechanical pipette device dedicated for use with liquid radioisotopes would be appropriate to label (or to keep in a labeled stand or enclosure) due to the potential for internal and external contamination of the device.
- 6) Packaged radioactive material should have the label or tag visible through the package or affixed to the outside.
- 7) Labeling for sealed sources should include the isotope, quantity, and assay date. Sources which are too small to be labeled with all of the stated information should be labeled, at a minimum, with the words "Caution, Radioactive Material" and the standard radiation symbol.
- 8) Radiological warning tape, consisting of yellow and magenta striping with the standard radiation symbol, and/or "Caution, Radioactive Material" tape, should be used as a demarcation of the boundaries of small work areas. An example is a designated area on a bench top covered with absorbent paper and used for radioisotope work. Dedicated radiological work surfaces should not be used for non-radiological work. All items within the boundaries of this type of posted area should be considered potentially contaminated until proven otherwise by a radiological survey.
- 9) Instrumentation or equipment that contains radioactive materials shall be labeled with the words "Caution, this instrument contains Radioactive Materials" or an RSO approved equivalent.

4.0 POSTING AND LABELING OF RADIOACTIVE WASTE CONTAINERS

- When a waste container is in use, post the container with a "Caution Radioactive Material" label/tag.
- Waste container labels should include the isotope(s) and estimated maximum quantity (i.e. mCi amount).
- Waste containers that are empty should be labeled as such.
- Complete the appropriate paperwork for each waste container in accordance with Chapter 11, *Radioactive Waste Handling and Disposal*.



- The use of a labeled shielding enclosure for a waste container does NOT eliminate the need to label the waste container within.

5.0 EXEMPTIONS TO POSTING REQUIREMENTS

The following items/locations are not required to be posted in accordance with this procedure.

- 1) Industrial products that contain exempt quantities of radioactive materials, including; smoke detectors, self illuminated signs, etc.
- 2) Naturally occurring radioactive material (NORM) in exempt quantities or concentrations.
- 3) X-ray, imaging devices, and radioactive materials controlled under medical (human) use protocols or that are controlled in accordance with Chapter 290-5-22, *Rules and Regulations for X-Rays*. This includes a posting exemption for Radiation Areas and High Radiation Areas that are due exclusively to diagnostic or therapeutic radiation producing equipment used in the healing arts.
- 4) Radioactive material shipments that are packaged and labeled in accordance with 49 CFR 172 (DOT regulations).
- 5) Any radioactive materials in quantities less than the amounts specified in 10 CFR 20 Appendix B, Table 2.
- 6) Individual containers of radioactive materials in quantities less than the amounts specified in 10 CFR 20 Appendix C, as long as the containers are properly controlled to prevent unauthorized access, use, or disposal.
- 7) Manufactured products containing exempt radioactive materials as defined by the State of Tennessee Department of Environment and Conservation Division of Radiological Health.
- 8) Items or situations otherwise exempted from posting as described by the State of Tennessee Department of Environment and Conservation Division of Radiological Health.



1.0 PRECAUTIONS / LIMITATIONS

- In situations where personal safety is, or may become, in jeopardy, no radiation safety requirement shall be considered as limiting any action necessary to protect personal health and safety.
- In the event of a fire or release of hazardous materials; warn personnel in the affected area, evacuate the area, call (9) 911, and follow the directions of emergency response personnel.
- The Radiation Safety Officer and staff may be reached by calling Environmental Health and Safety Services (EHS) at 615-898-581. During off-normal working hours, the campus police should be called at 615-494-2424. The campus police have responsibility for notifying the Campus Radiation Safety Officer, Murfreesboro Fire Rescue Department and the 45th Civil Support Team in support of radiological emergencies and incidents.
- Follow all University safety requirements and directions from emergency response personnel during the implementation of all aspects of this procedure.

Note: Radiological incidents such as accidental spills, personnel contamination events, etc. that are handled and reported in accordance with this procedure will NOT result in disciplinary actions to the persons involved unless deliberate misconduct has occurred. Deliberate misconduct does not include accidents or errors, but does include the willful disregard of Radiation Safety policy. Do not hesitate to seek the assistance of the Radiation Safety staff in support of any incident. Failure to report incidents may result in improper actions, violations of policies or regulations, and the unnecessary spread of contamination.

2.0 RESPONSE TO PERSONNEL INJURY IN RADIOLOGICAL AREAS

If a personnel injury occurs in a radioactive materials area, or in the course of performing work with radioactive materials, the following actions should be implemented:

- 1) **Medical considerations are of primary importance.** Radiological concerns are secondary. Administer first aid within the limits of your training and qualifications. Do not attempt to move the victim unless there are significant hazards in the immediate location. Utilize appropriate precautions for blood borne pathogen control (i.e. use gloves, etc.)
- 2) Notify the Authorized User or designee. Follow the guidance of the laboratory safety plan for the handling of personnel injuries including notification to emergency response personnel, if appropriate.
- 3) Notify the RSO of any actual or suspected personnel contamination involving an injury. Follow the directions provided by the RSO. If Radiation Safety personnel arrive on the scene, provide them with all appropriate assistance and information.
- 4) If immediate medical treatment and transport by ambulance is indicated, the Radiation



Safety staff or any individual with radiation safety training should take measures to control the spread of contamination. **Do not interfere with patient care in the course of radiation safety activities.** When emergency response personnel arrive on the scene; offer to assist them by performing monitoring, removing the victims potentially contaminated lab coat or gloves (PPE), or other appropriate actions. Do not attempt decontamination or removal of PPE of injured personnel without the consent of medical professionals. A person with a contaminated injury will be taken to St. Thomas Hospital Rutherford Hospital for treatment.

- 5) An AU, Advanced Radiation Worker, or Radiation Worker with a portable monitoring instrument should continuously accompany the patient until a representative of the Radiation Safety staff arrives or all radiological concerns are resolved.
- 6) If immediate medical treatment is not indicated, the Radiation Safety staff should perform personnel contamination monitoring of the individual(s) involved. If the Radiation Safety staff cannot arrive promptly, any trained individual (AU, ARW, RW) should scan the individual(s) involved for contamination with a portable instrument in accordance with section 4.2 of this procedure.
- 7) If the individual is cleared of radiological contamination take any additional precautions needed to secure the area of radiological hazards. Document survey information on a Radiological Survey Form (RSF) or take notes for future reference to report the incident. Documentation should include the individuals name, social security number, date/time, location, and general circumstances of the event. Perform and document follow up surveys, as appropriate, to ensure that no spread of contamination occurred.

3.0 RESPONSE TO A SPILL OF RADIOACTIVE MATERIAL

3.1 Major Spills

A spill is considered a major spill if it involves millicurie quantities of radioisotopes, includes materials with the potential to produce significant airborne radioactivity (mist, dust, fumes), covers a large area (more than a few square feet of area), or if the spill is not easily contained or controlled. Any malfunctions of radiation producing devices (irradiators, large quantity sealed sources, X-ray devices) with the potential to result in high radiation levels should be treated in the same manner as a major spill.

Respond to a major spill as follows:

- 1) Take no actions which could result in injury or unnecessary contamination to yourself or others.
- 2) Stop work. If necessary secure any immediate safety hazards.
- 3) Warn other individuals in the area. All personnel should leave the immediate area but take appropriate measures not to spread contamination. Potentially contaminated individuals should gather in a location nearby for monitoring prior to being released.
- 4) Isolate the area to prevent the spill from spreading.
- 5) If any volatile materials are involved or if there is the potential for airborne radioactivity,



make sure that fume hoods are operating and that the sash is partially open. Close any available doors to control ventilation. If outdoors, stay upwind.

- 6) Secure the area to prevent personnel access. Lock doors, post warning signs, or post an individual trained in radiation safety to control access to the affected area from a safe distance.
- 7) Notify the RSO or any member of the Radiation Safety staff. If they are not available, contact the campus police.
- 8) Notify the Authorized User (AU) or other individuals responsible for the area.
- 9) Remain in a safe location until assistance arrives.
- 10) Personnel involved should not leave the scene until cleared by Radiation Safety or emergency response personnel.

3.2 Response to Spilled Radioactive Materials on Skin or Personal Clothing

If radioactive material in a dispersible form is spilled onto a person's skin or clothing, take the following actions:

- 1) **If the contamination is associated with a hazardous material, immediately remove the hazardous material using whatever means are necessary to ensure personal safety.** Notify your lab safety representative as soon as possible.
- 2) If the spill is on clothing, immediately remove the clothing and proceed with monitoring of the skin for contamination as described in section 4.2 of this procedure. When removing clothing use caution not spread contamination to other parts of the body, especially the facial area.
- 3) If the radioactive material may have volatile characteristics (radioiodine, S-35, etc), place the contaminated clothing in an operating fume hood or securely closed plastic bag.
- 4) If the radioactive material is spilled directly onto skin, immediately rinse the affected area with running water. It is best to use water that is lukewarm. Cold water may cause the pores of the skin to close, trapping contamination within the layers of skin. Hot water may cause the pores to open, causing a potential avenue for contamination to travel deeper into layers of the skin.
- 5) Pat the affected area dry with a disposable towel and proceed with contamination monitoring as described in section 4.0 of this procedure.
- 6) Promptly notify the RSO or a member of the Radiation Safety staff of any suspected or confirmed radioactive contamination of the skin or personal clothing.

3.3 Minor Spills

A minor spill involves a small quantity of radioactive materials and does not meet the criteria described for a major spill. Minor spills that are recognized and properly controlled should not result in personnel contamination.

A minor spill should be handled as follows:



- 1) Stop work. If necessary secure any immediate safety hazards.
- 2) Warn other individuals in the area to stay out of the spill location. Notify the AU and/or Advanced Radworker, they should perform/direct further activities.
- 3) If assistance is needed, promptly notify the Radiation Safety staff.
- 4) Isolate the area to prevent the spill from spreading. Cover liquid spills with absorbent materials.
- 5) Perform contamination monitoring of any individuals with the potential to have become contaminated as a result of the spill. If personnel contamination is indicated or suspected, refer to section 4.0 of this procedure for instructions.
- 6) Trained personnel wearing gloves, lab coats, and other appropriate PPE should carefully clean up the spilled material. Remove absorbent materials and place in radioactive waste containers for disposal.
- 7) Survey the affected area for contamination in accordance with Chapter 7 of this manual. Compare the survey results to the action levels specified in Chapter 7 and implement appropriate actions in accordance with that procedure.
- 8) If contamination is indicated, decontaminate the affected area as described in section 3.4 or contact the Radiation Safety staff for guidance.
- 9) When contamination is below limits, record the survey on a RSF. Document both the “as found” contamination levels and the final levels following decontamination.
- 10) Provide copies of the survey results to the Radiation Safety Office.

3.4 Decontamination of Areas and Equipment

Area or equipment decontamination (decon) should be performed as follows:

- 1) Wear PPE (lab coat & gloves), control access to the area, and do not allow personal clothing or unprotected skin surfaces to contact potentially contaminated surfaces during decontamination or when performing post-decon surveys.
- 2) Locate the approximate boundaries of the contaminated area by radiological survey (direct scans, wipe testing).
- 3) Mark the boundaries with a temporary marking of tape or by a similar method.
- 4) Carefully clean the affected location using commercial cleaning materials and disposable wipes. Do not use volatile solvents or larger than necessary quantities of water or cleaning solutions.
- 5) If using cleaners applied by spray, do not spray directly onto contaminated surfaces at a close proximity to the surface. Aggressive spray techniques may spread the contamination.
- 6) When wiping with disposable towels, it is often useful to wipe the most highly contaminated section first, covering the smallest practical area and immediately discarding that towel. Then wipe from the outer boundary (less contaminated) toward the center (more contaminated) of the contaminated area. Make single passes when



wiping and use a new surface of the towel for each wipe. An inward spiraling circular motion is often effective. The method used should prevent spreading the contamination.

- 7) Dispose of all waste properly. Wet contaminated towels should be placed in a dry radioactive waste container with sufficient absorbent material to prevent any visible liquid from developing.
- 8) Perform follow up surveys and continue decontamination efforts if needed.
- 9) Perform personnel contamination monitoring after each decon effort.
- 10) If three attempts at decontamination are unsuccessful, you should use different decontamination agents or methods. Contact the Radiation Safety staff for assistance as needed.
- 11) Decontamination is considered complete when a radiological survey indicates that contamination is below appropriate limits, waste materials have been properly disposed of, and surveys have been documented.

4.0 RESPONSE TO SUSPECT PERSONNEL CONTAMINATION

4.1 Precautions

- 1) Verify that no personnel injury has occurred, if the contamination is related to a personnel injury, follow the instructions of section 3.0 of this procedure.
- 2) **If the contamination is associated with a hazardous material, immediately remove the hazardous material using whatever means are necessary to ensure personnel safety.** Notify the lab safety representative as soon as possible.
- 3) If the personnel hazard is not immediate, perform and document contamination survey information prior to removal of the material by decontamination.
- 4) Always notify the Radiation Safety staff of any suspect or confirmed contamination of skin or personal clothing.
- 5) Whenever possible, the affected individual should seek the assistance of another trained Radiation Worker, an ARW, or the AU in handling the situation and in contacting the Radiation Safety staff.
- 6) Stay calm. Remember that the health risks are very minimal from personnel contamination with the typical quantities and concentrations of radioisotopes used at MTSU. A small time delay to take appropriate actions is insignificant compared to the risk of overreacting and causing a personal injury or the spread of contamination.

4.2 Personnel Contamination Monitoring

Perform personnel contamination monitoring as follows:



- 1) Turn the instrument scale to the lowest setting and allow the instrument to stabilize to area background. Personnel contamination monitoring should be performed in an area with the lowest available background radiation levels.
- 2) SLOWLY scan (approximately 2 inches per second) with the detector of the instrument at a distance of approximately 1/2 inch from the surface being monitored.
- 3) Monitor your hands first to ensure that you do not spread contamination.
- 4) Survey all other areas of the body and clothing with the potential for contamination. This should include, but is not limited to, the front of the torso, elbows, arms, face, and shoes (top and bottom).
- 5) If an audible increase in the count rate is heard, or if the meter reading increases, hold the detector still over that location for 5 to 10 seconds and determine if the reading is higher than the background level.
- 6) If contamination is indicated as in item 5 above, it is best to stay where you are to prevent the spread of contamination and have someone assist you in notifying the RSO or a member of the Radiation Safety staff. While waiting for assistance, avoid unnecessary contact between areas of suspected contamination and "clean" surfaces.
- 7) If no contamination is detected, evaluate the situation to determine if additional work area surveys or monitoring of other personnel is indicated.

4.3 Response to Personnel Contamination Events

- 1) If contamination of skin is confirmed, always notify the RSO or a member of the Radiation Safety staff.
- 2) Before beginning decontamination, attempt to determine the location and approximate size of the contaminated area. Record the maximum reading found with the instrument at a distance of 1/2" (near contact) from the contaminated area. For fastest results simply write down the instrument reading and the scale used. In the event that the instrument reading is off-scale at contact, attempt to obtain and record an on-scale reading at a measured distance away. A pencil, pen, or piece of paper may be used to "measure" the distance since this will provide a reference to be measured at a later time. Also note the time (or best estimate) of the initial contamination occurrence. This information is needed to assist in calculating an accurate assessment of the amount of radiation exposure to the skin.

<u>Example:</u>	Time	9:15am
	Approximate size/location	2 square inches, right forearm
	Instrument contact reading	3.5
	Instrument scale	x 0.1 (mr/hr)

- 3) Simple skin contamination can usually be removed by washing the affected area with soft soap and lukewarm water. Make sure that you do not spread the contamination to other areas of the body during the decontamination process.



- 4) Dry the area by patting lightly with a disposable towel. Re-survey the affected area immediately following decontamination. If necessary, repeat decontamination by soap and water.
- 5) When there is no detectable contamination remaining, record the time of the survey.
- 6) If three consecutive decontamination attempts using soft soap and water are not successful, additional measures such as an industrial grade hand cleaners may be used.
- 7) Do not abrade the skin, use harsh chemicals, or attempt decontamination of injuries, the eyes, or body orifices without the assistance of medical professionals and the RSO or designee. However, if no medical complications are apparent, injuries, eyes, or body orifices may be flushed with lukewarm water or saline solution to promptly remove any hazardous materials or radioactive contamination from the affected area. Use precautions not to spread the contamination and capture any rinse water in a suitable container. The rinsate may require analysis in support of a radiation exposure assessment.
- 8) Any facial contamination, contamination involving breaks in the skin, or contamination with the potential for skin absorption or internal contamination will require a determination by the RSO of the need for a bioassay.
- 9) If necessary, restrict and control access to any work locations where contamination events have occurred until follow up surveys can be completed.
- 10) The Radiation Safety staff should perform a preliminary evaluation of incidents to determine the potential causes and to take measures to ensure that no additional personnel contamination events occur as a result of existing conditions or circumstances.

5.0 FOLLOW UP ACTIONS FOR RADIOLOGICAL INCIDENTS

- Document radiological surveys on a Radiological Survey Form or an RSO approved equivalent.
- A *Radiological Improvement Program Report (RIPR)*, or an RSO approved equivalent, should be used for reporting and tracking of significant radiological incidents.
- RSC and DNR notification of incidents will be performed by Radiation Safety in accordance with regulatory requirements and as described in Chapter 12, *Radiological Improvement Program*.
- A critique should be conducted for significant incidents. At a minimum, participants of the critique should include the individuals involved in the incident, the AU, and the RSO or designee. The critique should focus on determining why the event occurred with the goal of determining the appropriate path forward to prevent future occurrences.



1.0 RADIATION SAFETY TRAINING

1.1 Radiation Worker Training

All individuals who work with radioactive materials at the University are considered to be Radiation Workers (Radworkers). Individuals who routinely occupy or frequently work in locations where radioactive materials are used or stored may also be considered Radworkers. All Radworkers must receive documented training in radiation safety. A standard form for use in recording Radworker training is available from Radiation Safety. It is the responsibility of the Authorized User to ensure that this training has been completed. Radworker training should be completed prior to the performance of any tasks using radioactive materials or involving radiation exposure. The minimum requirements for Radworker training shall include:

- Reading this Manual.
- General rules of radiation safety.
- Specific rules for the authorized uses and use locations.
- Directions for contacting the Radiation Safety Officer and Radiation Safety Staff for assistance.
- Directions for notifying the proper authorities in the event of an emergency or accident.

1.2 Advanced Radiation Worker Training

The Authorized User is required to have at least one worker in the authorized use location certified as an Advanced Radiation Worker by successful completion of training approved by Radiation Safety. A period of 90 days will normally be allowed to complete this training requirement. Any individual who is certified as an Advanced Radworker is considered to have met all Radworker training requirements. Advanced Radworkers should provide direct guidance to Radworkers in the performance of radiological work activities.

1.3 Visitors, Members of the Public, and Maintenance Personnel

Visitors, members of the public, and maintenance personnel should not be allowed access to radioactive materials or radiation sources. However, if such personnel should have a justifiable need to perform tasks associated with, or in the vicinity of radioactive materials, they must be adequately protected and informed of the radiation hazards. Radiation exposure to non-Radworker personnel must be kept to minimal levels (<100 mrem/year from all licensed sources). In most cases, direct and continuous guidance should be provided for such activities by a trained Radworker. If this is not practical, appropriate measures must be taken to control access to radiation hazards or radioactive materials, or to perform radiological surveys and release locations or components to unrestricted use.



2.0 RADIOLOGICAL WORK PLANNING

- Plan the layout of the laboratory in relation to your radiological work. When practical, locate all radiological use and storage areas in the same part of your laboratory. The exception to this is to allow adequate distance from radiation sources to reduce personnel exposure.
- Use the smallest reasonable quantity of radioactive material for the desired purpose.
- When a choice of radionuclides is available, use the least hazardous radioisotope for the planned experiment.
- Do not order more radioactive material than needed for the anticipated use. Handling of excess material may increase personnel exposure. Also, regardless of half life, all compounds containing radioactivity undergo decomposition as a result of radiation effects.
- Prior to the individual performance of a first time operation, practice the task with inert (non-radiological and non-hazardous) materials. This is especially important for delicate operations or when working with larger than normal quantities or concentrations of radioisotopes.
- Verify that all needed equipment, instrumentation, and supplies are available and operational prior to beginning radiological work.

3.0 RADIOACTIVE MATERIALS SECURITY

Federal and state regulations require that radioactive material be kept secure from unauthorized access. This requirement applies to all licensed (non-exempt) radioactive materials. See Chapter 8 of this manual, *Radiological Postings* for additional information about exempt radioactive materials. You may meet this security requirement by using one or more of the following options:

- keep the doors locked for all rooms where radioactive materials are located,
- keep all radioactive materials (including waste) in locked enclosures, and/or;
- ensure that all radioactive materials are continuously controlled by individuals with training in radiation safety who are willing to challenge other personnel who might be attempting unauthorized access.

Radioactive material in the form of small quantity sealed sources that are an integral part of a non-portable piece of equipment (i.e. liquid scintillation counters and gas chromatographs) are considered secure from unauthorized access when the equipment is located in an authorized use location.

Note: Any lost or missing radioactive materials must be reported to Radiation Safety immediately.
--

4.0 ENGINEERING CONTROLS

Engineering controls are the physical equipment and mechanical devices used for control of radiological hazards. Engineering controls facilitate the safe performance of radiological work and can reduce the need for restrictive personnel protective equipment.



- 1) Radioactive materials that are handled or used in unsealed forms should be confined to control the release of materials and to prevent the spread of contamination.
- 2) Use trays and/or absorbent surface covers (secondary containment) to catch and retain spilled materials in all appropriate radioisotope work locations.
- 3) Plastic bags may be used for temporary storage of labware or associated contaminated items. The bags should be labeled and only used for short periods of time until the potentially contaminated items are surveyed "clean" of contamination, decontaminated, or held for radioactive decay.
- 4) Use secondary containment devices for any bulk storage of liquid radioisotopes. This should include the use of trays or bins under your liquid waste carboys to contain spills or leakage.
- 5) The use of an approved fume hood is required for any activity likely to generate dust, fumes or vapors containing radioactive materials.
- 6) Fume hoods should be used when working with volatile radioactive materials, and when initially opening vials containing milliCi quantities of radioisotopes.
- 7) Use radiation shielding when working with gamma or high energy beta emitting radioisotopes to keep dose rates ALARA.
- 8) Store radioisotopes in the original shipping container, or in a container that provides equivalent or better radiation shielding than the original shipping container.
- 9) Survey radioactive material use, storage, and waste container locations for radiation dose rates, as described in Chapter 7, *Radiological Surveys*. If significant radiation levels are found at 1 foot from the source, use shielding to lower the work area radiation levels. Contact Radiation Safety for assistance if necessary.
- 10) High energy beta emitting isotopes such as P-32 should be shielded with low density materials such a plastic, plexiglass, or Lucite. This type of shielding is commercially available through lab safety suppliers.
- 11) Gamma emitting isotopes (I-131, Cr-51, Fe-59, etc.) are best shielded with dense materials such as lead bricks, blocks, or sheets. Surplus lead shielding materials are sometimes available on campus, contact Radiation Safety for details. However, use caution when handling or working with lead. Lead (Pb) is considered a hazardous material due to risks of inhalation, ingestion, or absorption of this heavy metal into the body.
- 12) Use remote handling tools in the form of work stands, tongs, tweezers, etc. to reduce exposure to the extremities (hands & fingers) and whole body when appropriate.

5.0 PERSONAL PROTECTIVE EQUIPMENT (PPE)

Personal protective equipment is clothing and equipment that is worn for the purpose of reducing exposure to workplace hazards.

- 1) Lab coats and disposable gloves are considered the minimum acceptable PPE for use by personnel handling unsealed radioactive materials.



- 2) Appropriate footwear with a closed toe (no sandals) must be worn when working with radioactive materials that have the potential to be spilled on the foot.
- 3) If PPE is required for both radiological and laboratory safety purposes, the PPE that provides the greatest protection should be used.
- 4) The use of double gloves (two pair) is encouraged and should be considered mandatory when working with isotopes that can be absorbed through the skin (i.e. tritiated water, radioiodine).
- 5) Eye protection in the form of safety glasses or face shields should be used by persons performing operations with the potential for liquid splash, or during the conduct of procedures that might otherwise result in contamination of the eye.
- 6) Eye protection is also required when handling P-32 (or other high energy beta emitters) in individual quantities >1 millicurie to reduce the amount of Beta radiation that reaches the eye.
- 7) Radiological use PPE should not be worn outside of a posted radioactive materials area or radiological use laboratory. When transporting radioactive materials outside of posted areas, the radioactive materials should be packaged or contained in a manner such that no PPE is necessary.
- 8) Gloves should be monitored periodically during work with radioisotopes. Contaminated gloves should be promptly removed. After removal of contaminated gloves, monitor the inner pair of gloves (or skin surface, if only 1 pair is used) for contamination. If skin or personal clothing contamination is detected, take appropriate actions as described in Chapter 9, *Response to Radiological Incidents*.
- 9) Lab coats should be scanned for contamination at a minimum frequency of monthly, at any time contamination is suspected, and prior to laundering. The ends of the sleeves, front of the lab coat, and pockets are likely locations for contamination to be present. If contamination is detected on a lab coat due to short lived radioisotopes, it may be bagged, labeled, and stored for decay. If the contamination is due to long lived radioisotopes, contact Radiation Safety for recommendations on decontamination. A replacement lab coat should be used until radiological surveys indicate no detectable activity on the previously contaminated lab coat.
- 10) The exemptions to personnel contamination monitoring detailed in section 6.0 below also apply to monitoring of PPE described in this section.

6.0 PERSONNEL CONTAMINATION MONITORING

Personnel contamination monitoring is the only practical method to ensure that your skin or personal clothing is not contaminated with radioactive material. Neglecting to perform monitoring can result in the spread of contamination and increases the risk of inhalation, ingestion, or absorption of radioactive material. Personnel contamination monitoring is commonly referred to as “frisking” in the field of radiation protection.

The following requirements apply to personnel contamination monitoring.

- 1) Personnel contamination monitoring is required prior to exiting a radiological use laboratory after handling unsealed radioactive materials.



- 2) Personnel contamination monitoring should be performed upon the completion of any single operation involving the handling of unsealed radioactive materials.
- 3) The minimum standard for personnel contamination monitoring consists of a slow scan with the probe of a portable monitoring instrument, checking the hands, shoes, and any other areas of the body or clothing with the potential to have become contaminated during the operation conducted.
- 4) After a spill or unplanned contamination event, a “whole body frisk” should be performed. A whole body frisk is a scan of the entire body/clothing for contamination. When properly performed, a whole body frisk takes two to three minutes.
- 5) The “hand & foot frisk” involves a scan of the palms, fingers, and thumbs of both hands and the soles of the shoes. This simple task greatly reduces the risk of inhalation or ingestion of radioactive material and ensures that if contamination is present on floors it is not spread to normally “clean” areas.
- 6) Perform personnel contamination monitoring in a low background area with the instrument on the lowest scale. A background level <0.05 mr/hr is recommended.
- 7) Notify the AU, Advanced Radworker, and Radiation Safety of any instances of skin or personal clothing contamination.
- 8) For additional information about personnel contamination monitoring and response to personnel contamination events, see Chapter 9, *Response to Radiological Incidents*.
- 9) This requirement for personnel contamination monitoring does not apply to laboratories using exclusively H-3 or that are exempted from having a portable monitoring instrument in accordance with Chapter 4, *Facilities and Equipment Considerations*.

7.0 PERSONNEL DOSIMETRY

7.1 Dosimetry Requirements

- 1) Radiation monitoring dosimetry is required for all individuals working with gamma and high energy beta emitting isotopes (P-32, I-125, I-131, Na-22, Tc-99m, Cr-51, etc.) except as noted below.
- 2) Radiation Workers without dosimetry may perform limited tasks approved and supervised by an AU or Advanced Radiation Worker. Individuals without dosimetry should not be exposed to dose rates ≥ 2 mr/hr or allowed to frequent areas with dose rates ≥ 0.2 mr/hr. These radiation exposure levels are for whole body dose rates as measured at 30 cm (approximately 1 foot) from the radiation source.
- 3) Extremity monitoring (finger rings) is required for all individuals performing operations that involve handling individual quantities ≥ 1 milliCi of P-32 or other gamma and high energy beta emitting isotopes.
- 4) Dosimetry is not required for personnel working in laboratories permitted only for milliCi quantities of isotopes which emit primarily beta radiation with energies below 250 keV (H-3, C-14, S-35, and P-33). The exclusive use of I-125 immunoassay kits with < 25 μ Ci per kit is also exempted.



- 5) Laboratories where only small quantities (i.e. $\leq 250 \mu\text{Ci}$) of gamma and high energy beta emitting isotopes are handled during single operations, or where radioisotopes are used infrequently need not have all individuals working with the radioisotopes monitored with dosimetry. In these cases, and as otherwise approved by the Radiation Safety staff, only a representative individual(s) responsible for performing the majority of the radiological work should be monitored.
- 6) Dosimetry may be discontinued for individual workers on a case by case basis if historical data indicates that exposures are consistently minimal. This determination will be made by the Radiation Safety staff.

7.2 Procurement and Control of Dosimetry

- 1) When it has been determined that dosimetry is needed, the individual to be monitored must submit a *Dosimetry Request Form* (or RSO approved equivalent) to Radiation Safety. Allow a minimum of 2 weeks for the processing of a new request for dosimetry.
- 2) Individuals who have had prior occupational radiation exposure at other institutions will need to complete an *Individual Radiation Exposure History Data Sheet* (or RSO approved equivalent) in order to be badged.
- 3) When not in use, dosimetry badges should be stored in a low background area. A designated location for dosimetry badge storage is recommended.
- 4) Take care not to contaminate dosimetry badges. If you suspect your badge may be contaminated, promptly notify Radiation Safety.
- 5) Immediately report lost, misplaced, or damaged dosimetry to Radiation Safety. An investigation in support of a radiation exposure estimate must be initiated for lost dosimetry.
- 6) Radiation monitoring dosimetry is used to determine a legal record of individual radiation exposure received at the University. Never tamper with a badge or wear anyone else's dosimetry.
- 7) Do not use your MTSU dosimetry when traveling to other institutions without the approval of the RSO or designee. Also, do not wear your dosimetry when away from MTSU facilities or during any personal medical care.
- 8) Dosimetry badges are typically changed out on a monthly or quarterly cycle. Turn in dosimetry badges to the designated badge coordinator for your work location at the assigned time. If you are terminating work with radioactive materials at MTSU, you are responsible for returning your dosimetry badge to Radiation Safety in order to ensure that your radiation exposure is properly measured and recorded.

7.3 Radiation Exposure Reports

- Individual radiation exposure reports will be distributed to monitored personnel on an annual basis.
- Individual radiation exposure reports may be requested from Radiation Safety at any time. Requests should be submitted in writing and include the signature of the monitored individual due to the privacy issues associated with radiation exposure reports.



- Radiation exposure report summaries may be provided to Authorized Users or supervisory personnel as a part of the ALARA program. Personal information that is inappropriate for distribution (dates of birth, social security numbers) will be omitted or defaced on these reports. However, the data contained in these summary reports should still be considered confidential with respect to individual privacy.

8.0 RADIATION SAFETY RECORDS

Records in support of the requirements described in this Radiation Safety Manual must be maintained in the laboratory. These records must be available for review by the Radiation Safety staff or regulatory agencies. Unless otherwise specified, it is recommended that records be organized in labeled binders for easy access and to facilitate the review process. Examples of these records include:

- radioactive materials permit application or initial radioactive materials license application
- radioactive materials permit or initial radioactive materials use approval
- radioactive materials permit sign-in sheets (new style permits only)
- radioactive materials permit amendments
- monthly radiological survey records
- sewer disposal records
- radioactive materials inventory summary sheets
- inventory of radioisotopes forms
- training records

9.0 SAFE RADIOLOGICAL WORK PRACTICES

- 1) No eating, drinking, smoking, applying cosmetics, or handling of contact lenses should be performed in a radiological use laboratory or posted radioactive materials area.
- 2) Do not store food, drink, or use/store items for the preparation of food or drink in radiological use areas.
- 3) Radioactive material areas posted exclusively for the presence of sealed sources may be exempt from the two requirements listed above, if specifically approved by the RSO or designee.
- 4) Please be aware that the presence of empty food or drink containers in radioactive material areas may be regarded as evidence of consumption of these products by personnel performing laboratory inspections (either the MTSU Radiation Safety staff or representatives of regulatory agencies).
- 5) Do not work with unsealed radioactive materials if you have any cuts or breaks in the skin with the potential to result in internal contamination. Never pipette by mouth. Avoid all activities that are likely to result in the ingestion, inhalation, or absorption of radioactive materials.



- 6) Store radioactive materials in clearly labeled containers. Labels should include the isotope, quantity, and date.
- 7) Notify the RSO if you have recently had, or are scheduled to have, any medical treatment involving the internal administration of radioactive materials (not X-rays). Individuals who have recently had a medical internal administration of radioactive materials can have incorrect (excessive) exposure recorded on personnel dosimetry and difficulty in monitoring for radiation or contamination.
- 8) Laboratory workers shall not initiate any changes to experimental procedures using radioactive materials without prior approval of the Authorized User or designee. Also, any abnormal occurrences in radiological use locations should be promptly reported to the AU or designee. If the AU is not available, the Environmental Health and Safety Services may be contacted for assistance.
- 9) Radioactive materials are only to be used or stored in authorized use locations. Changes to authorized use locations must be processed through the permit amendment process.
- 10) Radioactive waste must be properly packaged, labeled, and controlled. See Chapter 11, *Radioactive Waste Handling and Disposal* for additional information.
- 11) Perform routine and non-routine radiation and contamination surveys at a frequency adequate to ensure that personnel exposure is ALARA. See Chapter 7, *Radiological Surveys* for additional information.
- 12) During radiological work, a portable monitoring instrument should be turned on and near the work location. When working in a fume hood, the instrument should be in an easily accessible location outside the hood. This requirement does not apply for laboratories exempted from monitoring as described in section 6 of this chapter.
- 13) Potentially contaminated laboratory equipment must be surveyed and determined to be free of contamination in accordance with the requirements of Chapter 7, *Radiological Surveys* prior to removal from a radioactive materials area.

10.0 SPECIFIC RADIOLOGICAL HAZARDS

10.1 Internal Hazards

Contamination occurs when an unsealed radioactive material (liquid or dispersible solid) is in an undesirable location. The primary hazard of contamination is inhalation, ingestion, or absorption of radioactive material into the body. All dispersible radioactive materials may cause contamination and are therefore considered internal hazards. Internal hazards are controlled by surveys and monitoring, engineering controls, and personal protective equipment (PPE).

10.2 External Hazards

Radiation is energy, in the form of particles or waves, emitted from radioactive materials. An external radiation hazard occurs only when the amount of radiation emitted is powerful enough to reach and interact with the human body. External hazards are controlled by the principles of time, distance, and shielding.



- 1) **Time**
Less time exposed equals less total exposure. For example a person in a radiation area for 1 hour where the dose rate is 10 mrem/hr will receive a radiation exposure of 10 mrem. If the time spent in the radiation area was reduced to 30 minutes, the individual exposure would be reduced to 5 mrem.
- 2) **Distance**
If you double the distance from a radiation source your exposure is reduced by a factor of four (inverse square law).
- 3) **Shielding**
Increasing the amount of appropriate shielding also reduces the dose rate from a radiation source. Shielding can be in the form of specifically designed materials as discussed in other parts of this manual. Also, commonly available laboratory materials such as the sash of a fume hood, glassware, water, and shipping containers provide some degree of shielding.

10.3 Radioactive Iodine

- 1) Radioactive iodine (I-125, I-131) is both an internal and external hazard.
- 2) I-125 has a radiological half life of 59.7 days. I-131 has a radiological half life of 8.04 days.
- 3) Radioactive iodine in an unbound state may readily become airborne, resulting in an inhalation hazard. It may also be absorbed into the body via direct contact with the skin. Once inside the human body, radioactive iodine will concentrate in the thyroid gland.
- 4) The most volatile forms are sodium iodide (NaI) and radioiodine in acidic solutions.
- 5) Training for users of radioactive iodine should include observing Radworkers experienced in radioiodine procedures, practicing procedures with non-radioactive materials, and demonstrating proper work practices to an experienced radioiodine worker prior to un-supervised performance.
- 6) Double disposable gloves (wear 2 pair) are required for radioiodine work.
- 7) Only small quantities of radioiodine may be handled on an open bench, such as RIA kits that contain ≤ 25 microcuries. See section 4.1 of Chapter 3 for additional information about fume hood requirements.
- 8) Use syringes and needle guides for removal of radioiodine through the septum of shipment vials. Charcoal traps are also available. Follow the vendor's instructions for the use of these products. If the package insert instructions are not available, refer to vendor catalogs, websites, or call the vendor by telephone for technical information.
- 9) Containers of radioactive iodine must be kept tightly sealed at all times to prevent airborne radioactivity. Ziplock style plastic bags should be used to contain small contaminated items. Remember to seal and label the bags.
- 10) Fume hoods should be used to reduce the risk of inhalation. The sash of the hood should be kept at the lowest practical level during work.



- 11) Monitoring must be performed at frequent intervals to detect and prevent the spread of contamination. A conventional GM probe is very inefficient for the detection of I-125, which emits low energy radiation (electron capture X-rays). A scintillation detector designed for detecting I-125 is the best choice of detector for a portable monitoring instrument. I-131 emits a combination of beta and gamma radiation and is easily detected with portable instruments equipped with conventional GM detectors.
- 12) Contamination surveys should include wipe tests analyzed by liquid scintillation counting or by use of a low energy gamma counter.
- 13) In addition to contamination surveys, radiation dose rate surveys should be performed in radioiodine laboratories, except for laboratories where only small quantity RIA kits are used. Radiation dose rates should be measured at 1 foot from use areas, storage locations, and waste containers as described in Chapter 7, *Radiological Surveys*.
- 14) Individuals working with radioactive iodine must have thyroid bioassays in accordance with the requirements of Chapter 3, *Radiation Exposure Limits*. Notify the Radiation Safety staff to schedule a thyroid bioassay.
- 15) Any individual who has had skin contamination due to radioactive iodine or has reason to suspect that they may have inhaled, ingested, or absorbed radioiodine should promptly notify the Radiation Safety staff to schedule a thyroid bioassay.

10.4 Phosphorus-32

- 1) Phosphorus-32 (P-32) is primarily an external hazard, but it is also an internal hazard. P-32 decays by the emission of a high energy beta particle. This intense beta radiation has the potential to result in very significant personnel exposure, especially to the skin and extremities (hands or fingers). The lens of the eye should also be protected from beta radiation by the use of safety glasses or other protective measures.
- 2) P-32 has a radiological half life of 14.3 days.
- 3) Extremity dosimetry (ring badge) is required for persons performing direct handling of P-32 in individual quantities ≥ 1 millicurie.
- 4) P-32 should never be directly shielded with dense materials such as lead, due to the Bremsstrahlung effect. Bremsstrahlung radiation is the production of X-rays as a result of charged particle interaction with a dense material. After the high energy beta radiation has been attenuated by a low density shielding material (plastic, acrylic, etc.), it may be shielded with lead or other high density materials without generating Bremsstrahlung radiation.
- 5) Plexiglass, acrylic, or Lucite plastic of 3/8" minimum thickness is recommended for shielding of P-32.
- 6) Never work directly over an open container of P-32, since the walls of the container (plastic, glass) provide some shielding for the beta radiation.
- 7) Do not handle containers of P-32 any longer than necessary. Use tongs, work stands, and associated devices to limit direct handling.
- 8) P-32 is not a significant absorption hazard, but like all unsealed materials may be ingested.



- 9) The high energy beta associated with P-32 is easily detected with a portable monitoring instrument using a thin window GM detector (efficiency >30%). Work area surveys for contamination may be performed by direct scans and wipe testing as described in Chapter 7, *Radiological Surveys*.
- 10) In addition to contamination surveys, radiation dose rate surveys should be performed in P-32 laboratories. Radiation dose rates should be measured at 1 foot from use areas, storage locations, and waste containers as described in Chapter 7, *Radiological Surveys*

10.5 Sulfur-35

- 1) Sulfur-35 (S-35) is primarily an internal hazard. However, direct skin contact with S-35 can result in significant beta exposure to the affected location.
- 2) S-35 has a radiological half-life of 87.2 days.
- 3) S-35 has volatile characteristics, especially in the form of cysteine or methionine compounds. Temperature changes promote volatility. Use a fume hood to reduce inhalation risks.
- 4) Some chemical reactions with S-35 can generate sulfur dioxide or hydrogen sulfide, both of which are gases and therefore an airborne (inhalation) hazard.
- 5) S-35 is not a significant absorption hazard, but like all unsealed materials may be ingested.
- 6) Portable survey instruments with thin window GM detectors have a low efficiency for S-35 (approximately 5%), so it is not easily detected by scanning. Direct scanning for contamination must be done slowly (1 to 2 inches per second) in a close proximity (1/2") to the surface being scanned. Contamination surveys should focus on wipe testing with the wipes counted in a liquid scintillation counter.

10.6 Phosphorus-33

- 1) Phosphorus-33 (P-33) is primarily an internal hazard. However, direct skin contact with P-33 can result in significant beta exposure to the affected location.
- 2) P-33 has a radiological half life of 25.3 days.
- 3) P-33 is not a significant absorption hazard, but like all unsealed materials may be ingested.
- 4) Portable survey instruments with thin window GM detectors have an adequate efficiency for S-35 (approximately 15%), so it is easily detected by scanning. Contamination surveys should focus on a combination of scanning wipe testing with the wipes counted in a liquid scintillation counter.

10.7 Tritium

- 1) Tritium (H-3) is an internal hazard. There is virtually no external radiation hazard because the low energy beta radiation emitted is shielded by the outer layer of skin.
- 2) H-3 has a radiological half life of 12.3 years.



- 3) Because tritium is essentially radioactive water, it may easily enter the body through inhalation, ingestion, or absorption. The most volatile form of tritium is tritiated water.
- 4) Tritium will penetrate disposable gloves over time. Wear double gloves and change the gloves often to prevent compromising their effectiveness.
- 5) Portable survey instruments will not detect tritium. Survey for tritium by wipe testing and count the wipes in a liquid scintillation counter.
- 6) Individuals involved in operations which utilize, at any one time, more than 100 millicuries of tritium in a non-contained form, must have a bioassay performed in accordance with the requirements of Chapter 3, *Radiation Exposure Limits*.

10.8 Carbon-14

- 1) Carbon-14 (C-14) is primarily an internal hazard. However, direct skin contact with C-14 can result in significant beta exposure to the affected location.
- 2) C-14 has a radiological half life of 5730 years.
- 3) C-14 can become an inhalation hazard. Radioactive carbon dioxide or similar gases may be generated by chemical reactions. Use a fume hood to reduce inhalation risks.
- 4) C-14 is not a significant absorption hazard, but like all unsealed materials may be ingested.
- 5) Portable survey instruments with thin window GM detectors have a low efficiency for C-14 (approximately 5%), so it is not easily detected by scanning. Direct scanning for contamination must be done slowly (1 to 2 inches per second) in a close proximity (1/2") to the surface being scanned. Contamination surveys should focus on wipe testing with the wipes counted in a liquid scintillation counter.

10.9 Other Radioisotopes

The previous information covers the significant hazards associated with some of the commonly used research radioisotopes at MTSU. For specific information about the hazards of other radioisotopes, contact Radiation Safety and review any vendor supplied information. You should always be aware of the primary hazards (internal, external, or both) and methods of detecting the radioisotopes that you are using.

10.10 Sealed Sources

- 1) Sealed radioactive sources are primarily an external radiation hazard. However, sealed sources must be used, handled, and stored in such a manner as to prevent the source from becoming an internal (contamination) hazard.
- 2) No sealed source may be opened or modified in any way. Sources may not be machined, drilled, cut, or altered.
- 3) Avoid handling the active surface of sources. Use tweezers, tongs, or other remote handling devices when working with sources that have the potential to produce significant personnel exposure. However, when using remote handling devices, take precautions not to scratch or damage the surface of the source.



- 4) Do not clean sealed sources with abrasives, chemicals, etc. Avoid other potentially damaging conditions such as temperature extremes, mechanical shock, etc.
- 5) Sealed sources must be labeled and posted as with any radioactive materials. They are also subject to the same security requirements.
- 6) Radioactive sources in electronic devices (i.e. gas chromatographs) must not be removed from the detector cells. Do not open or attempt to clean detector cells in these devices.
- 7) Sealed sources shall be leak tested at a frequency specified by the Radiation Safety Office. A leak testing kit will normally be sent to the Authorized User by the Radiation Safety staff at appropriate intervals.

11.0 USEFUL FORMULAS, CONVERSION FACTORS, AND TABLES

Radioactive Decay

This formula may be used to determine the actual activity of a radioactive source by calculating the correction for radioactive decay. Activity can be in units of curies, dpm, etc.

Elapsed time and half life must be in the same units (i.e. hours, days, years).

Decay Formula

Where: A = Activity

$$A = A_0 e^{-0.693 t / T_{1/2}}$$

A₀ = Original Activity

e = base of natural log

t = elapsed time

T_{1/2} = half life

“Rules of Thumb” for Radioactive Decay

- After 7 half-lives the activity of any radioisotope is reduced to <1% of the original value.
- For radioisotopes with half-lives >6 days, the change in activity in a single 24 hour period is <10%.

Inverse Square Law (Point Source)

The inverse square law may be used to calculate the dose rate at a known distance from a radiation source (point source), when another dose rate and distance are known. For example, if a radiation source is generating a known dose rate at 1 foot, you could use this formula to calculate the dose rate at 3 feet.

$$(I_1) (D_1)^2 = (I_2) (D_2)^2$$

Where: I₁ = dose rate at 1st distance (initial dose rate)

D₁ = 1st distance (initial)

I₂ = dose rate at 2nd distance (new dose rate)

D₂ = 2nd distance (new distance)



Gamma Exposure Rate Calculation

This formula may be used to calculate the dose rate at one foot from a radioactive source, when the activity of the source in curies and the isotope are known. This formula is effective only for gamma radiation dose rates.

$$I_{1ft} = 6CEN$$

Where: I = the gamma dose rate in Rem/hr at one foot

C = the source activity in curies

E = the gamma energy in MeV

N = the photon yield

- Accuracy is approximately 20% for gamma energies from 0.05 to 3 MeV.
- If N is not given, assume 100% photon yield (N=1).
- If more than one photon energy is given, take the sum of each photon energy multiplied by its percentage.

For example Co-60 emits a 1.173 and a 1.332 MeV gamma, both at a 100% yield. Therefore the EN value of the equation for Co-60 is $(1.173 \times 1) + (1.332 \times 1) = 2.505$

The calculated gamma dose rate at 1 foot from a 100 millicurie Co-60 source would be:

$$I_{1ft} = 6CEN$$

$$I_{1ft} = 6 \times 0.1 \text{ Ci} \times 2.505$$

$$I_{1ft} = 1.503 \text{ Rem/hr} = 1,503 \text{ mrem/hr}$$

Beta Dose Rate Calculation

The dose rate at 1 cm from a beta emitting point source varies only slightly with differences in energy of the beta radiation. However, note that beta radiation is rapidly attenuated in air.

As a “rule of thumb”, the following equation may be used to estimate the 1 cm (contact) dose rate with a beta emitting point source:

$$\text{Beta Dose Rate @ 1cm} = 300 \text{ rad/hr per mCi}$$

The beta dose rate in a solution may be estimated by the following formula:

$$\text{Dose Rate (rad/hr in a solution)} = 2.12 \times E_{\text{avg}} \times C$$

Where E_{avg} = the average beta energy in Mev and C = the concentration in $\mu\text{Ci}/\text{cm}^3$.

This assumes a density of approximately $1 \text{ gram}/\text{cm}^3$.

The dose rate at the surface of the solution will be approximately $\frac{1}{2}$ of the value in the solution.



Beta Particle Energy and Range Estimation

As a "rule of thumb", the average energy (E_{avg}) of a beta particle is 1/3 of its maximum energy (E_{max}).

For example: P-32 $E_{max} = 1.71$ MeV, therefore the E_{avg} is approximately 0.6 MeV

The range in air for a beta particle is approximately 12 feet per MeV.

Using the average energy of 0.6 MeV for P-32 gives an average range in air of 7.2 feet. The maximum range in air for a P-32 beta by this calculation is 20 feet.

Based on this thumb rule, a person observing an experiment with P-32 would be unlikely to receive any significant beta radiation exposure if they were more than 7.2 feet from the source.

Unit Conversion

Based on a given set of units, you may convert to a desired unit by means of a conversion factor. The conversion factors shown here are ratios of two equivalent physical quantities expressed in different units. When expressed as a fraction, the value of a conversion factor is 1.

Conversion factors in the form of fractions may be built as shown in the following example:

1 millicurie (mCi) of a radioisotope has been diluted in a gallon of solution. What is the activity of the solution in $\mu\text{Ci/ml}$?

Given: 1 mCi/gal, convert to units of $\mu\text{Ci/ml}$

Units: 1 mCi = 1000 μCi
1 liter = 0.26418 gal
1 liter = 1000 ml

The unit conversion formula may be set up as follows:

$$\frac{1 \text{ mCi}}{1 \text{ gal}} \times \frac{1000 \mu\text{Ci}}{1 \text{ mCi}} \times \frac{0.26418 \text{ gal}}{1 \text{ liter}} \times \frac{1 \text{ liter}}{1000 \text{ ml}} = 0.26418 \mu\text{Ci/ml}$$

Note that the un-desired units cancel each other out. When only the desired units remain, the conversion has been properly set-up and may be calculated.

Radiological Unit Conversion Factors

Curie units

1 curie (Ci)	1 E +3 millicurie (mCi)
1 curie (Ci)	1 E +6 microcurie (μCi)
1 curie (Ci)	1 E +9 nanocurie (nCi)
1 curie (Ci)	1 E +12 picocurie (pCi)

Standard activity units

1 curie (Ci)	3.70 E +10 dps
1 curie (Ci)	2.22 E +12 dpm
1 millicurie (mCi)	2.22 E +9 dpm



1 microcurie (μCi)	2.22 E +6 dpm
1 nanocurie (nCi)	2.22 E +3 dpm
1 picocurie (pCi)	2.22 dpm

Rem Units

1 rem	1000 millirem (mrem)
1 rem	1 E +6 microrem (μrem)
1 millirem (mrem)	1000 microrem (μrem)

International activity units

1 Megabecquerel (MBq)	1 E +6 dps
1 becquerel (Bq)	1 dps

Curie to Becquerel conversion

1 curie (Ci)	37 Gigabecquerels (GBq)
1 millicurie (mCi)	37 Megabecquerels (MBq)
1 microcurie (μCi)	37 kilobecquerels (kBq)
1 nanocurie (nCi)	37 becquerels (Bq)
1 picocurie (pCi)	37 millibecquerels (mBq)

Becquerel to Curie conversion

1 Terabecquerel (TBq)	27 curies (Ci)
1 Gigabecquerel (GBq)	27 millicuries (mCi)
1 Megabecquerel (MBq)	27 microcuries (μCi)
1 kilobecquerel (kBq)	27 nanocuries (nCi)
1 becquerel (Bq)	27 picocuries (pCi)

Rem to Sievert conversion

100 rem	1 sievert (Sv)
1 rem	10 millisievert (mSv)
1 millirem (mrem)	10 microsievert (μSv)
1 microrem (μrem)	10 nanosievert (nSv)

Rad to Gray conversion

100 rad	1 gray (Gy)
1 rad	1 centigray (cGy)
1 rad	10 milligray (mGy)
1 millirad (mrad)	10 microgray (μGy)
1 microrad (μrad)	10 nanogray (nGy)



1.0 RADIOACTIVE WASTE REDUCTION

1.1 Limiting Waste Production

Whenever practical, limit the production of radioactive waste. Some ways to limit waste production include:

- Training personnel in proper handling and disposal of waste.
- Using the safe work practices and containment devices described in Chapter 10, Laboratory Procedures.
- Avoiding the use or storage of non-essential items or excess packaging materials in locations where they may become contaminated.

1.2 Segregation of Radiological and Non-radiological Waste

- Radioactive waste should be limited to non-useable radioactive materials or to materials that are known or likely to be contaminated with radioactive materials.
- Never dispose of non-radioactive waste in radioactive waste containers.
- When appropriate to reduce waste volumes, perform radiological surveys of potentially contaminated dry solid materials to verify that the materials are suitable for non-radioactive disposal or release to unrestricted use.
- Potentially contaminated liquids or dry bulk materials (powders, granulated materials, etc.) may be sampled and analyzed for release as described elsewhere in this chapter.
- Always keep radioactive waste containers closed and properly labeled to reduce the likelihood of spills or improper disposals.

1.3 Re-Use and Transfer of Materials

- Properly label and store contaminated items or equipment for re-use.
- When appropriate, decontaminate items instead of disposing of them.
- Items contaminated with short half life isotopes may be packaged, labeled, and stored for radioactive decay. After being allowed to decay for 10 half-lives, the materials may be surveyed or analyzed for release to unrestricted use.

Radioisotopes or contaminated equipment may be transferred from one Authorized User to another instead of becoming waste. Always contact Radiation Safety prior to initiating a transfer.



2.0 DRY SOLID RADIOACTIVE WASTE HANDLING

2.1 Segregation of Dry Solid Waste

Segregate dry solid radioactive waste according the following categories:

- 1) Long lived waste (half-life >120 days)
- 2) Short lived waste (half-life <120 days)
- 3) Long lived mixed waste
- 4) Short lived mixed waste
- 5) Sealed radioactive sources

Long lived waste will normally be stored by Radiation Safety pending disposal via a commercial radioactive waste disposal vendor. Please limit the production of this type of waste since commercial disposal is expensive. Long lived dry waste may be mechanically compacted to achieve volume reduction or incinerated by a licensed vendor. Non-compactable materials and materials that cannot be incinerated should not be put into containers of long lived dry radioactive waste. Non-compactable and non-incinerable materials include, but are not limited to, metal objects, aerosol cans, and lead shielding materials.

Short lived waste will normally be held for radioactive decay by Radiation Safety. Following decay for a time period of 10 radioactive half-lives, the waste will be monitored for the presence of residual radioactivity. If no residual radioactivity is detected the waste will be disposed of as non-radioactive. Containers used to store short lived waste will be returned to the Authorized User after disposal of the contents.

Mixed waste is any combination of a hazardous waste and a radioactive waste. Handling and disposal of mixed waste is expensive. A hazardous waste is any material listed as hazardous by the EPA (refer to the MSDS for this information). Consult with the Environmental Health and Safety Services prior to generating mixed waste. If the estimated cost of disposal of a quantity of long-lived dry mixed waste exceeds the average cost of disposal of a similar quantity of long-lived dry radioactive waste by more than 10%, this will trigger a review by the Radiation Safety Committee. The RSC may then require the Authorized User who generated the waste to arrange for funding to pay for all or part of the disposal costs beyond the average disposal cost for a drum of long-lived dry waste. Short lived mixed waste will be held for radioactive decay and disposed of as hazardous waste.

Sealed radioactive sources consist of radioactive material that is permanently bonded or constructed in such a manner as to prevent the release or dispersal of the radioactive material under normal use conditions. Certain instruments and manufactured articles contain sealed radioactive sources such as gas chromatographs and liquid scintillation counters. Contact Radiation Safety for specific instructions regarding disposal of sealed sources or surplus equipment that contains radioactive material. If the estimated cost of disposal of one or more sealed radioactive sources submitted for disposal by an Authorized User exceeds the average cost of disposal of a standard size drum of long-lived dry radioactive waste by more than 10%, this will trigger a review by the Radiation Safety Committee. The RSC may then require the Authorized User who generated the waste to arrange for funding to pay for all or part of the disposal costs beyond the average disposal cost for a drum of long-lived dry waste.



The above listed categories should be additionally sub-divided into separate containers when appropriate. For example, different types of hazardous (mixed) waste should not be combined into one container.

Note: Dry radioactive waste materials that are in process will be referred to as **dry active waste (DAW)**. “In process” means that the materials have not officially been classified as radioactive waste for purposes of transportation and final disposal. Treatment options, such as decay in storage, compaction, and incineration, may be used prior to the final classification of this material as low level radioactive waste.

2.2 Dry Active Waste (DAW) Containers

- 1) The standard container for DAW is a 30 gallon fiber drum with a reinforced metal lock-rim closure lid.
- 2) Alternative approved containers include 5 gallon plastic pails with secure screw top lids and 10 to 20 gallon capacity all fiber drums. All fiber drums are preferred for use with long lived DAW because they are completely incinerable, although they may be used any time a smaller container is more practical. Smaller containers should be used only in laboratories that generate small quantities of DAW, so that the need for waste pick-ups will not be excessive.
- 3) Other special use containers may be approved by the RSO/RSC on a case by case basis.
- 4) Authorized Users that use more than one of the categories listed in section 2.1 must have separate containers for each category.
- 5) Procurement of waste containers is the responsibility of the Authorized User.
- 6) Clearly label the containers and train laboratory personnel to prevent the possibility of mixing the different categories of waste.
- 7) All radioactive waste containers must be marked with the standard radiation symbol and the words “Caution, Radioactive Materials.” Labeling should also include the isotope(s) and the estimated maximum activity (mCi) in the container. A minimum of two labels should be used with each label placed on opposite sides of the container.
- 8) Empty waste containers should be marked with an “Empty” label in addition to the radioactive materials label.
- 9) Temporary collection containers for waste may be used to improve efficiency and reduce the risk of spills. The physical construction of the container must be appropriate for the type of waste. Temporary collection containers should remain closed when not in active use and must not be allowed to overflow. Temporary collection containers should be labeled in the same manner as other waste containers.
- 10) All DAW containers must be lined with a removable polyethylene liner bag (or bags) to achieve a minimum thickness of 4 mil. Liner bags should not have radioactive materials markings and should not be closed or labeled with radiological warning tape.
- 11) Used waste containers that are no longer needed must be turned over to Radiation Safety for disposal or reuse on campus.



2.3 DAW Packaging

- 1) No free standing (visible) liquids of any kind may be placed in a DAW container.
- 2) Small amounts of liquid may be added to absorbent materials and then placed in the container. Ensure that a sufficient quantity of absorbent material is used when absorbing liquids for disposal as DAW.
- 3) Empty liquid containers may be placed in the dry waste container, but they must not contain any free standing liquid. Empty liquid containers should have the lids removed prior to disposal to prevent moisture condensation during storage.
- 4) Empty scintillation vials that were used for analysis of H-3 or C-14 may be disposed of in regular (non-radioactive) trash. Empty scintillation vials that were used for analysis of other isotopes may be disposed of in regular (non-radioactive) trash, IF the count rate of the samples did not exceed 500 cpm. This value is based on the fact that only a small percentage of the original activity in the scintillation cocktail will remain on the surface of the empty vial as contamination. If the counting results exceed this value the empty vials must be rinsed with water. According to industry standards a triple rinse will remove >90% of the residual activity. The rinsed vials may then be disposed of as non-radioactive.
- 5) Items that have a high moisture content require special handling. When appropriate, dry these items under low heat in a fume hood prior to disposal. If this is not practical, you must surround these items with a sufficient quantity of absorbent materials to eliminate all free standing liquids that are present or likely to develop during storage.
- 6) Destroy and/or deface all radiological markings and radiation symbols prior to disposal of items in DAW containers used for short lived radioisotopes.
- 7) Sharp objects such as hypodermics, broken glass, and other sharp items must be packaged to avoid injury to persons who must handle the waste. Place such objects in an industry standard "sharps" container or in a plastic jar and secure with tape before placing in the dry waste container. (Label as sharp objects). Do not use radiological warning tape to secure the container if it is to be disposed of in a DAW container used for short lived radioisotopes.
- 8) Other than the obvious exceptions of sharp objects (Pasteur pipettes, syringes and hypodermic needles), un-damaged glassware should not be placed into a radioactive sharps container. Most glass items (test tubes, vials, etc.) can be decontaminated by washing with an industrial strength detergent.
- 9) Aerosol containers such as spray cans must not be disposed of as dry radioactive waste. Aerosol containers are hazardous when waste is being mechanically compacted. If the can is sealed and the contents are not radioactive, survey (and if necessary decontaminate) the outside of the container and dispose of as non-radioactive.
- 10) Lead (Pb) shielding materials must not be placed into a dry waste container. Lead waste is considered hazardous waste. If suspected to be contaminated, lead shielding should be surveyed for contamination in accordance with Chapter 7, *Radiological Surveys*. Contact Radiation Safety for specific information regarding disposal or decontamination of contaminated lead. Do not attempt to decontaminate lead by cutting, heating, or abrasive methods due to the risk of inhalation and ingestion of this hazardous material.



- 11) The maximum acceptable weight limit for an individual DAW container is 50 pounds.
- 12) Sealed radioactive sources shall not be put in DAW containers without specific approval from Radiation Safety.
- 13) DAW containers used for short lived waste will be returned to the Authorized User after disposal of waste. In order to facilitate the return of used containers, label the container with the name of the Authorized User and ensure that liner bags are used in such a manner that the container does not become contaminated. Since containers will be held for radioactive decay, extra containers should be purchased for use while full containers are being stored by Radiation Safety pending disposal.
- 14) If early return of containers is desired, very short-lived waste such as Phosphorous-32 (half life = 14 days) may be collected separately from other short-lived waste such as Sulfur-35 (half life = 88 days). Containers with both isotopes must be stored for 880 days based on the half life of Sulfur-35. Phosphorous-32 containers must be stored for only 143 days.
- 15) DAW containers will be checked for content and activity after pick-up. If radioactive materials are discovered to have been improperly packaged or labeled, the Authorized User will be held responsible for repackaging the waste.

2.4 Method for Determining the Amount of Radioactivity in DAW

The contents of a typical dry active waste container consist of 2 primary components: associated waste and known additions. This section describes the methodology for determining the amount of radioactivity that each of these components contributes to the total activity of the container.

Associated Waste

The majority of the volume of most DAW is associated waste. Associated waste consists of general laboratory waste that has been in contact with radioactive materials and is therefore potentially contaminated. Associated waste includes such items as used gloves, paper towels, disposable pipette tips, etc. Associated waste may be subdivided into two types: secondary contact waste and direct contact waste.

- 1) **Secondary Contact Waste**
The bulk of associated waste is secondary contact waste. Secondary contact waste consists of materials that have been in limited contact with radioactive materials or have only been in contact with diluted radioactive materials. Based on standard models of transferable contamination, secondary contact waste is calculated to be contaminated to a maximum level of 1% of the original activity with which it was used.
- 2) **Direct Contact Waste**
The other component of associated waste is direct contact waste. Direct contact waste is waste that has been in direct contact with un-diluted radioactive materials (stock solutions). Based on standard models of transferable contamination, direct contact waste is calculated to be contaminated to a maximum level of 10% of the original activity with which it was used.



Associated Waste Contamination Factor

Based on these criteria, the activity of the associated waste in a DAW container may be calculated as follows:

$\% \text{ Secondary Contact Waste} \times 1\% = \text{Secondary Contact Waste Contamination Factor (SCWCF)}$

$\% \text{ Direct Contact Waste} \times 10\% = \text{Direct Contact Waste Contamination Factor (DCWCF)}$

$\text{SCWCF} + \text{DCWCF} = \text{Associated Waste Contamination Factor (AWCF)}$

Based on a standard model of 80% secondary contact waste and 20% direct contact waste, the Associated Waste Contamination Factor for use at MTSU is 3%. Therefore, 3% of the total radioactivity that was used during the time period from the initial date the container was put in service to the date of closure is the calculated activity of the associated waste in the container.

In the event that a laboratory's associated waste does not meet this standard model, Radiation Safety will develop a revised Associated Waste Contamination Factor (AWCF) based on input from laboratory personnel regarding the characteristics of waste generated.

Known Additions

When radioactive materials of a known isotope and activity are added to the container, these materials should be listed separately from associated waste and added to the total activity of the container. Known additions include any media suitable for the dry waste container that contains measured or calculated quantities of radioisotopes. If there are no known additions to a waste container the total activity of the contents will be determined exclusively by use of the associated waste contamination factor.

2.5 Use of the DAW Container Log

- Initiate a *DAW Container Log* when a dry active waste container is put into service. A *DAW Container Log* may be printed and attached to the container with the start date and isotope(s) listed on the form. Known additions and the B Numbers of completely used radioisotope orders may be written on the form in the spaces provided as waste is being added to the container. The *DAW Container Log* may also be maintained exclusively in an electronic format as long as the container is labeled with the standard radiation markings, the isotope(s), and the estimated total activity that the container is likely to hold.
- Use separate containers and log sheets for each category of waste, as described in section 2.1 of this chapter.
- If more than one container is in use at any one time, special care must be taken not to mix up the data from one log sheet to another.

When a DAW container is full or when you are ready to have the container picked up by Radiation Safety, the following tasks must be performed:

- 1) The final copy of the *DAW Container Log* should be completed in an electronic format for increased efficiency. The electronic format must be approved by the RSO and



obtained from Radiation Safety. After the electronic form is completed, it must be printed and signed. A signed copy is required for labeling the container.

- 2) If the electronic format *DAW Container Log* is unavailable or is not being used for any reason, the data may be entered by hand on the form. Radioactivity calculations will have to be performed manually. Contact Radiation Safety for assistance if needed.
- 3) Record the required data in support of the associated waste calculation to account for non-specific waste in the container.
- 4) Record the addition of known quantities of radioactive materials in the space provided.
- 5) The total amount of radioactivity in the container is the total of the associated waste calculation and the known additions. The electronic version of the form will perform the required mathematical calculations automatically.
- 6) Perform a contamination survey of the exterior of each container and record the results in the space provided on the form. Contamination levels on containers must not exceed 1000 dpm/100 cm². Contaminated containers should be decontaminated and resurveyed as described in Chapter 10, *Laboratory Procedures*.
- 7) Perform a radiation dose rate survey of the exterior surface of the waste container and record the results in the space provided on the form. If the contact dose rate exceeds 0.5 mrem/hr, notify Radiation Safety of the dose rate on the container when you request a pick-up. The Radiation Safety staff will verify the radiation dose rates and provide appropriate labeling for the container at the time of pick-up.
- 8) Sign and date the form in the space provided. Waste container paperwork should only be completed by, or under the supervision of, an Authorized User or Advanced Radworker.
- 9) Attach the completed *DAW Container Log* to the container and notify Radiation Safety that the container is ready for pick-up.

3.0 ANIMAL CARCASSES AND BIOHAZARDOUS WASTE

Note: Refer to the University's Biosafety Manual for specific information about biohazardous waste.

- 1) Notify Radiation Safety prior to initiating any new projects resulting in the generation of animal carcasses or biohazardous waste contaminated with radioactive materials.
- 2) Animal carcasses and biohazardous waste may be disposed of as if it were not radioactive IF the disposal is documented and approved by Radiation Safety, the disposal method is appropriate for the physical and biohazardous properties of the material, and the material consists of one or more of the following:
 - Animal tissue that does not contain more than 0.05 μ Ci of H-3 or C-14 per gram.
 - Waste that contains radioisotopes in concentrations that do not exceed the appropriate effluent limit specified in 10 CFR 20 Appendix B, Table 2.
 - Waste that contains short lived radioisotopes that has been held for radioactive decay for a minimum duration of 10 half lives and when monitored with an appropriate portable instrument shows no detectable activity.



- 3) Animal carcasses and biohazardous waste must be properly labeled and safely stored pending disposal.
- 4) Any radioactive biohazardous waste will NOT be picked up for storage or disposal by Radiation Safety unless the Authorized User has verified that the waste has been deactivated, decontaminated, or sterilized.
- 5) Waste that has been deactivated, decontaminated, or sterilized should not be labeled as biohazardous. Radioactive waste in bags or containers with biohazard labels will not be picked up for disposal by Radiation Safety.

4.0 LIQUID RADIOACTIVE WASTE HANDLING

4.1 Segregation of Liquid Waste

Segregate liquid radioactive waste according the following categories:

- 1) Long lived waste (half life >120 days)
- 2) Short lived waste (half life <120 days)
- 3) Long lived mixed waste
- 4) Short lived mixed waste
- 5) Non-biodegradable liquid scintillation counting fluid containing exclusively H-3 and/or C-14 in concentrations not to exceed 0.05 $\mu\text{Ci}/\text{gram}$

Note: For best results when performing radioactive analysis of liquids, use separate containers for each radioisotope.
--

Disposal of liquid waste is typically performed using the following methods as appropriate for the isotopes, concentration, and form.

- Consolidate compatible materials,
- Sample and analyze for isotope/quantity,
- Release liquids with radioactivity levels below the ALARA action levels,
- Hold materials for radioactive decay,
- Perform disposal by sewer discharge in accordance with the limits of 10 CFR 20, Appendix B and the State of Tennessee *Rules and Regulations for Radioactive Materials*; or
- Perform disposal by off-site shipment to an approved waste disposal vendor.

The production of long-lived liquid mixed waste should be kept to a minimum. If the estimated cost of disposal of a quantity of long lived liquid mixed waste exceeds the average cost of disposal of a standard size drum of long-lived dry radioactive waste by more than 10%, this will trigger a review by the Radiation Safety Committee. The RSC may then require the Authorized User who generated the waste to



arrange for funding to pay for all or part of the disposal costs beyond the average disposal cost for a drum of long-lived dry waste.

Short lived liquid mixed waste will be held for radioactive decay by Radiation Safety and disposed of as hazardous waste.

State of Tennessee regulations permit disposal of 0.05 μ Ci or less of H-3 or C-14 per gram of medium used for liquid scintillation counting as if they were not radioactive. Also, scintillation fluid that contains other radioisotopes in concentrations below the ALARA action levels may be released. However, regulations require that appropriate records are kept for all waste disposals. Therefore, liquid scintillation fluid should be segregated by half-life and hazardous waste considerations, and consolidated into waste containers with other similar liquids for sampling and disposal. See section 4.2 for additional information about liquid scintillation fluid.

The above listed categories of waste should be additionally sub-divided into separate containers when appropriate. For example, different types of hazardous (mixed) waste should not be combined into one container. Liquids with low specific activity (i.e. buffers, dilutions, or rinsates with low concentrations of radioactivity) may be segregated into separate containers from liquids with higher specific activity. Liquids should always be segregated by isotope. This will facilitate sampling and analysis for release in accordance with the unrestricted area action levels described below.

The ALARA action levels for release of liquids represent 20% of the liquid effluent release values permitted by the Nuclear Regulatory Commission (NRC) in accordance with 10 CFR 20, Appendix B, Table 2, Column 2. These values are based solely on the concentration (μ Ci/ml) of radioactivity in the liquid. Each individual radioisotope has its own limit. Since some limits are much lower than others these action levels will be limited to the radioisotopes commonly used on campus that have release limits easily detected by conventional sample counting equipment. These very low levels of radioactivity are considered safe for release. See section 5.3 for additional information.

Disposal of waste by radioactive decay is performed by the Radiation Safety staff. Although some radioactive decay does occur while waste is being accumulated in authorized use locations, the tracking, storage, monitoring, and disposal of waste via the radioactive decay process is performed in a designated facility by Radiation Safety.

Sewer disposal involves the discharge of carefully measured and tracked quantities of radioactive liquids into the sanitary sewer system. These disposals may only be performed in accordance with specific regulatory limits on both the concentration of radioactivity in a liquid and the total amount of radioactivity that the University may release on a monthly and annual basis. Due to the large volume of water in a municipal sanitary sewerage system, these disposals become diluted and therefore do not contribute significantly to environmental radioactivity levels. The vast majority of sewer disposal at MTSU is performed by the Radiation Safety staff. Short lived radioisotopes are typically held for radioactive decay prior to disposal. Specific approval for sewer disposal may be granted to Authorized Users by the RSC on an individual basis. Adding or terminating sewer disposal approval is handled via the Radioactive Materials Permit amendment process.

Radioactive waste disposal by off-site shipment to an approved waste disposal vendor is performed exclusively at MTSU by the Radiation Safety staff. Such shipments are strictly regulated and expensive operations.

4.2 Disposal of Used Liquid Scintillation Counting Fluid



- 1) LSC fluid should be verified biodegradable by checking the manufacturer's specifications prior to purchase.
- 2) Biodegradable liquid scintillation fluid should be consolidated into a liquid waste carboy and segregated by isotope.
- 3) Non-biodegradable liquid scintillation fluid or any scintillation fluid that contains hazardous chemicals must be controlled as hazardous or mixed waste. Refer to Material Safety Data Sheets (MSDS) to determine if a material is listed as hazardous by the EPA. However, hazardous wastes that contain radioactive materials in concentrations below the effluent release limits of 10 CFR 20 will be considered hazardous waste and not mixed (radioactive) waste. Consolidate these liquids into a separate carboy for analysis by Radiation Safety prior to disposal.
- 4) Non-biodegradable liquid scintillation fluid or any scintillation fluid that contains hazardous chemicals containing exclusively H-3 or C-14 in concentrations below 0.05 μCi per ml will be considered hazardous waste and not mixed (radioactive) waste. Consolidate these liquids into a separate carboy for analysis by Radiation Safety prior to disposal.
- 5) If you are counting wipe test samples for surface contamination measurements, you may dispose of any wipe samples, the associated scintillation fluid, and the vials as non-radioactive IF the wipe test results are <200 dpm.
- 6) If any individual sample counting results are less than 2 standard deviations above the counting instrument's background, the scintillation fluid and sample vial may be disposed of as if it is not radioactive.

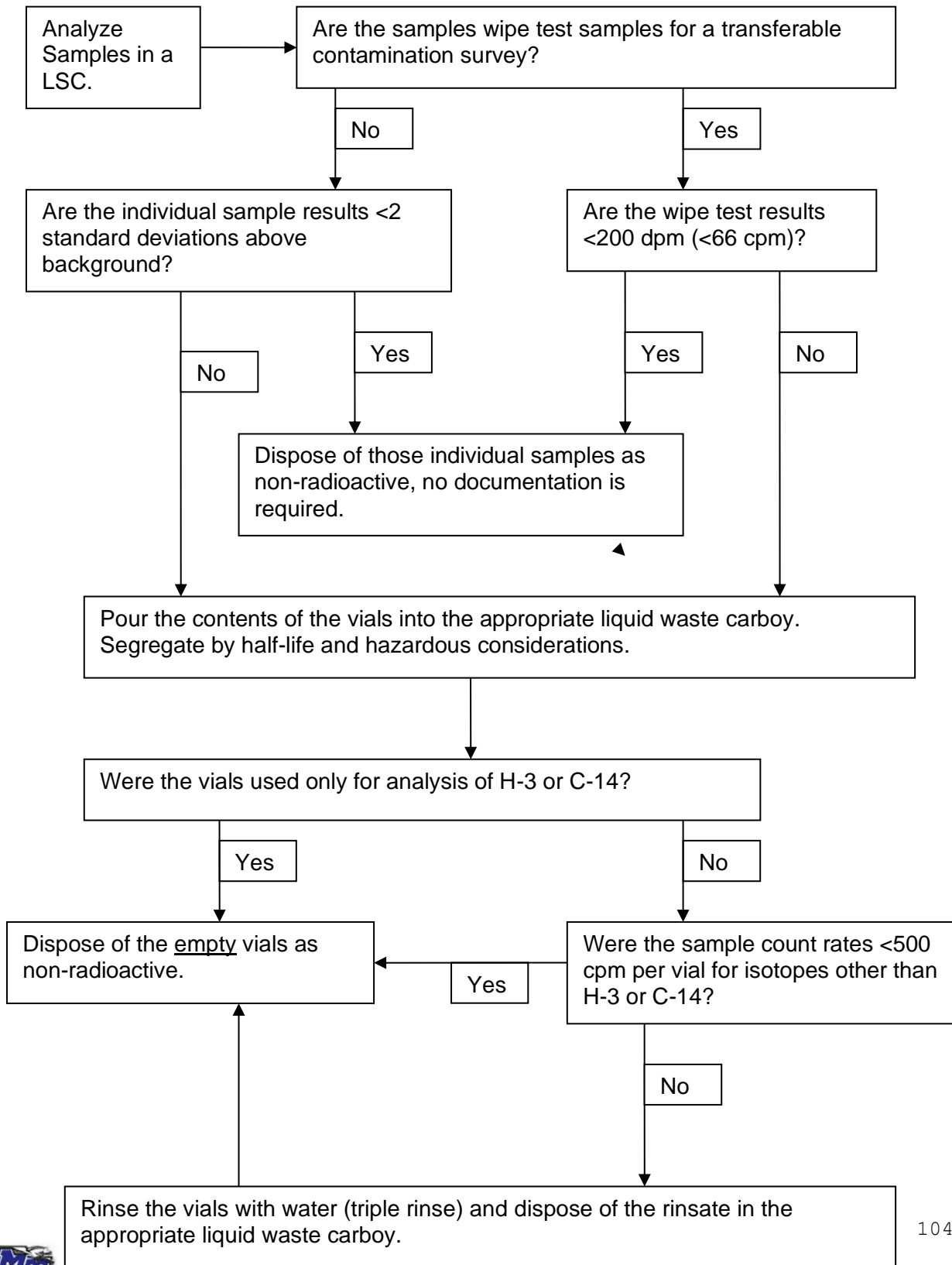
Example: A 1 minute background results in 25 counts. This equals a background count rate of 25 counts per minute (cpm). The square root of 25 cpm is 5, and $5 \times 2 = 10$. Therefore, if a sample does not exceed a gross result of 35 cpm, or a net result of 10 cpm (gross cpm – background cpm = net cpm), the sample is considered non-radioactive. Both the vial and its contents may be disposed of without regard to radiological concerns.
- 7) If the individual sample results are greater than 2 standard deviations above background (excluding wipe tests), the contents of the vials should be poured into an appropriate waste carboy. Segregate waste by half-life and hazardous characteristics as described in section 4.1.
- 8) Empty scintillation vials that were used for analysis of H-3 or C-14 may be disposed of in regular (non-radioactive) trash. Empty scintillation vials that were used for analysis of other isotopes may be disposed of in regular (non-radioactive) trash, IF the count rate of the samples did not exceed 500 cpm. This value is based on the fact that only a small percentage of the original activity in the scintillation cocktail will remain on the surface of the empty vial as contamination. If the counting results exceed this value the empty vials must be rinsed with water. According to industry standards a triple rinse will remove $>90\%$ of the residual activity. The rinsate should be disposed of in an appropriate liquid waste carboy. The rinsed vials may then be disposed of as non-radioactive.
- 9) If disposal of liquid scintillation fluid and vials will not occur promptly after counting,



segregate and label the vials while disposal is pending. Used vials of liquid with counting results <2 standard deviations above background should be separated from radioactive materials while disposal is pending. Used vials of liquids pending packaging for disposal as radioactive materials must be labeled, or kept in suitable containers (i.e. plastic bins) labeled with the standard radiation symbol, the words "Caution, Radioactive Materials", and the isotope, amount (μCi or mCi), and date. Storage of excessive quantities of used vials is not an acceptable practice. Also, Radiation Safety will not accept any waste containers that contain vials of scintillation fluid.



Flow Chart for Disposal of Used Liquid Scintillation Fluid & Vials



4.3 Liquid Radioactive Waste Containers

- 1) The standard approved container for liquid radioactive waste is a 2.5 gallon polyethylene Jerrican. Other containers may be approved by the RSO/RSC on a case by case basis.
- 2) Authorized Users that are approved for use of more than one of the categories listed in section 4.1 must have separate containers for each category.
- 3) Clearly label the containers and train laboratory personnel to prevent the possibility of mixing the different categories of waste.
- 4) Radioactive waste containers must be marked with the standard radiation symbol and the words "Caution, Radioactive Materials." Labeling should also include the isotope(s) and the estimated maximum activity (mCi). A minimum of two labels should be used with each label placed on opposite sides of the container.
- 5) Empty waste containers should be marked with an "Empty" label in addition to the radioactive materials label.
- 6) Temporary collection containers for waste may be used to improve efficiency and reduce the risk of spills. The physical construction of the container must be appropriate for the type of waste. Temporary collection containers should remain closed when not in active use and must not be allowed to overflow. Temporary collection containers should be labeled in the same manner as other waste containers.
- 7) Used waste containers that are no longer needed must be turned over to Radiation Safety for disposal or reuse on campus.

4.4 Liquid Radioactive Waste Packaging

- 1) Do not place any solid materials in liquid waste carboys. Filter papers, glass objects, and plant materials are prohibited. Materials too viscous to pour readily through a 20-mesh sieve cannot be accepted. Precipitates must be filtered out.
- 2) Materials that are insoluble in water, organic solvents, non-biodegradable scintillation fluid, and hazardous chemicals (mixed waste) must be segregated into separate containers by half life (long or short lived) and by the individual type of hazardous waste.
- 3) Do not overfill carboys. The liquid level must not exceed the 2.5 gallon (10 L) mark.
- 4) Viable bacteria, yeast, or other biological materials are not permitted. Liquid chlorine bleach (sufficient to achieve a 10% solution) or other appropriate material may be added to liquid waste carboys to ensure that no active microorganisms are present.
- 5) Isotopes with half-lives greater than 120 days should not be mixed with isotopes having half-lives less than 120 days.
- 6) When practical, carboys will be returned to the Authorized User after disposal of waste. Carboys should be labeled with the name of the Authorized User to facilitate return. Since carboys may have to be held for decay or for scheduling of disposal, extra carboys should be purchased for use while the full container is pending disposal.



- 7) Liquid radioactive materials will be analyzed for content and activity after pick-up. If radioactive materials are discovered to have been improperly packaged or labeled after pick-up, the Authorized User will be held responsible for repackaging the waste

5.0 SAMPLING, ANALYSIS, EVALUATION, AND DISPOSAL OF LIQUIDS

When a liquid waste container is full, or if disposal of the contents is desired, collect and analyze a representative sample of the contents of the container.

The method of analysis and documentation will be one of the following three options:

- If the liquid contains exclusively H-3, C-14, P-32, P-33, and/or S-35 in concentrations likely to be less than the ALARA action levels of Table 5.3 the liquid may be evaluated for release. Perform and document an analysis and evaluation for release in accordance with section 5.3, *Evaluation of Liquids for Release*.
- If the liquid does not meet the criteria described above, perform and document analysis for pick-up by Radiation Safety in accordance with section 5.4, *Liquid Radioactivity Analysis for a Waste Pick-Up*.
- If your Radioactive Materials Permit (license) authorizes sewer disposal, perform and document analysis in accordance with section 5.5, *Sewer Disposal Permits*.

5.1 Counting Instrument Considerations for Liquid Analysis

- 1) Instruments used for liquid waste disposal evaluations should have performance checks and routine maintenance performed as recommended by the manufacturer. Instruments that are not in good working order or properly maintained must not be used to evaluate samples for release to unrestricted areas. For assistance with instrument performance checks, contact Radiation Safety. Instrument repair needs should be directed to the campus electronics shop, qualified vendors, or the instrument manufacturer.
- 2) The counting equipment used must be capable of meeting the desired release limit. Therefore, the counters minimum detectable activity (MDA) value must be less than the release limit. In some cases, counting times may have to be extended to enable an MDA value to be reached. Calculate the MDA by use of the formula:

$$\text{MDA in } \mu\text{Ci/ml} = \frac{2.71 + 4.66 \sqrt{\text{bkg cpm} \times \text{count time}}}{(\text{efficiency}) (\text{count time}) (2.22 \text{ E } 6) (\text{sample vol})}$$

Example: A 1 minute counting time, 50 cpm background (bkg), LSC efficiency for H-3 of 0.35, and sample volume of 2 milliliters would give a MDA of 2.29 E-5 $\mu\text{Ci/ml}$. Therefore it would be appropriate to count a 2 ml sample for 1 minute for H-3 at this background level (or less) because the ALARA action level for release of H-3 is 2 E -4 $\mu\text{Ci/ml}$. If the calculated MDA is less than the action level, the variable parameters of counting time and background are suitable for the release analysis.

- 3) If a counting instrument's background is high (i.e. >50 cpm), the sample counting time may have to be increased in accordance with an MDA calculation. A high background



should be investigated, possible causes include contamination of the counting instrument or the placement of radiation sources (waste containers, stored isotopes, etc.) nearby.

- 4) Liquids that contain significant quantities of known quenching agents that are likely to contain radioactive material should be considered radioactive waste and not evaluated for release. Analyze samples of these liquids for pick-up by Radiation Safety as described in section 5.4. Coloring agents, non-homogenous samples, and certain chemicals will interfere with liquid scintillation counting. To ensure accurate counting, samples should have visible clarity (lack of coloration) and homogeneity.

5.2 Procedure for Sampling and Analysis of Liquids

- 1) Sampling must be representative. Liquids should be uniformly mixed (shaken, stirred, etc.) prior to sampling.
- 2) Collect and pipette a sample of the liquid waste into a sample counting vial. The standard sample volume to use is 1 milliliter. When performing sample analysis for release evaluations the sample volume must be adequate to ensure that the required minimum detectable activity (see section 5.1) is met.
- 3) Add the appropriate amount of scintillation fluid for use with your liquid scintillation counting instrument to the vial (i.e. 7, 10, or 20 ml of scintillation fluid).
- 4) If you are analyzing samples exclusively for P-32 and would like to perform Cerenkov counting, contact Radiation Safety for assistance. Cerenkov counting cannot be used for liquid release analysis and the counting efficiencies must be adjusted on the *Sewer Disposal Log* and *Liquid Radioactivity Analysis* forms.
- 5) If you are using a gamma counter follow the standard counting protocols for that instrument.
- 6) Set-up the instrument to count in the spectrum of the isotope known or suspected to be present. Multiple isotopes must have distinct energy spectrums to permit differentiation. Segregate liquids by radioisotope to facilitate analysis.
- 7) If a liquid waste carboy contains multiple isotopes that are not easily differentiated by analysis, the sample should be analyzed by full spectrum counting. The analysis sheet should list all the isotopes in the container and the total activity.
- 8) Count a background sample and the prepared sample for the appropriate minimum counting time. A minimum counting time of 1 minute should be used for radioactivity analysis or sewer disposal. Liquid release evaluations require longer counting times, see section 5.3 for details.
- 9) Perform radioactivity calculations as described on the analysis form or as automatically provided by the electronic application.

5.3 Evaluation of Liquids for Release

If you generate liquids that contain very low concentrations of certain radioisotopes you may evaluate these liquids for release in accordance with the regulations for liquid effluents. Each individual



radioisotope has its own release limit. The action levels provided only include those radioisotopes commonly used on campus that have release limits easily detected by liquid scintillation counting.

The MTSU ALARA action levels for release of liquids represent 20% of the liquid effluent release values permitted by the Nuclear Regulatory Commission (NRC) in accordance with 10 CFR 20, Appendix B, Table 2, Column 2. These values are based solely on the concentration ($\mu\text{Ci/ml}$) of radioactivity in the liquid. This very low level of radioactivity is considered safe for release as a liquid effluent. NRC models show that if a person were continually exposed to this level of radioactivity their annual exposure would only increase by 10 mrem in an entire year.

These effluent releases may be performed by sink disposal if the liquid is non-hazardous, aqueous, and biodegradable. Liquid effluents released at these very low concentrations of radioactivity are not required to be discharged directly into the sanitary sewer system or tracked in the same manner as sewer disposals (see Section 5.5). Unlike specifically permitted sewer disposal, all Authorized Users are eligible to perform these releases.

Appropriate records must be kept to provide verification that the releases are performed in accordance with the regulations. **If you have any doubt about whether or not a liquid is suitable for release, you should consider the liquid to be radioactive, perform analysis as described in section 5.4, and arrange for a pick-up by Radiation Safety.** In addition, if Radiation Safety determines that liquid releases are not being performed properly by an Authorized User, the option to use this disposal method may be revoked at the discretion of the RSO.

Table 5.3 provides a list of some typically used isotopes and their respective liquid release ALARA action levels in units of $\mu\text{Ci/ml}$ and in dpm/ml. These values should be used to evaluate the proper disposal route for liquid waste.

**Table 5.3
Liquid Release ALARA Action Levels**

Isotope	Liquid Release ALARA Action Level ($\mu\text{Ci/ml}$)	Liquid Release ALARA Action Level (dpm/ml)	Counting Method	Standard Counting Efficiency	Liquid Release ALARA Action Level (cpm/ml)
H-3	2.00E-4	444 dpm/ml	LSC	0.35	155 cpm/ml
C-14	6.00E-6	13 dpm/ml	LSC	0.85	11 cpm/ml
S-35	2.00E-5	44 dpm/ml	LSC	0.85	37 cpm/ml
P-33	1.60E-5	35 dpm/ml	LSC	0.85	30 cpm/ml
P-32	1.80E-6	4 dpm/ml	LSC	0.98	4 cpm/ml

The isotopes I-125 and I-131 are not suitable for release in this manner, due to the very low limits for release of these isotopes. Release limits for other radioisotopes not listed in Table 5.3 may only be approved by the RSO on a case by case basis.

Liquid Release Evaluation Procedure

- 1) The *Liquid Release Evaluation* form must be completed in an electronic format to ensure



consistent performance and eliminate the need to check for mathematical errors. The electronic format must be approved by the RSO and obtained from Radiation Safety. After the electronic form is completed, it must be printed and signed. A signed copy is required as a record of disposal.

- 2) If the electronic format *Liquid Release Evaluation* form is not available for use, sample analysis should be performed and documented on the form *Liquid Radioactivity Analysis*. This version of the form includes the same analysis information but excludes the ALARA action level comparison and does not allow for disposal by release. To use this method see section 5.4.
- 3) Collect a representative sample of the liquid waste in accordance with section 5.2. The sample volume must be adequate to ensure that the required minimum detectable activity is met, as shown in the table below.
- 4) Add the appropriate amount of scintillation fluid for use with your counting instrument to the vial containing the liquid waste sample.
- 5) Analyze a background sample and the prepared liquid waste sample for a counting time that is adequate to meet the required minimum detectable activity. Examples of suitable sample volumes, instrument background levels, and minimum counting times are specified in the following table.

Radioisotope	Sample Volume	Maximum Background	Minimum Counting Time
H-3, S-35, P-33	1 ml	50 cpm	5 minutes
H-3, S-35, P-33	2 ml	50 cpm	1 minute
C-14	1 ml	50 cpm	20 minutes
C-14	2 ml	50 cpm	10 minutes
P-32	2 ml	75 cpm	30 minutes
P-32	3 ml	75 cpm	15 minutes

- 6) Complete the required data on the *Liquid Release Evaluation* form. The form will automatically calculate the sample activity. An automatic comparison of sample results to the ALARA action levels for release will also be performed. One of the following 2 options will be indicated on the form:
 - If the sample results are less than the ALARA action levels for release of liquids, the electronic form will indicate that the liquid in the container is suitable for release. The liquid may be disposed of as appropriate for its physical and chemical properties. This will typically be sink disposal if the liquid is biodegradable, aqueous, and non-hazardous. If the liquid has hazardous or other constituents that make it inappropriate for sink disposal, it may be disposed of via the normal (non-radioactive) disposal route for that liquid.
 - If the sample results exceed the ALARA action levels for release, the electronic form will indicate that the liquid is NOT suitable for release. Use the *Liquid Release Evaluation* form to label the container and store it until a pick-up is scheduled with Radiation Safety. See section 7.0 for waste pick-up information.



- 7) If the liquid is not suitable for release, the following actions are required:
 - Perform a contamination survey of the exterior of the container and record the results in the space provided on the form. Contamination levels on containers must not exceed 1000 dpm/100 cm². Contaminated containers should be decontaminated and resurveyed as described in Chapter 10, *Laboratory Procedures*.
 - Perform a radiation dose rate survey of the exterior surface of the waste container and record the results in the space provided on the form. If the contact dose rate exceeds 0.5 mrem/hr, notify Radiation Safety of the dose rate on the container when you request a pick-up. The Radiation Safety staff will verify the radiation dose rates and provide appropriate labeling for the container at the time of pick-up.
- 8) Sign and date the form in the space provided. Release evaluation paperwork should only be completed by, or under the supervision of, an Authorized User or Advanced Radworker.
- 9) Notify Radiation Safety when a container is ready for pick-up and attach the *Liquid Release Evaluation* form to the container.
- 10) **If disposal is performed by release, you must provide a copy of the completed *Liquid Release Evaluation* form to Radiation Safety.** When used, *Liquid Release Evaluation* forms should be sent to Radiation Safety in conjunction with monthly Radiation Surveys.

5.4 Liquid Radioactivity Analysis for a Waste Pick-up

Use the *Liquid Radioactivity Analysis* form to document the analysis of a liquid waste sample. The results of this analysis will be used to label the container in order to facilitate proper transportation, storage, and disposal of the liquid by Radiation Safety.

- 1) The *Liquid Radioactivity Analysis* form should be completed in an electronic format for increased efficiency. The electronic format must be approved by the RSO and obtained from Radiation Safety. After the electronic form is completed, it must be printed and signed. A signed copy is required for labeling the container.
- 2) If the electronic format *Liquid Radioactivity Analysis* is un-available or is not being used for any reason, sample analysis may still be performed and documented on the form. Radioactivity calculations will have to be performed manually. Contact Radiation Safety for assistance if needed.
- 3) Collect a representative 1 ml sample of the liquid as described in section 5.2.
- 4) Count a background sample and the prepared liquid waste sample for a minimum of 1 minute in an appropriate counter.
- 5) Complete the required data on the *Liquid Radioactivity Analysis* form. The electronic version of the form will perform the required mathematical calculations automatically.
- 6) Perform a contamination survey of the exterior of each container and record the results in the space provided on the form. Contamination levels on containers must not exceed 1000 dpm/100 cm². Contaminated containers should be decontaminated and resurveyed as described in Chapter 10, *Laboratory Procedures*.



- 7) Perform a radiation dose rate survey of the exterior surface of the waste container and record the results in the space provided on the form. If the contact dose rate exceeds 0.5 mrem/hr, notify Radiation Safety of the dose rate on the container when you request a pick-up. The Radiation Safety staff will verify the radiation dose rates and provide appropriate labeling for the container at the time of pick-up.
- 8) Sign and date the form in the space provided. Waste container paperwork should only be completed by, or under the supervision of, an Authorized User or Advanced Radworker.
- 9) Notify Radiation Safety when a container is ready for pick-up and attach the *Liquid Radioactivity Analysis* form to the container.

5.5 Sewer Disposal Permits

- 1) Sewer disposal permits allow the controlled release of low levels of liquid radioactive materials in concentrations that are higher than the limits of Table 5.3. Sewer disposal permits will be limited to Authorized Users who show the need to conduct these releases.
- 2) Sewer discharge is only allowed into public sanitary sewerage systems. Private systems, septic tanks, or leach fields shall not be used for disposal of radioactivity at these levels.
- 3) Except as listed in section 5.3, no radioactive materials may be disposed of by sewer disposal without specific approval in the Radioactive Materials Permit of the Authorized User. When such disposal is approved, records must be maintained listing the isotope, amount, and date of disposal.
- 4) When approved for a sewer disposal permit, sewer disposal records must be submitted to Radiation Safety every month. Since sewer disposals are tracked on a monthly basis, sewer disposal records are required to be submitted regardless of the amount of disposal that occurred. Even if the sewer disposal value is zero, monthly reporting is required.
- 5) Approved concentrations for disposal will generally not exceed 0.05 microcuries per milliliter. The standard activity limits are as follows: 500 μCi for H-3, 100 μCi for C-14, and 100 μCi for all other isotopes combined. Sewer disposal of radioactive iodine (I-125/131) or other isotopes in toxicity groups 1 or 2 (see Chapter 4, Table 3.1) is generally prohibited. In the event that sewer disposal of a non-standard isotope or quantity is requested the RSO and RSC will evaluate the request on a case by case basis.
- 6) Liquids pending disposal in accordance with a sewer disposal permit should be consolidated in a standard liquid waste container (carboy) or equivalent.

Sewer Disposal Procedure

- 1) The *Sewer Disposal Log* should be completed in an electronic format for increased efficiency. The electronic format must be approved by the RSO and obtained from Radiation Safety.
- 2) If the electronic format *Sewer Disposal Log* is un-available or is not being used for any reason, sample analysis may still be performed and documented on the form.

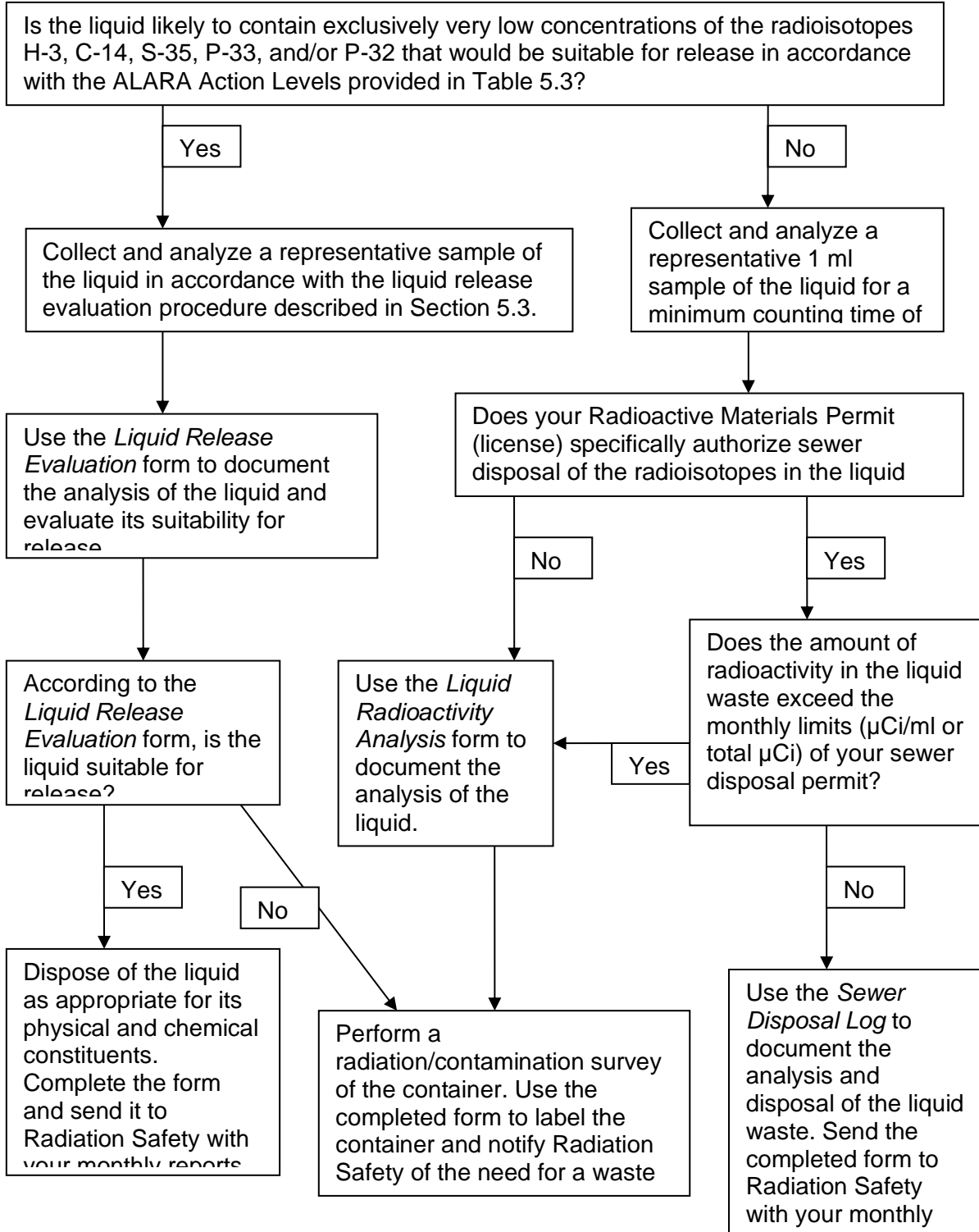


Radioactivity calculations will have to be performed manually. Contact Radiation Safety for assistance if needed.

- 3) Collect a representative 1 ml sample of the liquid as described in section 5.2.
- 4) Count a background sample and the prepared liquid waste sample for a minimum of 1 minute in an appropriate counter.
- 5) Enter the required data on the *Sewer Disposal Log*. The electronic version of the form will perform the required mathematical calculations automatically.
- 6) If the sample results exceed the limits in your sewer discharge permit (either the $\mu\text{Ci}/\text{ml}$ or total μCi), do not proceed with sewer discharge. Delete the entry from your *Sewer Disposal Log* and use the *Liquid Radioactivity Analysis* form to document the analysis. Complete all the information on the *Liquid Radioactivity Analysis* form as described in section 5.4. Use the *Liquid Radioactivity Analysis* form to label the container and schedule a waste pick-up with Radiation Safety.
- 7) When all sewer disposals for the month are completed, the electronic form must be printed and signed. A signed copy is required as a record of disposal. Laboratory copies may be maintained in either electronic or hard-copy format.
- 8) Send the completed *Sewer Disposal Log* to Radiation Safety in conjunction with your monthly radiological survey. If no sewer disposal is performed for the current month this should be noted in the space provided on the *Radiological Survey Form*.
- 9) Sewer disposal shall be performed only at designated locations in posted Radioactive Materials Areas.
- 10) Discharge liquid waste slowly to minimize splashing with water running to be sure that the material moves out of the sink and into the sewer system.
- 11) Survey the sink and surrounding work surfaces to confirm that no residual material or contamination remains in the sink or on the work surfaces. Decontaminate as appropriate.



Flow Chart for Evaluation and Disposal of Liquid Waste



6.0 WASTE PICK-UPS

Used radioactive materials collected from University laboratories are taken to the MTSU Hazardous Materials Treatment Facility (HMTF). There they are classified and placed in one of several channels for disposal. **Used radioactive materials are not officially designated as radioactive waste until they have been received at HMTF and classified.** Channels of disposal include storage for decay, evaporation, solidification, incineration, sewer, and compaction for shipment to a commercial disposal site.

Full radioactive waste containers are not allowed to accumulate in a laboratory. Contact Radiation Safety and schedule waste pick-ups to prevent accumulation of full containers in work locations.

6.1 Preparing for Pick-Up

- Verify that each individual container has either a *DAW Container Log*, a *Liquid Radioactivity Analysis* form, or a *Liquid Release Evaluation* form attached.
- Make sure that the paperwork contains all required information. Complete each section of the forms.
- Perform a contamination survey of the exterior of each container. Contamination levels on containers must not exceed 1000 dpm/100 cm². Contaminated containers should be decontaminated and resurveyed as described in Chapter 10, *Laboratory Procedures*.
- Perform a radiation dose rate survey of the exterior surface of the waste container. If the contact dose rate exceeds 0.5 mrem/hr, notify Radiation Safety of the dose rate on the container when you request a pick-up. The Radiation Safety staff will verify the radiation dose rates and provide appropriate labeling for the container at the time of pick-up.
- Sign and date the forms in the space provided. Waste container paperwork should only be completed by, or under the supervision of, an Authorized User or Advanced Radworker.

6.2 Scheduling and Performance of Waste Pick-Ups

- Notify Radiation Safety of your need for a waste pick-up. You will need to specify the isotopes, type of material, and number of containers.
- Radioactive materials pick-ups will generally be on the Thursday following your call. The date and time of pick-up will be provided when you request the pick-up.
- Escort packaged materials to the loading dock of your building. **Do not leave radioactive materials un-attended.**
- Improperly packaged materials will not be picked up. If radioactive materials are discovered to have been improperly packaged or labeled after pick-up, the Authorized User will be responsible for repackaging the waste.



1.0 PURPOSE

The purpose of this chapter is to provide guidance in the implementation of the Radiological Improvement Program. This program provides a record of observed radiological deficiencies and opportunities for improvement, a method for reporting these items to management for action, and a means to trend radiological performance. The Radiological Improvement Program may also be used as a self assessment tool, providing a method to encourage continual improvement of the radiation safety program.

2.0 SCOPE

This chapter applies to all personnel involved in the performance of radiological work at Middle Tennessee State University. Any radiation worker may use this program as a means of reporting concerns or improvement opportunities directly to the management of the radiation safety program (Radiation Safety Officer and Committee).

3.0 ACRONYMS / DEFINITIONS

RIP – Radiological Improvement Program

RIPR –Radiological Improvement Program Report

RSC - Radiation Safety Committee

RSO - Radiation Safety Officer

Responsible Individual(s) – as used in this chapter, the responsible individual(s) is that person or persons who have primary responsibility or involvement for any incident, event, item, or occurrence detailed in a RIPR

4.0 RESPONSIBILITIES

The **Radiation Safety Committee** is responsible for supporting specific elements of this program; including evaluation and development of plans for improvement.

The **Radiation Safety Officer** is responsible for development and implementation of this program; including reviewing all RIPR's, determining the category and tracking codes, performing any required notifications, and assisting in development of appropriate corrective actions and improvement plans.

The **Radiation Safety staff** is responsible for assisting in the identification of opportunities for improvement and supporting implementation of corrective actions.

The **Authorized User** and all **Radiation Workers** are responsible for participation and support of this program.



5.0 RADIOLOGICAL IMPROVEMENT PROGRAM REPORT

5.1 RIPR Initiation

- 1) A RIPR may be generated by any person working under the MTSU Radiation Safety Program.
- 2) The RIPR should be initiated promptly after the discovery of any significant radiological occurrence.
- 3) RIPRs are initiated by completing only section "A" of the form and forwarding the document to the RSO for review.
- 4) RIPRs should be written to document opportunities for improvement including, but not limited to, the following:
 - Radiation Safety Manual non-compliance
 - violations of RMP (license) conditions
 - radiological posting or labeling violations
 - poor radiological work practices
 - radiation safety training deficiencies
 - recommendations for significant improvements to the radiation safety program
- 5) The RIPR should not be used to document conditions or occurrences that are trivial or problems that can be remedied on the spot. The exception to this would be a repetitious occurrence where tracking or trending of the situation would be beneficial to the radiation safety program.
- 6) A RIPR must be documented in a responsible, factual, and professional manner. Hearsay, opinions, or accusations are never appropriate. Placing blame is never the goal, making improvements in radiation safety is the desired outcome.
- 7) RIPR's should not be used to document conditions or occurrences that have already been documented through some other corrective action program (such as the lab inspection program), unless the other corrective action program has not been effective in achieving a satisfactory outcome.
- 8) In the event that a RIPR is submitted for a condition or occurrence that has already been identified and/or a correction plan is already in effect, this situation should be described on the RIPR and the RIPR may be considered closed.

5.2 RSO Review and Classification

The RSO will review the RIPR for legibility, clarity, and to ensure that it is relevant to radiological safety. If the RIPR does not meet acceptable standards for these criteria, the RIPR initiator will be notified. The RIPR initiator and RSO should discuss the RIPR. Inappropriate RIPRs may be rejected by the RSO. If the RIPR initiator is not satisfied with the resolution of the issue, the RIPR may be transmitted directly to the attention of the RSC.

If the RIPR is acceptable, the RSO or designee shall initiate section "B" as follows:



- 1) Assign the RIPR tracking number. Each RIPR is numbered in the following format; where XX-001 represents the first RIPR for the year XX.
- 2) Determine the category in accordance with the following table, and document on the RIPR in the space provided.

RIPR Category	DNR Notification Requirement	Description
I	Immediate notification	Violations and/or deficiencies that require immediate notification to the DNR in accordance with the requirements of Rule .03(15) of the Rules and Regulations for Radioactive Materials Chapter 391-3-17
II	Notification within 24 hours after the discovery of the event	Violations and/or deficiencies that require notification within 24 hours after the discovery of the event to the DNR in accordance with the requirements of Rule .03(15) of the Rules and Regulations for Radioactive Materials Chapter 391-3-17
III	Notification within 30 days after the discovery of the occurrence	Violations and/or deficiencies that require notification within 30 days after the discovery of the occurrence to the DNR in accordance with the requirements of Rule .03(15) of the Rules and Regulations for Radioactive Materials Chapter 391-3-17
IV	None	All other occurrences or opportunities for improvement

NOTE: If a category I or II is determined, the immediate notification of the RSC chairman and initiation of an investigation is warranted. If the RIPR is determined to be valid, the remaining RSC members should be notified.

- 3) Reference the appropriate regulatory document and article, Radiation Safety Manual chapter number, or other technical document identifier associated with the description. Document this information on the RIPR in the space labeled 'Reference Documents'.
- 4) If appropriate, notify the RSC chairman and implement any necessary immediate corrective actions.

5.5 Improvement or Corrective Action Evaluation

- 1) If the RIPR is a category I or II a critique will be performed by the RSC. A corrective action plan will be developed and documented.
- 2) If the RIPR is a category III, the RSO and RSC chairman should develop and document an appropriate corrective action plan. The remaining RSC members should be notified no later than the next scheduled RSC meeting.
- 3) When practical, a root cause analysis should be performed to determine why an incident or deficiency occurred.



- 4) When completed, the improvement plan will be attached to the RIPR. The RSO should note that the plan is attached by completing the space provided on the RIPR.
- 5) The target date for completion of the improvement plan shall also be determined and noted on the RIPR in the space provided.
- 6) Category IV RIPRs shall be handled as follows:
 - The RSO should determine what corrective actions or improvements (if any) are needed and should consult with the responsible individual(s) and other involved parties when necessary. The improvement plan will be attached to the RIPR.
 - The RSO should prepare a time line to implement any recommended improvements or corrective actions. This information should be recorded on the RIPR in the space indicating the completion target date.
 - The RSO will notify the responsible individual(s) in writing of the recommended corrective actions or improvements and of the proposed time line for implementation.
 - If the responsible individual(s) and the RSO disagree in regards to the recommended actions, each contributor may document their recommendations on a separate sheet and attach a copy to the RIPR. The issues will be presented to the RSC for resolution.
 - If an improvement plan target completion date is overdue, the RSO should notify the responsible individual in writing. The responsible individual's supervisor or department head and the RSC chairman should also be notified of the overdue response.
 - In the case where an Authorized User is the responsible individual, access to procurement of radioactive materials may be denied if a RIPR response is overdue.
 - If an improvement plan target completion date remains overdue following written notification to the responsible individual(s), the RIPR will be turned over to the RSC for resolution.

5.6 RIPR Closure

When all issues related to the RIPR are resolved and documented, the RSO and RSC chairman will sign and date the RIPR in the space provided. The original copy of the RIPR should be maintained with radiation safety program records. A RIPR summary will be provided to the RSC at quarterly meetings.



CHAPTER 13 RADIATION PRODUCING EQUIPMENT

1.0 PURPOSE AND SCOPE

The purpose of this chapter is to provide instruction for the use and control of radiation producing equipment at Middle Tennessee State University. The information in this chapter is based on the requirements set forth by federal agencies and the State of Tennessee Department of Environment and Conservation Division of Radiological Health. This chapter applies to all personnel working under the MTSU radiation safety program.

Radiation producing equipment is defined as any equipment that produces or contains sources of ionizing radiation. This equipment may be used in the disciplines of the healing arts (i.e., medicine, osteopathy, dental or veterinary) or non-healing arts (industry, education or research). In most cases, equipment covered under this procedure contains a sealed source of radiation or an x-ray producing vacuum tube or housing. Industrial products and manufactured equipment containing exclusively exempt quantities of radioactive material are excluded from the requirements of this chapter.

2.0 PRECAUTIONS AND LIMITATIONS

- Radiation shall not be applied to human beings except as prescribed by persons licensed to practice in the healing arts. Human medical use regulations are outside the scope of this document.
- The operation of any radiation machine in the State of Tennessee is prohibited unless the user and equipment is registered with the Department of Human Resources.
- No routine operations should be conducted that would require an individual to expose any part of their body to the primary beam of a radiographic device, unless that individual is a patient in a healing arts procedure.
- Unqualified personnel must not attempt to remove sealed sources from instruments, equipment, or housings. This task must be performed by authorized personnel or qualified vendors. Contact Radiation Safety for specific information.
- No one is permitted to open or breach the containment of any radioactive sealed source contained in radiation producing equipment. Potentially serious radiological consequences could occur.
- Non-radiological safety hazards (mechanical, electrical, etc.) may be associated with radiation producing equipment and are beyond the scope of this chapter.

3.0 GENERAL INFORMATION

3.1 X-ray Generating Equipment

Like gamma radiation, x-rays are a type of ionizing electromagnetic radiation. X-rays are produced when charged particles, usually electrons, are accelerated in a vacuum by an electrical voltage. The electrons



interact with a target material, resulting in a release of energy from the target in the form of x-rays. Examples of this equipment include x-ray machines, fluoroscopes, and equipment that may produce x-rays as an unwanted by-product, such as electron microscopes.

When x-rays interact with any material, some x-rays may pass completely through the material, some may depart all of their energy within the material, and some will scatter. The scattering effect occurs when x-rays “bounce off” surfaces and results in the majority of exposure to personnel operating radiographic equipment.

3.2 Sealed Source Irradiators

Sealed source irradiators typically consist of a shielded radiation source that can be mechanically activated (unshielded) to cause a target to be exposed. When in the shielded mode (off position) radiation levels are usually minimal. The type and energy of radiation emitted is dependent on the isotope used as a source. Gamma emitting isotopes with relatively long half lives are commonly used.

3.3 Radiation Safety Considerations

Radiation safety measures for radiation producing equipment include the following:

- access controls
- training of personnel
- appropriate use of time, distance, and shielding (see Chapter 10, *Laboratory Procedures*)
- radiological postings
- warning indicator lights that alert personnel when equipment is operational
- mechanical interlocks on doors and access panels to prevent x-ray production during personnel access
- periodic testing and maintenance to ensure that equipment is operating properly.

4.0 REGISTRATION OF RADIATION PRODUCING EQUIPMENT

All instrumentation or equipment capable of producing ionizing radiation must be registered with Radiation Safety. Registration is made by completing the registration form (or an approved equivalent) provided as an attachment to this chapter. The form should be sent to Radiation Safety a minimum of 10 days before the instrument is placed in service at MTSU. All information on the registration form should be complete and accurate. The individual primarily responsible for use and/or ownership of the equipment will be considered the registered user.

Radiation producing equipment that contains radioactive sources is subject to the authorization, procurement, control, and disposal requirements for radioactive materials as described in this Radiation Safety Manual.

Radiographic equipment is not subject to the radioactive materials requirements of this manual. However, in addition to registration with Radiation Safety, radiographic equipment must be registered with the State of Tennessee Department of Environment and Conservation Division of Radiological



Health. It is the responsibility of the individual owner/user to ensure that their equipment is registered with the Department of Human Resources.

5.0 TRAINING

Radiation Safety can provide training in the fundamentals of radiation safety and basic x-ray safety. Training in proper operation and safety for specific equipment must be performed or supplied by the registered user/primary operator. The registered user must maintain documentation adequate to assure the Department of Human Resources that all radiation machines and associated equipment under the control of the registered user are operated only by individuals instructed in safe operating procedures. Instruction must begin within 30 days after employment and be completed no later than 90 days after date of employment. Prior to the completion of training, direct guidance (i.e. continuous supervision) by qualified individuals should be provided to any un-trained personnel.

5.1 Training of Operators who Administer X-ray in the Healing Arts

The registered user must ensure that persons operating his/her radiation machine and associated equipment receive, at a minimum, six hours of instruction. The following subject categories are to be covered:

- 1) Protection Against Radiation
 - a) Protective Clothing
 - b) Patient Holding
 - c) Time, Distance, Shielding
 - d) Radiation Protection Standards
- 2) Dark Room Techniques
 - a) Developing Chemicals
 - b) Film Protection
 - c) Cassettes
 - d) Screens
- 3) Patient Protection
 - a) Beam Limitation
 - b) Setting Up Techniques
 - c) Biological Effects of Radiation
- 4) Machine Safety
 - a) Machine Functions
 - b) Safety Procedure
 - c) Recognizing Problems

5.2 Training of Operators Who Work With Radiation Producing Machines in All Other Applications (Non-Healing Arts)



The registered user must ensure that persons operating his/her radiation machine and associated equipment receive, at a minimum, two hours of instruction in the following six subject categories:

- 1) Fundamentals of Radiation Safety
 - a) Characteristics of radiation
 - b) Units of radiation measurement
 - c) Significance of radiation dose and exposure (radiation protection standards and biological effects)
 - d) Sources and levels of radiation
 - e) Methods of controlling radiation dose (time, distance, and shielding)
- 2) Radiation Detection Instrumentation to be Used
 - a) Use of radiation survey instruments (operation, calibration, limitations)
 - b) Use of personnel monitoring equipment (dosimetry)
- 3) Radiographic Equipment to be Used
 - a) Remote handling equipment
 - b) Radiographic exposure devices and sealed sources
 - c) Operation and control of x-ray equipment
- 4) Pertinent Federal and State Regulations
- 5) The Registered Users Written Operating and Emergency Procedures
- 6) Case Histories of Radiography Accidents

6.0 PERSONNEL EXPOSURE LIMITS

The requirements of Chapter 3, *Radiation Exposure Limits*, must be complied with. In addition, users of radiographic equipment must comply with the following exposure limits.

Table 6
Radiographic Equipment Quarterly Exposure Limits

Location	mrem/quarter Limit
Whole body; head and trunk; active blood forming organs; lens of eyes; or gonads	1250 mrem
Hands and forearms; feet and ankles	18,750 mrem
Skin of the whole body	7500 mrem

- Individuals under 18 years of age shall be limited to 10% of the limits in Table 6.
- Radiation exposure to declared pregnant women shall comply with the requirements of Chapter 3, *Radiation Exposure Limits*.



- Patients undergoing procedures in the healing arts are exempt from these exposure limits.
- Radiation exposure rates in unrestricted areas shall be such that, if an individual were continuously present in the area, the exposure to that individual would not exceed 2mrem in any one hour or 100 mrem in any 7 consecutive days.

7.0 PERSONNEL MONITORING

Radiation monitoring dosimetry is required for all individuals:

- likely to receive 25% of the limits specified in Table 6
- entering high radiation areas
- under 18 years of age in x-ray training schools or employed in occupations that involve exposure to radiographic equipment
- using non-medical x-ray devices who are likely to receive 25 mrem per week.

When using protective aprons, personnel dosimetry shall be worn outside the apron at collar level.

For additional information about procurement and control of personnel dosimetry, see Chapter 10, *Laboratory Procedures*.

8.0 SAFETY REQUIREMENTS FOR RADIATION PRODUCING EQUIPMENT

- 1) Facilities considerations, including design requirements must comply with the Rules and Regulations for X-Rays, Chapter 290-5-22 and must ensure that the radiation exposure limits for unrestricted areas described in section 6 of this chapter are met. Where appropriate, a qualified expert should be consulted in the design of new facilities or in the modification of existing facilities.
- 2) Installation, calibration, maintenance, repairs, testing, and radiological monitoring must be performed by qualified personnel. Vendors and associated personnel responsible for these duties must keep documentation adequate to show evidence of compliance with the rules and regulations.
- 3) Radiation producing equipment shall be tested prior to initial use, after the performance of any modifications, maintenance, or repairs with the potential to affect safety, at any time an abnormal condition is noted, and in accordance with regulatory requirements.
- 4) Equipment warning labels and labels that contain information related to the make, model, or manufacturer of radiation producing equipment are to be maintained in a legible condition. Refer to Chapter 8, *Radiological Postings*, for information regarding radiation warning signs, labels, and postings.
- 5) The registered user is responsible for maintaining appropriate documentation in support of regulatory compliance.
- 6) A copy of the State of Tennessee, Rules and Regulations for X-Rays should be in the possession of all registered users (preferably at the work location) and shall be complied with.



- 7) Radiation producing equipment capable of generating a high radiation area (100 mrem/hr @ 30 cm from the source of radiation) must be kept locked or otherwise controlled to prevent unauthorized access.
- 8) The useful beam of radiographic equipment shall be limited to the smallest area practicable, consistent with the objectives of the radiological examination or treatment.
- 9) All interlocks, shutters, dead-man switches, beam limiting devices, collimating devices, filters, primary and secondary barriers, and fail-safe devices shall be used or installed in accordance with regulatory requirements, must be properly maintained, and cannot be modified in any way that would compromise their safety or effectiveness.
- 10) X-ray films, intensifying screens, and other image recording devices should be as sensitive as is consistent with the requirements of the examination or procedure being conducted.
- 11) Particular care should be taken to align the x-ray beam to ensure that only the target area is irradiated and to reduce the need for performing more procedures than necessary.
- 12) Only persons whose presence is necessary may be allowed in radiographic areas during exposure.
- 13) Protective clothing, in the form of gloves and aprons with a shielding ability of at least 0.25mm lead equivalent, should be provided and worn in radiographic areas during exposure, except when individuals are entirely behind a protective barrier.
- 14) Radiographic equipment, as well as image processing and film devices, should be maintained under a quality control program adequate to minimize the unproductive use of radiation.
- 15) Fluoroscopic equipment used in the healing arts is required to have periodic measurements performed of the Entrance Exposure Rate (exposure rate at the point where the center of the useful beam enters the patient) and the exposure rate at staff positions around the table and panel. These measurements are required to be performed on an annual basis and after the performance of any maintenance that might affect the exposure rate.
- 16) Radiation producing equipment used for therapeutic purposes is required to be calibrated on an annual basis. Spot-check measurements are required on a periodic basis. Therapeutic radiographic equipment operating at energies ≥ 1 Mev must be calibrated by a qualified expert and have spot-check measurements reviewed by a qualified expert. The training and experience requirements for a qualified expert are described in rule 290-5-22-.04(18)(e) of the *Rules and Regulation for X-Rays*.
- 17) In veterinary applications where an animal patient must be held or positioned manually, the individual holding the animal shall wear protective gloves having at least 0.5 mm lead equivalency and a protective apron of at least 0.25 mm lead equivalency. Even when using protective clothing, personnel exposure to the primary beam must be avoided.
- 18) Radiography or teletherapy devices containing sealed radioactive sources must have a durable, legible, and clearly visible label describing the isotope, activity, assay date, manufacturer, and model or serial number of the device. Source assemblies, shields, shutters, etc. are to be properly maintained and cannot be modified in any way that would compromise their effectiveness. The sealed radioactive source of all devices in active use must be leak tested at a minimum frequency of every 6 months.



- 19) Equipment that produces x-rays as an unwanted by-product, such as electron microscopes and cathode-ray tubes, is not allowed to exceed a radiation dose rate of 0.5 mr/hr at a distance of 5 centimeters (2 inches) from any readily accessible point.

10.0 TRANSFER AND DISPOSAL OF RADIATION PRODUCING EQUIPMENT

10.1 Transfers of Radiographic Equipment

Radiation Safety should be notified prior to the transfer of radiographic equipment from one registered user to another or to an off-campus location. The registered user on file with Radiation Safety is responsible for initiating this notification. Appropriate paperwork will need to be filed with the State of Tennessee Department of Environment and Conservation Division of Radiological Health to reflect the change in registration for the radiographic equipment.

10.2 Disposal of Radiographic Equipment

Radiographic equipment that is to be disposed of (not transferred) must be rendered in-operable to ensure that it will not be a danger to unqualified personnel. Contact Radiation Safety for guidance in proper disposal of this equipment.

10.3 Transfer and Disposal of Equipment Containing Radiation Sources

The requirements for transfer of radioactive materials are described in Chapter 6, *Procurement and Transfer of Radioactive Materials*. For disposal of radiation sources contact the Radiation Safety staff and refer to Chapter 11, *Radioactive Waste Handling and Disposal*.





