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Radiation safety training for general laboratory workers

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RADIATION SAFETY TRAINING FOR GENERAL LABORATORY WORKERS

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ABSTRACT

RADIATION SAFETY TRAINING FOR GENERAL LABORATORY WORKERS

by John James Pickering

Current radiation safety training programs are not adequate to ensure safety and/or compliance to regulations. Guidance from the regulatory community does not provide content. Typical training programs use outdated materials and information and do not address many issues with which the radiation worker must be familiar. In addition, no standard program exists. As a result, laboratory workers may receive exposures which can be prevented, working habits in the laboratory vary tremendously, and workers cannot comply with regulations. The focus of this research was on existing safety programs, regulations, recommended subject matter content, and guidelines for radiological safety training. The information collected was substantial enough to allow for the production of two publications:

- Radiation Safety Training Plan
- Radiation Safety Study Guide For General Laboratory Workers

These publications meet current regulatory requirements for general laboratory safety. The Study guide contains all the material needed to conduct a safety training course.

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First and foremost, I would like to thank my family for patience through this process. Without their support and understanding, this effort would not have been made. It is for them that I made the effort.

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I would like to thank my previous employers who provided me with the experience base to perform this study and who made the need obvious to me. I truly hope this material reaches them, as well as the other researchers who lack such training.

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SECTION I INTRODUCTION

A. *CURRENT NEED*

Over the last ten years there has been an increased use of radioactive materials and radiation sources in the general laboratory environment. This use has spread to small businesses. As a result, professional staffing supporting this audience, such as health physicists, is seldom available, especially for the rapidly growing number of biotechnology companies. Most small businesses cannot afford full-time technical staff to provide the health physics support needed when the use is minimal. This atmosphere provides workers with less than adequate understanding of the hazards presented in the laboratory from the use of radiation.

In the United States there are more than 20,000 companies using radioactive materials on a regular basis -- 2,000 in California alone. In California there are also authorizations for more than 6,000 companies to use x ray sources. The California figures do not include those of the federal government which are located in California. The number of radiation workers varies from a few to several hundred under any one license.

Traditional radiological safety training was designed for nuclear reactor personnel. It therefore does not meet the needs of very diverse groups of radiation workers found in the general laboratory environment.

Neither have there been many standardized training programs established for radiation workers in a general laboratory. Regulatory guidelines provide a few basic topics to be covered, but little on appropriate breadth and depth of coverage. Radiological safety training had been developed and implemented in many formats for other audiences by regulatory agencies and universities.

This study reviews existing programs, materials and audiences to investigate the broader range of training needs. The goal of this project is to produce a management plan and a flexible study guide which will improve worker safety and regulatory compliance, and establish a standardized radiation safety training program for a general laboratory environment.

1. Biotechnology

New biotechnology companies (startup companies) have increased faster than most industries which use radiation sources. This industry commonly employs 10 to 300 radiation workers per company. Basic biomedical laboratory activities are conducted. Generally, unsealed materials are used in large volume and contaminated waste is produced. Radiation workers in these companies most often do not have sufficient radiological safety training. Company size seldom allows for the employment of a health physicist.

2. Medical

Diagnostic and therapeutic use of radiation sources has been expanding to a much larger variety of options. New disciplines such as radiation oncology and dermatology are now using radiation sources. Nursing personnel are commonly treating patients with therapeutic sources that are implanted or injected. New techniques are being introduced in patient care for treatments which require more radiochemical processes to evaluate. These processes introduce more variety into the analytical laboratory within the medical facility. Research capable medical facilities that can house one thousand patients commonly employ 100 to 700 radiation workers.

3. Universities

University instructional and research laboratories routinely use radioactive materials for activities in the fields of biology, molecular biology, marine biology, chemistry, material science, nursing studies, medical research, geology, nuclear science, and environmental science activities. Many universities provide medical services which include radiation sources. Often this includes analytical laboratory activities. A large university such as the University of California, San Francisco, commonly employs up to 2000 radiation workers depending of the types of programs offered. The University of Southern California employs up to 2200 radiation workers between its two campuses.

a. Research Laboratories

Research laboratories typically employ 5 to 50 staff and/or students per principal investigator. Every semester new students need radiological safety training tailored to the specific laboratory environment. At San Jose State University there are 20 permits issued to principal investigators who use radiation sources.

b. Teaching Laboratories

Many universities such as San Jose State University provide laboratory courses which involve the use of radiation sources. Class sizes commonly involve 10 to 60 students handling radioactive materials. San Jose State University offers more than 30 courses which use radiation sources.

4. Environmental Studies and the Waste Industry

The number of laboratories which provide environmental analytical services has increased. Both sealed and unsealed materials are now used by this industry. Tagging samples with radioisotopes for analysis is much more common than ever before.

A tremendous shift in radiological waste handling has occurred over the last fifteen years. In the past there were three primary waste facilities in the United States for low-level radioactive waste. The states hosting these waste facilities successfully petitioned the federal government to shift disposal responsibilities to the states which generate the waste. As a result, more nuclear waste sites are being developed. Environmental monitoring is now a critical activity for these sites. A common number of radiation workers were not identified for this industry.

5. Pharmaceutical

The development of new drugs requires enormous testing of materials. This is one of the largest generators of low-level contaminated waste in the United States. According to licensing authorities, the variety and volume of radioisotopes have increased tremendously over the last ten years. Large research based pharmaceutical companies commonly employ 500 to 2000 radiation workers. For example, Genetech in South San Francisco employs more than 1000 radiation workers.

6. National Laboratories

Previously the Department of Energy's national laboratories have concentrated on the production and use of high-energy accelerators, nuclear weapons and nuclear energy programs. Over the past ten years, there has been an increase in biological research and technology transfer. Most of the national laboratories continue to develop and use radioactive materials. However, the fastest growing population of radiation workers is in this area -- 500 to 3000 per site. Existing training programs are not adjustable to this expanding audience.

B. SURVEY OF EXISTING RADIATION TRAINING PROGRAMS

Several surveys of different industries were done to obtain information about the target audience. The initial survey explored subject matter titles. A comparison with regulatory requirements, international guidance, and existing programs was performed following the results of this survey. The data gathered from this survey was analyzed, and an improved subject matter list was generated. A second survey, with selected sections of existing materials expected to be of value to the general laboratory audience, was submitted to the same list of participants. A third survey was performed to identify subject matters not routinely covered. The resulting information was formulated into a management plan. The Study Guide was constructed and sent out in a fourth survey for technical editing.

1. Survey Participants

A broad spectrum of institutions was surveyed to identify appropriate subject matter. Table 1 (below) provides a listing of the types of institutions involved in this study. Table 1 includes only those institutions which participated in the initial and follow-up surveys. Less than half of the institutions contacted in the initial survey continued through the final survey. The institutions who completed all the surveys represented an estimated 41,000 radiation workers. The surveys were performed with the assistance of Lawrence Livermore National Laboratory (LLNL) during a two-year period. The resulting training materials are now being used as the primary training program for the Biotechnology Department at LLNL.

An analysis of the data gathered identified a grouping of radiation workers according to function. This information is presented in Table 2 below.

Table 1
Industries Surveyed

Type of Industry	Number of Institutions	Number of Radiation Workers Represented
Universities	26	9100
Pharmaceuticals	7	7300
Private Contractors	12	700
Military Installations	2	800
National Laboratories	5	12000
Medical Facilities	17	5100
Government Agencies/ Departments	22	6160

2. Survey Questions

In general, the survey focused on information such as the size of the radiation worker force handling sealed or unsealed radioactive materials, the types of radioisotopes used, working conditions, training levels of the workers, copies of the existing training programs and materials, the type of training provided, common problems encountered before, during and after training, and other compliance issues. The survey form and questions remain the exclusive property of the Department of Energy due to various compliance issues involved in the survey.

3. Results

This research identified many subject areas which were not included in the training programs reviewed. Table 3 is a list of the subject areas. The subject areas were developed and later reviewed by those institutions participating in the survey. This research produced a study guide appropriate for radiation workers in the general laboratory environment. The focus was primarily for those handling radioactive materials, not x ray sources.

C. *DESCRIPTION OF NEW TRAINING MATERIALS AND PROCEDURES*

A standard training and education program at a university level is greatly needed for radiation workers in the general laboratory environment. This study analyzes the subject matter which provides the basic knowledge, skills and abilities these workers must possess.

Table 2
Groups of Radiation Workers

Groups	Description
General Worker	Personnel who may routinely enter radiologically controlled areas and encounter radiological barriers, postings, radiation sources, or radioactive materials. This group does not handle radiation sources, nor do they stay in controlled areas for long periods of time. This audience would include visitors, managers and administrative support staff.
Occasional Radiation Workers	Personnel whose job assignments involve working around or with radiation sources in order to provide special services needed to continue operations. This audience includes maintenance personnel, janitorial staff, visiting researchers, inspectors and tour guides.
General Laboratory Radiation Workers	Personnel whose job function involves working with higher radiation levels, x ray sources which may produce significant partial body exposures, and unsealed radioactive materials in small amounts. This audience would include researchers, laboratory technicians, clinicians and others who are found in universities, pharmaceutical plants, small research and counting facilities, biotechnology industry and medical research facilities.
Industrial Radiation Workers	Personnel whose job function involves large radiation sources that may cause serious injury or health risks. This audience would include radiotherapists, radiographers, power plant personnel and military/nuclear weapons handlers.
Health and Safety Workers	Personnel whose job function involves program management and monitoring. This audience would include health physicists and technicians, trained emergency responders and radiation safety officers or managers.

1. Content of the Program

The training content and procedures are provided in the management plan in Section II. This plan describes the administration of the training program which will meet current regulatory requirements and guidelines. More importantly, it will meet the current needs of industry so that a safe work environment may be better achieved. The management plan includes a listing of the course content, testing procedures, and follow-up training.

Section III contains a study guide to be used in conjunction with the training program. The study guide is intended to be used by the student with the aid of a well-qualified subject matter expert.

Table 3
Main Subject Areas with New Sub-topics Developed by this Study

Subject Area	Sub-topic
Radiological Contamination	Causes of Contamination
	Indicator of Contamination
Various Radioisotopes	Characteristics and Commonly Used Isotopes
Preparation of Area	Selection of Work Area
Conduct of Work	Personal Preparation
	Anti-Contamination Clothing
	Precautions for Liquids
Personal Protective Equipment	Basic Considerations, Limitations, Selection and Use
Release of Materials	Released to Controlled and Uncontrolled Areas, Monitoring and Documentation
Decontamination	When Not to Decontaminate
Survey Instruments	Selection of Instruments
Fume Hoods and Gloveboxes	When they are Needed, Protection Factors, Mechanical Function, Testing, Proper Use, Components and Emergencies
Storage and Containment	Segregation, Storage, Storage Areas, General Guidelines and Formation
Waste Management	Disposal Via Sewer
	Disposal Via Fume Hood
Animal Facilities	Training Animal Handlers, Monitoring, Surveying, Posting and Workstation Preparation
Gamma-Cell Irradiators	Dose Rates, Monitoring, Systems Operations, Emergencies, Training, Controls and Safety Procedures
Other Sealed Sources	General Hazards, Classification, Accountability and Leak Testing
X ray Sources	Characteristics of X Rays and Basic Safety
Practical Exercises	Physical Activities to Reinforce Learning Concepts

2. Structure of the Study Guide

The study guide consists of four modules. Module A contains core level information for background knowledge. This information (although modified by this research significantly) is consistent with established guidelines and/or established programs. Module B focuses on contamination control information. Module C focuses on special subject areas common in many general laboratories, but not necessarily for all general laboratories. Selected sections can be used independently for the workers being trained to meet their specific training needs. Module D contains concepts for practical exercises.

3. Methods

Training methods were studied during this research but are not the focus of the final product. The most adaptable training method observed is the classroom environment. Here the instructor can adjust the information to the learning style of the student. Technical references are provided in the reference section that can assist the subject matter expert in teaching techniques.

Various methods such as computer-based or computer-aided training resources are becoming available and show much promise. These tools will be invaluable in the future and are currently useful for students who respond well to such a learning environment. The use of computer-aided instruction is extremely effective in the classroom.

The least effective method of training is independent study. This method is useful for limited audiences. Observations have shown most people need some interaction with an instructor to maintain momentum with the training material.

SECTION II MANAGEMENT PLAN

A. *INTRODUCTION AND ORGANIZATION:*

1. Purpose and Scope of the Management Plan

This plan defines the four basic sections of the training program: (a) Core Training Information, (b) General Laboratory Procedures, (c) Supplemental Information and Procedures, and (d) Practical Exercises. It explains the instructor qualification and training process, material development requirements, standards and policies, and administration for individuals working in general laboratories where radioactive materials and radiation producing devices are handled and/or stored.

2. Compliance Requirement

The training program reflects the requirements identified in federal, state and international regulations and guidelines.

The training program, in its entirety, represents four basic modules (less any site-specific materials):

a. **Core Training Information** - An elementary background of radiation and radiation protection.
b. **General Laboratory Procedures** - A focus on contamination control and the laboratory environment, including information on radioisotopes routinely handled in the general laboratory.
c. **Supplemental Information and Procedures** - Specific information commonly associated with many general laboratories (i.e., irradiators, animal handling, etc.), but not specific to most programs.
d. **Practical Exercises** - Specific activities to reinforce specific training.

Each facility should implement a program of this magnitude and augment such materials to increase the individual's baseline level of competency. Appropriate training described in this manual does not eliminate or reduce the need for facility-specific training identified in its program and/or through a job evaluation. Each facility is responsible for developing their own specific training relative to the work performed (site specific). This would include such concepts as standard operating procedure for specific experiments, purchase requests for radioactive materials and internal processing.

3. Purpose and Goal of Standardized Training Programs

Management is responsible for establishing health and safety programs. This responsibility includes training. Commonly, a health and safety section or division will establish which will be responsible for approving and maintaining the standardized training materials associated with the radiation safety training program.

The purpose of the standardized training program is to provide a baseline level of knowledge and skills in radiological fundamentals for general laboratory employees (radiation workers). The goal of the training program is to provide a consistent level of proficiency for such workers throughout the facility.

4. Organizational Relationships and Reporting Structure

The Radiation Safety Organization or Radiation Safety Officer is responsible for approving and maintaining the standardized training materials associated with the use of radiation sources and reports to the president or senior manager. An oversight group, consisting of representatives from management, reviews, comments, and recommends program changes. Senior management, commonly identified as the Radiation Safety Committee, appoints members to the oversight group.

The training function can be performed by a separate training organization, but the responsibility for quality and effectiveness rests with the line management and the Radiation Safety Organization.

B TRAINING PROGRAM DESCRIPTIONS:

1. Overview of Training Program

General radiological training is required for all site personnel who may routinely enter laboratories and encounter radiological barriers. Training must be completed prior to potential occupational radiation exposures. Training is required for all radiation workers whose job assignments require access to radiation areas on a routine basis. This includes employees handling sealed radioactive sources or radioactive material. This training prepares the employee to work in various radiation levels and with contaminated materials. Employees who wish to keep their safety status current should meet refresher training and retraining requirements.

2. Description of Programs

Module A - Standardized Core Information for Training Includes the Following:

(1 Day of Training)

Section 1 Radiological Fundamentals

A. Atomic Structure
B. Definitions
C. Four Basic Types of Ionizing Radiation
D. Units of Measure

Section 2 Biological Effects

A. Sources of Radiation
B. Effects of Radiation on Cells
C. Acute and Chronic Radiation Dose
D. Prenatal Radiation Exposure

E. Risks in Perspective

Section 3 Radiation Limits

A. Dose Limits and Facility, Administrative Control Levels
B. Worker Responsibilities Regarding Dose Limits/Control Levels

Section 4 ALARA Program (As Low As Reasonably Achievable)

A. ALARA program
B. Responsibilities for ALARA Program
C. External Radiation Dose Reduction
D. Internal Radiation Dose Reduction
E. Radioactive Waste Minimization

Section 5 Personnel Monitoring Program

A. External Dosimeters
B. Internal Monitoring
C. Radiation Dose Records

Section 6 Radioactive Contamination Control

A. Comparison of Ionizing Radiation and Radioactive Contamination
B. Types of Contamination
C. Sources of Radioactive Contamination
D. Contamination Control Methods
E. Contamination Monitoring Equipment
F. Decontamination

Section 7 Radiological Postings and Controls

A. Standard Operating Procedures
B. Radiological Postings
C. Responsibilities of Worker Associated with Postings, Signs and Labels

Section 8 Radiological Emergencies

A. Emergency Alarms and Responses
B. Disregard for Radiological Alarms
C. Radiological Emergency Situations
D. Considerations in Rescue and Recovery Operations

Module B - General Laboratory Training Materials Include the Following:
(1.5 Days of Training)

Section 1 Radiological Contamination

A. Comparison of Ionizing Radiation and Radioactive Contamination
B. Types of Contamination
C. Units of Radioactive Contamination
D. Causes of Radioactive Contamination
E. Indicators of Possible Area Contamination
F. Primary Reasons for Contamination Control Measures
G. Contamination Control Measures

Section 2 Characteristics of Commonly Used Radionuclides

A. Introduction to Characteristics

B. Various Radioisotopes

Section 3 Preparation of Work Areas and Materials

A. Appropriate Selection of Work Area
B. Preparation of Work Areas
C. Preparation of Equipment
D. Shielding (if appropriate)
E. Ventilation Control
F. Marking, Labeling, Posting
G. Personnel Protective Equipment

Section 4 Conduct of Work - Good Practice

A. Personal Preparation
B. Requirements of Posted Contamination Areas
C. Dosimetry
D. Personnel Protective Clothing (Anti-C)
E. Storage and Containment of Radioactive Material
F. Good Housekeeping
G. Good Practices
H. Special Precautions for Liquids

Section 5 Personal Protective Equipment

A. Basic Considerations
B. Limitations of Personal Protective Equipment
C. Design and Construction Factors
D. Selection Decision Factors
E. General Laboratory Personnel Protective Equipment
F. Laboratories with High Levels of Potential Contamination

Section 6 Monitoring for Contamination

A. Contamination Monitoring Equipment
B. Conducting Surveys - General
C. Area Surveys
D. Personnel Surveys
E. Detection of Contamination
F. Decontamination or Not
G. Survey Documentation

Section 7 Release of Materials

A. Release to Controlled Areas
B. Unrestricted Release
C. General Monitoring techniques
D. Beta/Gamma Direct Monitoring
E. Wipe Surveys and Techniques
F. Documentation

Section 8 Decontamination

A. Decontamination or Not

B. Preventive Methods
C. Skin Decontamination
D. Material Decontamination

Section 9 Hand-held Survey Instruments

A. Basic Selection
B. Operational Checks
C. Limitations
D. Calibration, Source Checks, Background
E. Basic Survey Techniques (Area and Personnel)

Section 10 Use of Fume Hoods and Gloveboxes

A. Why Laboratory Fume Hoods are Needed
B. Protections Afforded by Fume Hoods
C. How Hoods Function Mechanically
D. Testing Hoods for Correct Operation
E. Proper Use of Laboratory Hoods
F. Why Gloveboxes are Used
G. Basic Components of Glovebox
H. Proper Use of Gloveboxes
I. Glovebox Emergencies

Module C - Supplemental Training Materials Include the Following:
(1 Day of Training)

Section 1 Storage and Containment of Radioactive/Hazardous Materials

A. Containment of Material
B. Segregation and Storage
C. General Guidelines
D. Storage Areas
E. Formation of Organic Peroxides
F. Storage of Radioactive Materials

Section 2 Radioactive Waste Management

A. Segregation
B. Waste Storage
C. Sharps
D. Minimize Waste Generation
E. Storage for Decay
F. Disposal via Sanitary Sewer
G. Disposal via Fume Hood
H. Disposal of Specific Waste per 10 CFR 20.2005
I. Mixed Waste
J. Volume Reduction

Section 3 Animal Facilities

A. Training of Animal Handlers
B. Monitoring, Surveying and Posting

C. Workstation Preparation

Section 4 Gamma-Cell Irradiators

A. Dose Rates Associated with Gamma-Cell irradiators
B. Monitoring
C. System Operation
D. Emergency Procedures
E. Procedures for Gaining Authorization for Use
F. Training Requirements
G. Responsibilities
H. Systems Controls
I. Other Safety Procedures

Section 5 Other Sealed Sources

A. General Hazard
B. Source Classification
C. Accountable Sources
D. Leak Testing of Sealed Sources
E. Calculating Source Activity or Dose Rate

Section 6 X ray Sources

A. Characteristics of X Rays
B. X ray Safety for Medical Personnel
C. Basic X ray Safety Requirements

Module D Practical Exercise

(1 day of Training)

A. Set up a Workstation
B. Identify Appropriate Posting or Labeling
C. Select Required Dosimeter(s), Instruments, Protective Clothing
D. Demonstrate the Use of Survey Instruments
E. Don/Doff Protective Clothing and Wearing Dosimeter(s)
F. Enter Simulated Area Demonstrate ALARA Techniques
G. Monitor for Contamination and Record Appropriate Information
H. Respond to Emergency Situation

3. Additional Training

Radiation workers and other employees will most likely require additional training to enhance their overall performance and skills. Examples of these additional courses may include specialized training for management, technical support personnel, planners, radiological control personnel, animal handlers, irradiator operators, emergency response personnel, and special procedures or techniques.

4. Refresher Training

Refresher training programs for radiation workers will be implemented based upon regulatory guidelines for the organization. For DOE facilities, this would be on the alternate year when full retraining is not required. For NRC or State licensees, this depends upon the license agreement. For many licensees, this may be the updating of lessons learned or new procedures. Refresher training programs are designed to maintain and enhance the proficiency of the worker. Refresher training is normally concentrated in areas of site specific training and procedures. The annual refresher training for Radiation Workers shall be documented. This is necessary to maintain current position status for any site license requirements.

Refresher training should include changes in requirements and updates of lessons learned from operations and maintenance experience and occurrence reporting for the site and across the facility license. The following topics may be included:

- New procedures and updates to existing procedures.
- New equipment and modifications to existing equipment or facilities.
- Lessons learned from facility operating experiences.
- Lessons learned from industry operating experiences.
- Causes for violations experienced at the facility.

5. Proficiency Requirements

Most regulatory agencies require written documentation of the workers understanding, and a written examination will satisfy that requirement. The minimum passing score (standard) for the written examination should be established at 80 per cent. A "satisfactory" score on the practical factors evaluation is required. The criteria for a satisfactory score is outlined in the standardized core lesson plan.

6. Retraining

Upon completion of initial training as a radiation worker, a retraining program should be completed every two years. This initial training may be substituted for retraining. Some regulators, specifically the DOE, require such training.

Retraining is a more in-depth review of knowledge than is refresher training. Retraining should include selected fundamentals of the initial training with emphasis on seldom-used knowledge and skills. It should be tailored to subjects for which trainee evaluations and experience indicate that special emphasis and depth of coverage is needed.

Minimum requirements for radiation worker retraining are successful completion of the written examination and practical factors exercise, training on lessons learned, and new procedures.

7. Instructor Training and Qualifications

All classroom instruction should be provided by instructors qualified in accordance with the facility license, if identified. Training staff should possess technical knowledge, experience, and the developmental and instructional skills required to fulfill their assigned duties.

a. Training staff responsible for program management, supervision, and development must have and maintain the education, experience and technical qualifications required for their jobs.
b. Instructors must have technical qualifications, including adequate theory, practical knowledge, and experience in the subject matter that they are assigned to teach.
c. Subject matter experts, without instructor qualification, may provide training in their area of expertise. However, these subject matter experts should be trained as instructors when this function occurs routinely.

C. *TRAINING PROGRAM MATERIAL DEVELOPMENT*

1. Lesson Plans, Study Guides, Examination Question Banks, Training Certificates.

Training materials for this program consist of study guides, lesson plans, and examination question banks. Supplemental material may be developed to address site specific radiological concerns.

A training certificate that identifies current training status of the core radiation worker training will be provided upon request to currently trained personnel who complete the training.

2. Training Aids

Site-specific training aids are the responsibility of the facility Radiation Safety Organization. Core training aids (lesson plans) are provided in the form of vugraphs, the use of computer support and student study guides.

D. *TRAINING PROGRAM STANDARDS AND POLICIES*

1. Written and Computer Based Training Examinations

Written examinations and/or Computer Based Training Examinations shall be used to demonstrate satisfactory completion of theoretical and classroom material and:

a. A minimum passing grade of 80 per cent must be attained,
b. Shall consist of a representative sample of the learning objectives from both standardized core material and site specific material,
c. Questions for the standardized material shall be randomly selected from the supplied question bank,
d. Each examination question bank should include at least two (2) questions per learning objective,
e. True/false questions shall not be used,
f. All questions shall consist of the multiple choice type,
g. The examination shall consist of a minimum of fifty (50) questions,

h. Remedial action for failure of Radiation Worker training shall be the responsibility of the site.

An examination answer key shall be developed prior to administration of the examination.

All site-specific examination questions should be maintained by the site and should be developed from any additional learning objectives.

Challenge examinations shall be designed for the standardized Radiation Worker training learning objectives only. Challenges to the site specific portions of the training program may be administered by the site. This challenge is suggested after the employee has demonstrated and documented an understanding of the core subject matter. There is a separate examination for the advanced section of the training program. A separate challenge examination shall be designed for this section of the training. Each learning objective should be presented on the examination. Successful completion of the initial challenge examination does not exempt the employee from the site specific examination, practical factors evaluation, and training in lessons learned/new procedures.

2. Practical Factors Evaluation

A practical factors evaluation shall be used to demonstrate satisfactory completion of skills for Radiation Worker training. A "satisfactory" score must be attained for each practical factor evaluation. Successful completion of the written examination is a prerequisite for the practical evaluation.

3. Lectures, Seminars, Training Exercises.

This standardized training program is designed to be delivered in a classroom setting. An alternate delivery method may be implemented with Computer Based Training (CBT) equipment. The presentation shall require the use of the approved standardized materials and site-specific information. In all cases, regardless of the setting or delivery method, examination requirements of Section 1 and 2 shall be followed.

4. Signature Requirements

Requirements for the Radiation Worker training:

a. Instructor signature indicating the trainee has met the requirements of the learning objectives through written examination and practical factors evaluation.
b. Student signature on the initial and retraining examinations.

5. Delinquent Training/Failure Procedures and Policies

Radiation Workers who are delinquent on refresher or retraining will lose their training status until successful completion of the delinquent training requirement.

6. Exceptions and Waivers

Exceptions and waivers are the responsibility of the Radiation Safety Organization of the facility.

E. *ADMINISTRATION*

1. Training Records

Training records and course documentation shall meet the requirements of the facility license or other regulatory commitment. The records of training and qualification in radiological control shall be maintained to demonstrate that the individual received appropriate information to perform the work assignment in a safe manner.

Formal records of training and qualification shall be readily available to first-line supervisors and managers of involved personnel to aid in making work assignments. The records should include detailed information of the course and its content. A copy of the training materials is highly recommended for regulatory and subject matter review.

2. Training Program Development/Change Requests

All requests for program changes and revisions shall use the form "Request for Changes to Standardized Core Training Materials".

3. Audits: Internal and External

The core training program materials and procedure will be evaluated by the Radiation Safety Organization on a periodic basis. The evaluation should include a comparison of program elements with applicable industry standards and requirements. Internal verification of training effectiveness shall be accomplished through the Radiation Safety Organization or by the facility supervisor observation of practical applications. Results should be documented and maintained by the organization responsible for the employee.

4. Evaluating Training Program Effectiveness

Verification of the effectiveness of Radiological Control training should be accomplished by surveying a limited subset of former students in the workplace. This evaluation should include observation of practical applications, discussion of the course material, and may include an associated written examination.

The survey should be performed by the Radiation Safety Organization and the individual supervisors, quality assurance personnel or senior instructors after the former student has had the opportunity to perform work for several months.

The results should be documented and incorporated into refresher or retraining programs.

SECTION III STUDY GUIDE

COURSE OBJECTIVE:

Upon completion of this training course, the participant should have the knowledge to work safely in areas controlled for radiological purposes using proper radiological practices.

OVERVIEW

Radiation worker training is required for the worker whose job assignment involves entry into all types of radiation contamination and airborne radioactivity areas.

Course Design - This study guide is presented in four (4) modules. Each module may be used as an independent training program. With this structure, some duplication of information was necessary to maintain complete concepts for each module. At the beginning of each section are the basic objectives for that section. This should help the instructor formulate examination questions.

Module A contains nine (9) sections which discuss the theory that the worker must know to work safely around radiological hazards.

Module B contains ten (10) sections which discuss the concept of safe handling of unsealed radioactive sources and which the worker must know to minimize contamination and exposures.

Module C contains six (6) sections which discuss additional training area for support operations and/or special sources or equipment that would significantly benefit the worker.

Practical Factors Exercise - Module D contains generic practical exercises that provides hands-on experiences for the worker.

Successful Completion (Evaluation Criteria) - To pass the course the participant must successfully complete a written exam and a practical evaluation to be qualified as a Radiation Worker. Successful completion of the written exam should be a prerequisite for the practical factors exercise.

Written Examination - The written exam should be based on the objectives in the theory portion of the course, radioactive material handling and supplemental training. Such material should be developed by the facility.

Practical Factors Evaluation - A satisfactory performance during the evaluation of an entry into a simulated controlled work environment must be achieved. The evaluation is based on the application of the theory portions of this course.

A. Module A - Core Training Information

Module A contains nine (9) sections which discuss the theory that the worker must know to work safely around radiological hazards. Each section is designed to be an independent lesson. The module is designed to be an entire course.

1. RADIOLOGICAL FUNDAMENTALS

LEARNING OBJECTIVES:

LO1 IDENTIFY the three basic particles of an atom.

LO2 DEFINE ionization.

LO3 DEFINE ionizing radiation, radioactive material and radioactive contamination.

LO4 DISTINGUISH between ionizing radiation and non-ionizing radiation.

LO5 DEFINE radioactivity and radioactive half-life.

LO6 STATE the four basic types of ionizing radiation.

LO7 IDENTIFY the following for each of the four types of ionizing radiation:

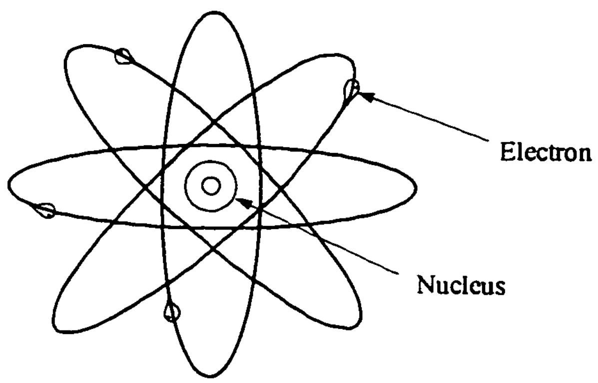
a. Physical Characteristics
b. Range/Shielding
c. Biological Hazard(s)

LO8 IDENTIFY the units used to measure radiation, contamination and radioactivity.

LO9 CONVERT rem to millirem and millirem to rem.

A. ATOMIC STRUCTURE

The basic unit of matter is the atom. The central portion of the atom is the nucleus, which consists of protons and neutrons. Electrons orbit the nucleus, see figure A.1.1.



Nucleus = Protons + Neutrons

FIGURE A.1.1 - THE THREE BASIC PARTICLES OF THE ATOM

1. **Protons**
- Protons are located in the nucleus of the atom.
- Protons have a positive electrical charge.
- The number of protons in the nucleus determines the element.
- If the number of protons in an atom changes, the element changes.

2. **Neutrons**
- Neutrons are located in the nucleus of the atom.
- Neutrons have no electrical charge.
- Atoms of the same element have the same number of protons, but can have a different number of neutrons.
- The atoms of the same element which have the same number of protons but different numbers of neutrons are called isotopes.
- Even though isotopes have the same chemical properties, the nuclear properties can be quite different.

3. **Electrons**
- Electrons orbit the nucleus of an atom.
- Electrons have a negative electrical charge.
- Electrons determine the chemical properties of an atom.

4. **Charge of the atom**

The number of electrons and protons determines the overall electrical charge of the atom. The term ion is used to define atoms or groups of atoms that have a positive or negative electrical charge.
- No charge (neutral) - If the number of electrons equals the number of protons, the atom is electrically neutral and does not have an electrical charge.
- Positive charge (+) - If there are more protons than electrons, the atom is positively charged.
- Negative charge (-) - If there are more electrons than protons, the atom is negatively charged.
- Stable and unstable atoms - Only certain combinations of neutrons and protons result in stable atoms.

If there are too many or too few neutrons for a given number of protons, the resulting nucleus will have too much energy in it and will not be stable. The unstable atom will try to become stable by giving off excess energy in the form of particles or waves (radiation). These unstable atoms are also known as radioactive atoms.

B. DEFINITIONS

1. **Ionization**

Ionization is the process of removing electrons from atoms. If enough energy is supplied to remove electrons from the atom the remaining atom has a positive (+) charge. The positively charged atom and the negatively charged electron are called an ion pair. Ionization should not be confused with radiation. Ions (or ion pairs) can be the result of radiation exposure and allow the detection of radiation.

2. **Ionizing Radiation**

Energy (particles or rays) emitted from radioactive atoms can cause ionization, see figure A.1.2. The four basic types of ionizing radiation that are of primary concern in the nuclear industry are alpha particles, beta particles, gamma rays and neutron particles.

3. **Non-ionizing Radiation**

Radiation that doesn't have the amount of energy needed to ionize an atom is called "non-ionizing radiation," see figure A.1.2. Examples of non-ionizing radiation are radar waves, microwaves and visible light.

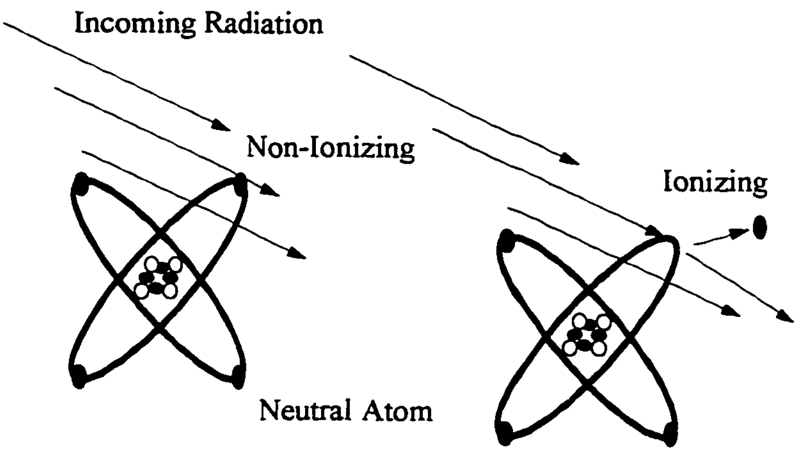


FIGURE A.1.2 - IONIZING RADIATION VERSUS NON-IONIZING RADIATION

- Radioactive material - Any material containing (unstable radioactive) atoms that emit radiation.
- Radioactive contamination - Radioactive material in an unwanted place. (There are certain places where radioactive material is beneficial).
- Radiation is a type of <u>energy</u> and contamination is a <u>material</u>. Therefore, exposure to radiation does not result in contamination of the worker.
- Radioactivity - The process of unstable (or radioactive) atoms trying to become stable by emitting radiation.
- Radioactive decay - The process of radioactive atoms releasing radiation over a period of time to try and become stable (non-radioactive). This is also known as disintegration.
- Radioactive half-life - Radioactive half-life is the time it takes for one half of the radioactive atoms present to decay. After seven half-lives the activity will be less than 1% of the original activity.

C. THE FOUR BASIC TYPES OF IONIZING RADIATION

The four basic types of ionizing radiation of concern in the nuclear industry are alpha particles, beta particles, gamma rays and neutron particles.

1. **Alpha Particles**

Physical characteristics

The alpha particle has a large mass and consists of two protons, two neutrons and no electrons, see figure A.1.3. It has a positive charge of plus two. It is a highly charged particle that is emitted from the nucleus of an atom. The positive charge causes the alpha particle (+) to strip electrons (-) from nearby atoms as it passes through the material, thus ionizing an atom.

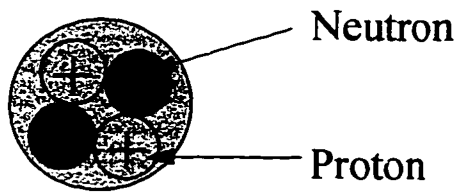


FIGURE A.1.3 - ALPHA PARTICLE

- Range

  The alpha particle deposits a large amount of energy in a short distance of travel. This large energy deposit limits the penetrating ability of the alpha particle to a very short distance. This range in air is about one to two inches.
- Shielding

  Most alpha particles are stopped by a few centimeters of air, a sheet of paper, or the dead layer (outer layer) of skin.
- Biological Hazard

  Alpha particles are not considered an external radiation hazard. This is because they are easily stopped by the dead layer of skin, see figure A.1.4. Should an alpha emitter be inhaled or ingested, it becomes a source of internal exposure. Internally, the source of the alpha radiation is in close contact with body tissue and can deposit large amounts of energy in a small volume of body tissue.

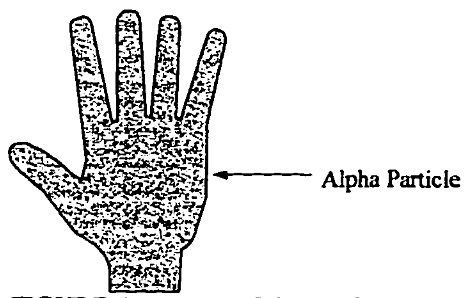


FIGURE A.1.4 - PENETRATION OF ALPHA PARTICLES

2. **Beta particles**

Physical Characteristics

The beta particle has a small mass and is negatively charged. It is emitted from the nucleus of an atom and has an electrical charge of minus one. Beta radiation causes ionization by displacing electrons from their orbits. The beta particle is physically identical to an electron. Ionization occurs due to the repulsive force between the beta particle (-) and the electron(-),both of which have a charge of minus one.

- Range

Because of its negative charge, the beta particle has a limited penetrating ability. Range in air is about 10 feet.

- Shielding

Most beta particles are shielded by plastic, glass, metal foil, or safety glasses.

- Biological Hazard

If ingested or inhaled, a beta emitter can be an internal hazard due to its short range. Externally, beta particles are potentially hazardous to the skin, see figure A.1.5, and eyes.

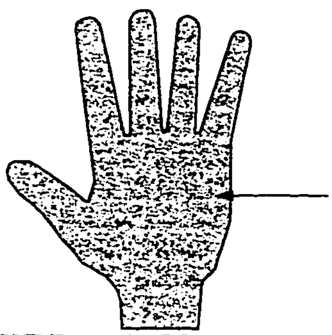


FIGURE A.1.5 - PENETRATION OF BETA PARTICLES

3. Gamma Rays/X Rays

Physical Characteristics

Gamma/x ray radiation is an electromagnetic wave or photon and has no electrical charge. Gamma rays are very similar to x rays. The difference between gamma rays and x rays is the place of origin. Also, gamma rays are typically more energetic than x rays. Gamma/x ray radiation can ionize as a result of direct interactions with orbital electrons. The energy of the gamma/x ray radiation is transmitted directly to its target.

- Range

Because gamma/x ray radiation has no charge and no mass, there is a very high penetrating power, see figure A.1.6. The range in air is very far compared to alpha and beta radiation. It will easily travel several hundred feet. The range depends upon the energy associated with the radiation.

- Shielding

Gamma/x ray radiation is best shielded by very dense materials such as concrete, lead or steel.

- Biological Hazard

  Gamma/x ray radiation can result in radiation exposure to the whole body.

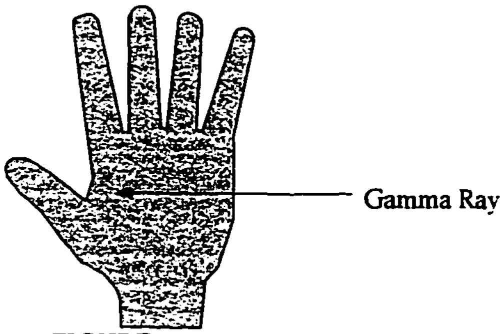


FIGURE A.1.6 - GAMMA PENETRATION

4. Neutron particles

Physical Characteristics

Neutron radiation consists of neutrons that are ejected from the nucleus. A neutron has no electrical charge. Due to their neutral charge, neutrons interact with matter either directly or indirectly.

A direct interaction occurs as the result of a collision between a neutron and a nucleus.

A charged particle or other ionizing radiation may be emitted during these interactions, which can cause ionization in human cells. This is called indirect ionization.

- Range

  Because of the lack of a charge, neutrons have a relatively high penetrating ability and are difficult to stop, see figure A.1.7. Range in air is very far. Like gamma rays, they can easily travel several hundred feet in air.

- Shielding

  Neutron radiation is best shielded by materials with a high hydrogen content, such as water or plastic.

- Biological Hazard

  Neutrons are a whole body hazard due to their high penetrating ability.

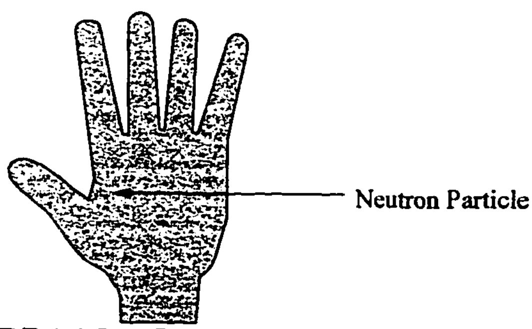


FIGURE A.1.7 - NEUTRON PENETRATION

D. UNITS OF MEASURE

1. Roentgen (R)

The Roentgen is a unit for measuring exposure in air. It is defined only for the amount of energy deposited in air. It is a unit of measure only for gamma and x rays. It does not relate biological effects of radiation to the human body. The International System of Units (SI) for Roentgens is Coulombs/kilogram (C/kg).

1 R (Roentgen) = 1000 milliroentgen (mR)

2. Radiation Absorbed Dose (RAD)

The rad is a unit for measuring absorbed dose in any material. Absorbed dose results from energy being deposited by the radiation. It is defined for any material. It applies to all types of radiation. It does not take into account the potential effect that different types of radiation have on the human body. The SI unit for absorbed dose is measured by the gray, (Gy), which is equal to 1 joule of energy absorbed per kilogram.

1 rad = 1000 millirad (mrad)
1 gray = 100 rad

3. Roentgen Equivalent Man (REM)

The rem is a unit for measuring dose equivalence. It is the most commonly used unit and pertains to man. The rem takes into account the energy absorbed (dose) and the biological effect on the body due to the different types of radiation. The SI unit for dose equivalence is the sievert, (Sv), which is equal to 1 biologically weighted joule per kg.

1 rem = 1000 millirem (mrem)
1 sievert = 100 rem

- Radiation Dose Rate

Dose is the amount of radiation you receive. Radiation dose rate is the rate at which you receive the dose. For example:

Radiation dose rate = dose/time; such as rem/hour or sieverts/hour

4. Contamination/Radioactivity

- Contamination Units
  a. Disintegration per minute (dpm)
  b. Counts per minute (cpm)

Radioactivity is measured as the number of disintegrations radioactive material undergoes in a certain period of time.

One curie (unit of radioactivity) =

2,200,000,000,000 (2.2×10^{12}) disintegrations per minute (dpm)

OR

37,000,000,000 (3.7×10^{10}) disintegrations per second (dps)

The SI unit for activity is the Becquerel (Bq), 1 Bq equals 1 dps.

For the radioactivity in air and water the curie (Ci) or microcurie (mCi) is most often used. One curie equals one million microcuries.

1 curie = 1,000,000 mCi

2. BIOLOGICAL EFFECTS

LEARNING OBJECTIVES:

LO1 IDENTIFY the average annual dose to the general population from natural background and man-made sources.
LO2 IDENTIFY the major sources of natural background and man-made radiation.
LO3 STATE the method by which radiation causes damage to cells.
LO4 IDENTIFY the possible effects of radiation on cells.
LO5 DEFINE the terms "acute dose" and "chronic dose".
LO6 STATE examples of a chronic radiation dose.
LO7 DEFINE the terms "somatic effect" and "heritable effect".
LO8 STATE the potential effects associated with prenatal radiation doses.
LO9 COMPARE the biological risks from chronic radiation doses to health risks workers are subjected to in industry and daily life.

INTRODUCTION

Of all existing environmental factors which are suspected to be a hazard to humans, we know more about the biological effects of ionizing radiation than any other. We have a large body of information available regarding exposures to humans as well as to animals.

There have been four events in recent history that exposed large groups of people to radiation. These events have allowed us to study the effects on human biology.

The first is some early workers such as radiologist who received large doses of radiation before the biological effects were recognized. Since that time, standards have been developed to protect workers.

The second group is the more than 100,000 survivors of the atomic bombs dropped at Hiroshima and Nagasaki. These survivors received estimated doses in excess of 50,000 mrem.

The third group consists of individuals who have been involved in radiation accidents, the most notable being the 1986 Chernobyl accident.

The fourth and largest group is comprised of radiation therapy patients who have undergone treatment for cancer.

A. SOURCES OF RADIATION

We live in a world which has always provided radiation exposures. As human beings, we have evolved in the presence of ionizing radiation which comes from the natural background radiation. The natural background is the radiation we receive primarily from the (1) cosmic, (2) terrestrial, (3) food, and (4) radon. The majority of us will be exposed to more ionizing radiation from natural background than from our employment.

The average annual radiation dose to a member of the general population in the US is about 360 millirem. This dose is from natural and man-made radiation sources.

1. **Natural Sources**

There are four primary sources of naturally occurring radiation exposures. The radiation emitted from these sources is identical to the radiation that results from the man-made sources.

a. Cosmic radiation

Cosmic radiation comes from solar (our sun) and galactic (deep outer space) sources and consists of positively charged particles as well as gamma radiation. At sea level, the average annual cosmic radiation dose is about 26 mrem. At higher elevations the amount of atmosphere shielding cosmic rays decreases and thus the dose increases. The total average annual dose to the general population from cosmic radiation is about 28 mrem.

b. Sources in earth's crust (terrestrial)

There are natural sources of radiation in the ground, rocks, building materials and drinking water. Some of the contributors to terrestrial sources are the natural radioactive elements radium, uranium and thorium. Many areas have elevated levels of terrestrial radiation due to increased concentrations of uranium or thorium in the soil. The total average annual dose to the general population from terrestrial radiation is 28 mrem.

c. Internal

Our food and water contain some trace amount of natural radioactive materials. These naturally occurring radioactive materials are deposited in our bodies and, as a result, cause an internal exposure to radiation. Some naturally occurring radioactive isotopes include Na-24, C-14, Ar-41 and K-40. Most of our internal exposure comes from K-40. Combined exposure from internal sources of natural background radiation account for a radiation dose of about 40 mrem per year.

d. Radon

Radon comes from the radioactive decay of radium, which is naturally present in the soil. Because radon is a gas, it can travel through the soil and collect in basements or other areas of a home. Radon emits alpha radiation. Because alpha radiation cannot penetrate the dead layer of skin on your body, it presents a hazard only if taken into the body. Radon and its decay products are present in the air. When inhaled it can cause a dose to the lung of approximately 2400 mrem per year. This is equivalent to a whole body dose of 200 mrem.

2. **Man-made Radiation Sources**

The four major sources of man-made radiation exposures are:

- Medical radiation
- Atmospheric testing of nuclear weapons
- Consumer products

- Industrial uses

a. Medical radiation sources

<u>X rays</u>

X rays are identical to gamma rays; however, they originate at the electron cloud outside the nucleus. X rays are an ionizing radiation hazard. A typical radiation dose from a chest x ray is about 10 mrem. The total average annual dose to the general population from medical x rays is 40 mrem.

<u>Diagnosis and therapy</u>

In addition to x rays, radioactive sources used in Nuclear Medicine, Radiation Oncology, Radiation Therapy and other specialties areas are used in medicine for diagnosis and therapy. The total average annual dose to the general population from these sources is 14 mrem.

b. Atmospheric testing of nuclear weapons

Another man-made source of radiation is residual fallout from atmospheric nuclear weapons testing in the 1950s and early 1960s. Atmospheric testing is now banned by most nations. The average annual dose from residual fallout is less than one mrem a year.

c. Consumer products

Examples of consumer products that contribute to radiation exposures include TVs, older luminous dial watches and some smoke detectors. This dose is relatively small compared to other naturally occurring sources of radiation and averages 10 mrem a year.

d. Industrial uses

Industrial uses of radiation include x ray machines (radiography) used to test pipe welds and bore-holes.

B. EFFECTS OF RADIATION ON CELLS

Each organ of the human body is made up of specialized cells. Ionizing radiation can potentially affect the normal operation of these cells.

1. Biological effects begin with the ionization of atoms

The method by which radiation causes damage to any material is by ionization of atoms in the material. Thus, the method by which radiation causes damage to human cells is by ionization of atoms in the cells. Atoms make up cells that make up the tissues of the body. These tissues make up the various organs of human body. Any potential radiation damage to the body begins with damage to atoms.

A cell is made up of two principle parts, the body of the cell and its center, the nucleus, which is like the brain of the cell.

When ionizing radiation hits a cell, it may strike a vital part of the cell like the nucleus or a less vital part of the cell. This occurrence is similar to being struck by a bullet; it may strike a vital part such as the head or may strike a less vital part such as a toe.

2. Cell sensitivity

Some cells are more sensitive to environmental factors such as viruses, toxins and ionizing radiation. Radiation damage to cells may depend on how sensitive the cells are to radiation.

Actively dividing cells (and non-specialized cells)

When a cell is in the process of dividing, it is less able to repair any damage. Therefore, cells in the body that are actively dividing are more sensitive to environmental factors such as ionizing radiation. Cells that rapidly divide include blood forming cells, the cells that line our intestinal tract, hair follicles and cells that form sperm.

Less actively dividing (and more specialized cells)

Cells which divide at a less rapid pace or are more specialized (such as brain cells or muscle cells) and are not as sensitive to damage by ionizing radiation. During mitosis, cells are larger and become an easier target for the incoming radiation to hit.

3. Possible Effects of Radiation on Cells

When a cell is exposed by something in its environment, such as ionizing radiation, several things can happen.

There may be no damage.

Cells repair the damage and operate normally.

The body of most cells is made up primarily of water. Therefore, when ionizing radiation hits a cell, it is most likely to interact with the water in the cell. Often the cell can repair this type of damage. Ionizing radiation can also hit the nucleus of the cell. The nucleus contains the vital parts of the cell such as chromosomes, which determines the cell function. When chromosomes replicate, they transfer their information to new cells. Although often more difficult, damage to chromosomes can also be repaired. In fact, the average human body repairs approximately 100,000 chromosome breaks per day.

Cells are damaged and operate abnormally.

The human cell is very resilient. In many cases it just repairs the damage and continues to function. But the damage might not be completely or even partially repairable. In that case, the cell may not be able to do its function, or it may die. It is possible that a chromosome in the cell nucleus could be damaged but not be repaired correctly. This is called a mutation or genetic effect. Genetic effects will be discussed when chronic radiation doses are considered.

Cells die as a result of damage.

At any given moment thousands of the body's cells are dying and being replaced by normal cells nearby. It is only when the dose of radiation is very high or is delivered very rapidly that a cell may not be able to repair itself or be replaced.

C. ACUTE AND CHRONIC RADIATION DOSE

Potential biological effects depend on how much and how fast a radiation dose is received. Radiation doses can be grouped into two categories, acute and chronic dose.

Radiation therapy patients receive high doses of radiation in a short period of time but, generally, only to a small portion of the body (not a whole body dose). Ionizing radiation is used to treat cancer in these patients because cancer cells are rapidly dividing and sensitive to ionizing radiation. Some symptoms of people undergoing radiation therapy are hair loss, nausea and tiredness.

1. Acute radiation doses

An acute effect is a physical reaction due to massive cell damage. This damage may be caused by a large radiation dose received in a short period of time, an acute dose. The body can't repair or replace cells fast enough from an acute dose, and physical effects such as reduced blood count and hair loss may occur. Slight blood changes may be seen at acute doses of 10,000-25,000 mrem but an individual should not otherwise be affected.

2. Radiation sickness

At acute doses greater than 100,000 mrem about half of the population will experience nausea (due to damage of the intestinal lining). Radiation therapy patients often receive doses in this range and above, although dose to the region of a tumor is many times higher than this.

If the acute dose to the whole body is very large (500,000 mrem or larger) it may cause so much damage that the body cannot recover. Thirty firefighters at Chernobyl received acute doses in excess of 800,000 mrem. These individuals succumbed to the effects of the burns they received, compounded by their radiation exposure.

3. After an acute dose to the whole body

After an acute dose, damaged cells will be replaced by new cells, and the body will repair itself, over the course of several of months. Only in those extreme accidents such as Chernobyl, would the dose be so high as to make recovery unlikely.

4. Acute doses to only part of the body

It is possible in that radiation exposure may be only to a limited part of the body such as the hand. There have been accidents, particularly with x ray machines, when individuals have exposed their fingers to part of the x ray beam. In some of these cases individuals have received doses of <u>millions</u> of mrem to their causing loss of one or more fingers. It is important for those who work with x ray equipment or similar equipment to be trained in the safe use of this equipment.

5. Probability of an acute dose

It is important to understand that it takes a massive acute dose of radiation before any physical effect is seen. These acute doses have only occurred in Hiroshima/Nagasaki, a few radiation accidents, and Chernobyl. The possibility of a radiological worker receiving an acute dose of ionizing radiation on the job is extremely remote. In many areas where radioactive materials are handled, the quantities handled are small enough that they do not produce a large amount of radiation. Where there is a potential for larger exposures, many safety features are in place.

6. Chronic radiation doses

A chronic radiation dose is typically a small amount of radiation received over a long period of time. A typical example of a chronic dose is the daily dose we received from natural background or the dose received from occupational exposure.

7. Chronic dose versus acute dose

The body is better equipped to tolerate a chronic dose than an acute dose. The body has time to repair damage because a smaller percentage of the cells need repair at any given time. The body also has time to replace dead or non-functioning cells with new, healthy cells. It is only when the dose of radiation is so high or is received very rapidly that the cellular repair mechanisms are overwhelmed, and the cell dies before repair can occur. A chronic dose of radiation does not result in physical changes to the body such as is seen with acute doses. Because of cell repair, even sophisticated analysis of the blood do not reveal any biological effects.

8. Genetic effects

The biological effects of concern from a chronic dose are changes in the chromosomes of a cell or direct irradiation of a fetus. Genetic effects refer to effects on genetic material in a cell chromosome. Genetic effects can be somatic (cancer) or heritable (future generations).

9. Somatic Effects

Damage to some genetic material in the cell could eventually cause that cell to become a cancer cell. This is an example of a somatic effect. The probability of this is very low at occupational doses.

10. Heritable effects

A heritable effect is a genetic effect that is inherited or passed on to offspring. Although, the individual has experienced damage to some genetic material in the cell that doesn't directly affect his/her body, it will be passed on to future generations. Although heritable effects from radiation have been observed in studies of plants and animals, they have , so far, never been observed in humans. Studies have followed the 77,000 descendants of the survivors of Hiroshima and Nagasaki, all of whom were conceived after the atomic bombs.

11. Factors affecting biological damage due to exposure to radiation:

Total dose - In general the greater the dose, the greater the biological effects.

Dose rate (how fast) - The faster the dose is delivered, the less time the cell has to repair.

Type of radiation - Alpha radiation is more damaging than beta or gamma radiation for the same energy deposited.

Area of the body exposed - In general, the larger the area of the body that is exposed, the greater the biological effects. Since extremities are less sensitive than internal organs. That is why the annual dose limit for extremities is higher than for a whole body exposure that irradiates the internal organs.

Cell sensitivity - The most sensitive cells are those that are rapidly dividing.

Individual sensitivity - Some individuals are more sensitive to environmental factors such as ionizing radiation. The developing embryo/fetus is the most sensitive, and children are more sensitive than adults. In general, the human body becomes relatively less sensitive to ionizing radiation with increasing age. The exception is that elderly people are more sensitive than middle aged adults due to an inability to repair damage as quickly (less efficient cell repair mechanisms).

D. PRENATAL RADIATION EXPOSURE

Although no effects were seen in Japanese children conceived after the atomic bomb, there were effects seen in some children who were exposed while in the womb to the atomic bomb radiation at Hiroshima and Nagasaki.

1. Sensitivity of the unborn

Embryo/fetal cells are rapidly dividing. This makes them sensitive to any environmental factors such as ionizing radiation.

2. Potential effects associated with prenatal exposures

Many chemical and physical (environmental factors) are suspected or known to cause damage to an unborn child, especially early in the pregnancy. Alcohol consumption, exposure to lead, heat from hot tubs are only a few that have been publicized lately. Some children who were exposed while in the womb to the radiation from the atomic bomb were born with low birth weights and mental retardation. It has been suggested but is not proven that exposures to the unborn may also increase the chance of childhood cancer. Only when doses exceed 15,000 mrem is there a significant increase in risk.

In an effort to be prudent, limits are established to protect the embryo/fetus from any potential effects which may occur from a significant amount of exposure to radiation. This exposure may be the result of exposure to external sources of radiation or internal sources of radioactive material. At present occupation dose limits, the actual risk to the embryo/fetus is negligible when compared to normal risk of pregnancy.

E. RISKS IN PERSPECTIVE

Because ionizing radiation can damage the cell's chromosomes it is possible that through incomplete repair a cell could become a cancer cell.

1. Risk from exposures to ionizing radiation

We do not know what the risks are at low levels of radiation exposure. No increases in cancer have been observed in individuals exposed to ionizing radiation at occupational levels, but the possibility of cancer induction cannot be dismissed because an increase in cancers has not been observed. Risk calculations have been derived from individuals who have been exposed to high levels of radiation.

2. Comparison of risks

Acceptance of a risk is a highly personal matter and requires a good deal of informed judgment.

The risks associated with occupational radiation doses are considered acceptable as compared to other occupational risks by virtually all the scientific groups who have studied them.

The following information is intended to put the potential risk of radiation into perspective when compared to other occupations and daily activities.

Table 4 compares the estimated days of life expectancy lost as a result of exposure to radiation and other health risks. Those estimates indicate that the health risks from occupational radiation exposure are smaller than the risks associated with readily accepted normal day-to-day activities.

Table 5 addresses the estimated days of life expectancy lost as a result of exposure to radiation and common industrial accidents at radiation-related facilities and compare these numbers to days lost as a result of fatal work-related accidents in other occupations.

Because there may be some small risk from exposures to ionizing radiation, public policy is to practice keeping your exposures As Low As Reasonably Achievable (ALARA).

Table 4
Average Estimated Days Lost Due to Daily Activities

Health Risk	Average Estimated Days Lost
Unmarried Male	3500
Cigarette Smoking	2250
Unmarried Female	1600
Coal Miner	1100
25% Overweight	777
Alcohol (US Average)	365
Construction Worker	227
Driving a Motor Vehicle	207
100 mrem/year for 70 years	10
Coffee	6

Table 5
Average Estimated Days Lost in Other Occupations

Industry	Average Estimated Days Lost
Mining/Quarrying	328
Construction	302
Agriculture	277
Radiation Dose of 5,000 mrem/yr for 50 years (Nuclear Industry)	250
Transportation/Utilities	164
All Industry	74
Government	55
Service	47
Manufacturing	43
Trade	30
Radiation Accidents (deaths from Exposure)	<1

3. RADIATION LIMITS

LEARNING OBJECTIVES:

L01 STATE the purposes of the facility administrative control levels.
L02 IDENTIFY the radiation dose limits, administrative control level and facility administrative control levels.
L03 STATE the site policy concerning prenatal radiation exposure.
L04 IDENTIFY the employee's responsibility concerning radiation dose limits and administrative control levels.
L05 DESCRIBE the action a worker should take if he or she suspects that dose limits or administrative control levels are being approached or exceeded.

INTRODUCTION

In order to minimize the potential risks of biological effects associated with radiation, dose limits and administrative control levels have been established.

A. DOSE LIMITS AND FACILITY ADMINISTRATIVE CONTROL LEVELS

The regulatory radiation dose limits are established for occupational workers based on guidance from the Environmental Protection Agency (EPA), the National Council on Radiation Protection and Measurements (NCRP), and the International Commission on Radiological Protection (ICRP).

Many facilities establish administrative control levels for radiation workers which are more conservative than the regulatory limits. This is to ensure that regulatory limits and control levels are not exceeded and to help reduce individual and total worker population radiation dose (collective dose).

The regulatory dose limits and administrative control levels are as follows:

1. Whole body

Definition: The "whole body" extends from the top of the head down to just below the knee. It also excludes the area just below the elbows. The "whole body" is the location of most of the blood-producing and vital organs.

Just as there are limits for external exposure to radiation, there are limits for internal exposure to radiation. Internal exposure is a result of radioactive material being inhaled, ingested, absorbed through the skin or a wound. Limits are based on the sum of internal and external exposure.

The regulatory radiation dose limit during routine conditions is 5 rem/year (0.05 sieverts). Many facilities, such as DOE, establish administrative control levels during routine conditions at 2 rem/year (0.02 sieverts).

2. Extremities

Definition: Extremities include the hands and arms below the elbow and the feet and legs below the knees.

This area is not as sensitive to radiation as the organs of the whole body.

Extremities can withstand a much larger dose than the whole body since there are no major blood producing organs located here.

The regulatory radiation dose limit for extremities during routine conditions is 50 rem/year (0.5 sieverts/year).

3. Skin and other organs

The regulatory radiation dose limit for skin and other organs during routine conditions is 50 rem/year (0.5 sieverts/year).

4. Lens of the eye

The regulatory radiation dose limit for lens of the eye during routine conditions is 15 rem/year (0.15 sieverts/year).

5. Declared pregnant worker (embryo/fetus)

General policy

A female radiation worker is encouraged to voluntarily notify her supervisor, in writing, when she is pregnant. The employer must provide the option of a mutually agreeable assignment of work tasks, with no loss of pay or promotional opportunity, such that further occupational radiation exposure is unlikely.

Regulatory limit

For a declared pregnant worker who chooses to continue working as a radiation worker, the following radiation dose limit will apply. The dose limit for the embryo/fetus (during entire gestation period) is 500 mrem (5 sieverts). Efforts should be made to avoid exceeding 50 mrem/month to the pregnant worker. If the dose to the embryo/fetus is determined to have already exceeded 500 mrem when a worker notifies her employer of her pregnancy, the worker shall not be assigned to tasks where additional occupational radiation exposure is likely during the remainder of the pregnancy.

The declaration may be revoked, in writing, at any time by the declared pregnant worker.

6. Visitors and public

The regulatory radiation dose limit for visitors and the public is 0.100 rem/year (0.001 sieverts).

B. WORKER RESPONSIBILITIES REGARDING DOSE LIMITS/CONTROL LEVELS

It is each employees responsibility to comply with regulatory dose limits/control level and Facility administraüve control levels.

Workers who suspect that dose limits or administrative control levels are being approached or exceeded, you should notify their supervisor immediately.

4. ALARA PROGRAM

LEARNING OBJECTIVES:

L01 STATE the ALARA concept.
L02 STATE the DOE/Site management policy for the ALARA program.
L03 IDENTIFY the responsibilities of management, Radiation Safety Organization and the radiation worker in the ALARA Program.
L04 IDENTIFY the basic protective measures of time, distance and shielding.
L05 IDENTIFY methods for reducing external and internal radiation dose.
L06 STATE the pathways through which radioactive material can enter the body.
L07 IDENTIFY methods a radiation worker can use to minimize radioactive waste.

INTRODUCTION

This unit is designed to inform the student of the concept of ALARA (As Low As Reasonably Achievable). Methods for reducing both external and internal doses from radiation and radioactive material are also discussed.

Even though there are dose limits and administrative control levels, it is preferable to keep radiation dose well below these. Employees should always try to maintain their radiation dose As Low As Reasonably Achievable (ALARA).

A. ALARA PROGRAM

1. ALARA Concept

ALARA stands for As Low As Reasonably Achievable.

This concept includes reducing both internal and external exposure to ionizing radiation. The ALARA concept is an integral part of all site activities that involve the use of radioactive materials.

The implementation of the ALARA concept is the responsibility of all employees.

2. Management Policy

Personal radiation exposure shall be maintained As Low As Reasonably Achievable. Radiation exposure of the work force and public shall be controlled such that:

Radiation exposures are well below regulatory limits.

There is no radiation exposure without commensurate benefit.

B. RESPONSIBILITIES FOR THE ALARA PROGRAM

Although the individual radiation worker is ultimately responsible for maintaining his/her radiation dose ALARA, management and Radiation Safety personnel also play an important role in the ALARA program. The following are some of the responsibilities of the three groups:

1. Management

Management is responsible for establishing the ALARA program at the site. It is also responsible to ensure that a management structure is in place to implement such a program, and that the worker follows the program.

Management is responsible to ensure that the program meets regulatory standards, guidelines, and regulations.

2. Radiation Safety Organization

Not only is the Radiation Safety Organization responsible for implementing the ALARA program at the Site, it is also responsible for implementing the requirements for the entire Radiation Safety program. These requirements are established by the facility license and regulations.

Radiation Safety Technicians (Health Physics Technicians) provide an interface point for the worker to obtain the most current radiological conditions in an area. They provide assistance when trying to interpret protective requirements or radiological information concerning a work assignment, and they address radiological questions/concerns.

3. Radiation workers

Each person involved in radiological work is expected to demonstrate responsibility and accountability through an informed, disciplined and cautious attitude toward radiation and radioactivity.

C. EXTERNAL RADIATION DOSE REDUCTION

The main goal of the ALARA program is to reduce both the external and internal radiation doses to a level that is As Low As Reasonably Achievable.

Basic protective measures used to reduce external exposure include minimizing time in a field of radiation, maximizing the distance from a source of radiation and using shielding whenever possible.

1. Methods for minimizing time

Reducing the amount of time in a field of radiation will lower the dose received by the workers.

a. Pre-plan and discuss the task thoroughly prior to entering the area. Use only the number of workers actually required to do the job.
b. Have all necessary tools before entering the area.
c. Use mock ups and practice runs that duplicate work conditions.
d. Take the most direct route to the job site.
e. Never loiter in an area controlled for radiological purposes.
f. Work efficiently but swiftly.
g. Do the job right the first time.

h. Perform as much work outside the area as possible or, when practical, remove parts or components to areas with lower dose rates to perform work.

In some cases, such as synthesis operations, the Radiation Safety personnel may limit the amount of time a worker may stay in an area. This is known as a "stay time". Once a stay time has been assigned, do not exceed this time. The exposure rate is inversely proportional to the square of the distance from the source.

2. Methods for maintaining distance from sources of radiation

a. Stay as far away as possible from the source of radiation.
b. For point sources, the dose rate follows the inverse square law.

$$\text{Dose} = 1/\text{Distance}^2$$

If the distance is doubled, the dose rate falls to 1/4 of the original dose rate. If the distance is tripled, the dose rate falls to 1/9 of the original dose rate.
c. Be familiar with radiological conditions in the area.
d. During work delays, move to lower dose rate areas.
e. Use remote handling devices when possible.

3. Proper uses of shielding

Shielding reduces the amount of radiation dose to the worker. Different materials shield a worker from the different types of radiation.

a. Take advantage of permanent shielding such as non-radiological equipment/structures.
b. Use shielded containers when available.
c. Wear safety glasses/goggles to protect the eyes from beta radiation, when applicable.
Temporary shielding (e.g. lead or concrete blocks) is often installed, and should be installed according to procedures established. Once temporary shielding is installed, it should not be removed without a thorough survey or proper authorization.
d. It should be remembered that the placement of shielding may actually increase the total dose (e.g., man-hours involved in placement, Bremsstrahlung, etc.).

4. Source Reduction

By reducing the source, the exposure rate is reduced in proportion to the source strength. Many sealed sources do not allow this options. However, if more than one source is being used, and only one is needed, remove the unneeded sources.

D. INTERNAL RADIATION DOSE REDUCTION

Internal exposure is a result of radioactive material being taken into the body. Radioactive material can enter the body through one or more of the following pathways; (1) inhalation, (2) ingestion, (3) absorption through the skin, and (4) injection.

Methods to reduce internal radiation dose

Reducing the potential for radioactive materials to enter the body is important. The following are methods the worker can use:

Wear respirators properly and when required (if qualified) when applicable.

Report all wounds or cuts before entering any area controlled for radiological purposes.

Comply with the requirements of work documents.

Do not eat, drink, smoke or chew gum in areas controlled for radiological purposes.

Additional methods to reduce dose

Source reduction is another method of reducing radiation doses. Source reduction normally involves procedures such as flushing radioactive systems, decontamination, etc. to reduce the amount of radioactive materials present in/on a system that contribute to radiation levels in an area.

E. RADIOACTIVE WASTE MINIMIZATION

One of the consequences of working in and around radioactive materials is that radioactive waste will be generated. Examples of radioactive waste include:

paper	scintillation vials
gloves	animal waste
glassware	containers
rags	sharps
brooms	mops

Ultimately, this radioactive waste must be disposed. To reduce personnel exposure and reduce costs associated with the handling, packaging and disposal of radioactive waste, it is very important for each employee to minimize the amount of radioactive waste generated.

1. Minimize the materials used for radiological work.

Take only the tools and materials you need for the job into areas controlled for radiological purposes especially contamination areas.

Unpack equipment and tools in a clean area to avoid bringing excess clean material to the job site.

Whenever possible, use tools and equipment identified for radiological work.

If you do not know where to get tools that are to be used for radiological work, ask your supervisor.

Use only the materials required to clean the area. An excessive amount of bags, rags, and solvent add to radioactive waste.

2. Segregate radioactive waste from nonradioactive waste.

Place radioactive waste in the receptacles identified for radioactive waste, not in receptacles for nonradioactive waste.

Do not throw radioactive material that may be reused or nonradioactive waste into radioactive waste containers.

Segregate material which may be compacted from material which can not be compacted.

3. Minimize the amount of mixed waste generated.

Use good housekeeping techniques.

F. RADIATION SAFETY ORGANIZATION

Regulatory agencies require that each licensee shall develop, document, and implement a radiation protection program commensurate with scope and extent of the licensed activities and sufficient to ensure compliance with the provisions of the appropriate regulations.

The licensee shall use, to the extent practicable, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to members of the public that are as low as is reasonably achievable.

The licensee shall periodically (at least annually) review the radiation protection program content and implementation.

To control the use of radiation sources and maintain compliance, an organization has been established to oversee the program. Many of the members of this organization are identified by name on the license. This organization consists of a Radiation Safety Committee, Radiation Safety Officer, Principle Users (permits), and the individuals authorized to handle radiation sources.

G. RESPONSIBILITIES OF THE ORGANIZATION AND THE USERS

1. The Radiation Safety Committee

The Radiation Safety Committee is charged with the responsibility of assuring that radioactive material is used safely and in accordance with all pertinent State and Federal regulations. The committee is authorized to establish appropriate internal rules and regulations to control and restrict the use of radioactive materials. The Committee consists of representatives from management and research groups involved with different aspects of radiation use. The Radiation Safety Officer is a permanent member of the Radiation Safety Committee. The committee meets at least quarterly. The Chairman is identified by name on the license from the regulatory agency.

2. The Radiation Safety Officer

It is the primary function of the Radiation Safety Officer to assure radiation safety and to ensure compliance with all Federal and State regulations with regard to radiation protection. The Radiation Safety Officer is identified by name on the license from the regulatory agency.

Specific responsibilities include:

a. Assuming responsibility with respect to radiation safety for all programs involving ionizing radiation.
b. Serving as liaison representative with the regulatory agency in matters of licensing, registration, and radiation protection. The Radiation Safety Office will act as a central repository for all records required.
c. Reviewing applications and granting permission for (or disapproving) the use of and/or the location of radioactivity and radiation-producing devices.
d. Reviewing and approving request for radioisotopes; maintaining inventory records.
e. Arranging for disposal of all radioactive waste, and maintaining waste records.
f. Performing all leak tests; maintaining records of sealed sources.
g. Providing personal monitoring equipment (dosimeters) and maintaining exposure records for all personnel; assigning individuals to appropriate internal radiation monitoring programs as necessary; maintaining all radiation exposures in accordance with regulatory requirements.
h. Establishing procedures where necessary for the safe use and handling of radioactivity or radiation producing devices.
I. Specifying all radiation accessories including monitoring, instrumentation and shielding.
j. Authorizing shutdown of a laboratory or modifying laboratory procedures in any area when the health of personnel or the general public is endangered by radiation, or where existing Federal or State regulations may be violated.
k. Reviewing and prescribing special conditions, requirements, and restrictions which may be necessary for the use of radioisotopes, or where the health of personnel or the general public may be endangered.
l. Monitoring and performing audits on all facilities utilizing radioactivity or radiation producing devices; ensuring the control of contamination and safe operation with respect to radiation safety, and maintaining records of same.
m. Notify the regulatory agency when the following occurs: loss of control of radioactive material, radiation exposures in excess of regulatory limits, loss of use of the facility, or damage in excess of $5000 due to a radiation accident.

3. Radiation Safety Assistant (Radiation Support Staff/Personnel)

The Radiation Safety Officer may delegate responsibility for technical radiation protection activities to personnel working for him/her and under his/her direct supervision. Training for these functions will be provided by the Radiation Safety Officer.

These functions may include but are not limited to:

a. Reviewing purchase request for completeness and correctness.
b. Receiving and check-in of radioisotope shipments.

c. Processing and arranging disposal of radioactive waste.
d. Monitoring such as laboratory surveys, bioassays, and air sampling.
e. Personal monitoring equipment as required by the Radiation Safety Officer.
f. Performing calibration of survey instrumentation.

4. Responsibilities of Principal Users

Principal Users are responsible for the safe use and handling of radioisotopes by all personnel operating under their supervision.

Specific responsibilities include:

a. Carrying out the radiation safety program as defined in the Radiation Safety Manual.
b. Familiarity with appropriate regulations and procedures for the safe use and handling or radioactive materials.
c. Notifying persons entering the research areas of the presence of radioactive material or radiation and the necessary precautions.
d. Instructing subordinates and training them in safety procedures required for handling radioactive material specific to laboratory/project operations.
e. Maintaining contamination surveys and inventory records for the laboratory.
f. Notifying the Radiation Safety Officer in the event of radiation hazard involving contamination of the laboratory, loss of control of radioactive material, or exposure of personnel.
g. Following proper procedures in procurement, storage, security, transfer, and disposal of radioactive material.

5. Responsibilities of Individual Users

Individual users are responsible for:

a. Familiarity with appropriate regulations and procedures for the safe use and handling of radioactive materials.
b. Notifying the Principal User and the Radiation Safety Officer in the event of a spill, personnel contamination, or loss of control of radioactive material.
c. Notifying persons entering the research areas of the presence of radioactive material or radiation.
d. Maintaining laboratory housekeeping in areas utilizing ionizing radiation.
e. Following proper procedures in procurement, storage, transfer, and disposal of radioactive material.

H. TRAINING

The facility provides radiation safety training to all employees. The training includes an orientation lecture, a copy of the Radiation Safety Manual, and an annual refresher course provided by the Radiation Safety Officer. Additional training may be required for a specific audience if the Radiation Safety Committee and/or the Radiation Safety Officer feel it is necessary to maintain exposures as low as reasonably achievable.

5. PERSONNEL MONITORING PROGRAMS

LEARNING OBJECTIVES:

L01 STATE the purpose of each of the personnel dosimeter devices used at the site.

L02 IDENTIFY the correct use of each of the personnel dosimeter devices used.

L03 STATE the purpose of each type of internal monitoring method used.

L04 IDENTIFY worker responsibilities concerning internal monitoring programs.

L05 STATE the method for obtaining radiation dose records.

L06 IDENTIFY worker responsibilities for reporting radiation dose received from other sites and from medical applications.

INTRODUCTION

To assess each employee's external and internal exposure to ionizing radiation, special types of monitoring equipment are used. Various types will be used depending on the radiological hazards present. Each type needs to be handled correctly.

A. EXTERNAL DOSIMETRY

Various types of external dosimeters are used to measure personnel dose to external sources of radiation. Most programs receive their monitoring devices from various vendors (companies who specialize in dosimetric devices). These vendors evaluate the information recorded on the monitoring devices and provide the associated reports to their customers. They produce several different types of monitoring devices depending on the customers application. The purpose of each dosimeter device must be known and understood so that each can be used correctly.

- Wear dosimeters at all times in areas controlled for radiological purposes and when required by signs, work permits or radiation safety personnel. Dosimeters must be worn on the chest area between the waist and the neck.
- When pocket or electronic dosimeters are required, they shall be worn within close proximity to the primary dosimeter.
- While in an area controlled for radiological purposes, take proper actions if a dosimeter is lost, off scale, damaged or contaminated. These actions include:

  Place work activities in a safe condition
  Alert others
  Immediately exit the area
  Notify Radiological Control personnel
  Know the proper dosimeter storage location.
  Return dosimeters for processing periodically. Personnel who fail to return dosimeters must be restricted from continued radiological work.
  Wear dosimeters only at site for which they are issued.

B. INTERNAL MONITORING

Potential sources of internal exposures can be placed into two categories. One category is natural radioactivity in all food and water, the air, and medical procedures that use radioactive materials and radioactive contamination.

The other category is accidental or inadvertent internal uptake (incorporation into the cells) of radioactive material (internal contamination) that can cause additional dose to the whole body or individual organs.

Internal Monitoring Methods

To indirectly measure the amount of radioactive material present inside the body, whether from naturally occurring or inadvertent uptakes, whole body counters and/or bioassay samples may be used. From this measurement, an internal dose may be calculated.

The purpose of each type of internal monitoring method is to maximize the possibility of detection for the nuclide involved.

It is each worker's responsibilities to participate in the monitoring program according to the established procedures.

C. RADIATION DOSE RECORDS

- Methods for obtaining dose records usually involve a written request.
- Report radiation dose received from other facilities and medical applications.
- Notify Radiological Control personnel prior to and following of any radiation dose received at another facility so that dose records can be updated.
- Medical applications (excluding routine medical and dental x rays) are not included as occupational exposures.
- Dose record reports.
- Personnel (non-visitors) who are monitored with dosimeters will be provided an annual report of their radiation dose.
- Upon request, personnel should receive a current radiation dose record.
- Terminating personnel will receive a report of the radiation dose received at that site.

D. DOSIMETRY PROGRAM

A monitoring program has been established to determine and record the absorbed dose of staff and visitors, and to insure compliance with regulations. The program consists of:

1. Dosimeters issued based upon exposures.

Dosimeters shall be issued to all staff who are likely to receive 300 mrem/quarter absorbed dose to the whole body, 400 mrem/quarter absorbed dose to the skin of the whole body, or 900 mrem/quarter to the hands, forearms, feet, or ankles.

2. Issuing dosimeters to new employees

Dosimeters shall be issued as soon as possible to employees, but before they begin work handling radiation sources. Dosimeters issued will be dependent on the isotopes used and the procedures involved. However, all radiation workers will be issued whole body dosimeters.

3. Responsibility of the wearer

Any dosimeter issued to an individual will become the responsibility of the individual. Dosimeters must never be taken from the facility except under the direction of the Radiation Safety Officer. All dosimeters will be stored in a radiation free area when not worn. Control dosimeters will be used to monitor environmental exposure to all films when they are in storage or in transit.

4. When and how to wear the dosimeters

Working with RAM without appropriate dosimeters in place is prohibited. Dosimeters will be worn in the following manner:

a. Whole body dosimeters -- on the front of the torso, in a location where they are unlikely to become contaminated.

b. Extremity dosimeters (ring) -- on any finger of hand most likely to receive the greatest exposure. The ring label is worn inside.

5. Dosimetry records.

- Accounting records shall be kept of the arrival and shipping of all dosimeters.
- All dosimeters shall be surveyed for contamination prior to shipping to the vendor.
- All lost or damaged dosimeters will require dosimetry estimates whenever possible.
- All estimates shall involve an interview with the individual being monitored, so that an agreement on the estimate is reached. Only then will the vendor be notified by letter (legal document).

6. Monitoring of visitors

Visitors who receive occupational radiation exposure during their visit will be issued temporary dosimeters. Records will be kept of each visitor's name, dates of exposure, social security number, date of birth and exposure received.

7. Dosimetry reports to workers

Dosimetry reports will be examined, initialed and dated by the Radiation Safety Officer when they are received from the vendor. Exposure notification will be sent to anyone having been exposed. Regulations requires individual dosimetry data be made available to persons who are monitored. However, dosimetry reports are confidential, and should not be released to anyone outside the facility except regulatory inspectors.

8. Spare dosimeters and damaged dosimeters

Spare dosimeters shall be issued to new employees working for 2 weeks or less or as replacements for lost or damaged dosimeters.

E. BIOASSAY PROCEDURE FOR THE UPTAKE OF IODINE-125

Iodine-125 presents a special risk to the individual working with or near unsealed sources due to its ability to translocate. Special procedures have been established to determine the thyroid burden from Iodine-125 deposited internally by inhalation, ingestion, or absorption through the skin. The actual procedures are maintained and administered by the Radiation Safety Officer.

Monitoring schedules have been established for individuals handling Iodine-125 between 24 and 72 hours after the use of specific quantities. These quantities differ if the form is volatile or not.

F. BIOASSAY PROCEDURE FOR THE UPTAKE OF H-3

Handling tritium also presents a special risk. Approximately half of the uptake experienced by an individual from tritium is obtained by absorption through the skin. To determine the whole body burden from H-3 deposited internally by inhalation, ingestion or absorption through the skin, a special monitoring program has been established.

Bioassays are performed within one week (of primary use) for persons using H-3 in unsealed form if the quantity handled at any one time or cumulatively over a month's period is 100 millicuries or more as precursors of deoxyribose nucleic acid, or 1 curie or more in other forms of tritiated compounds.

The actual procedures are maintained and administered by the Radiation Safety Officer.

6. RADIOACTIVE CONTAMINATION CONTROL

LEARNING OBJECTIVES:

L01 DEFINE fixed, removable and airborne contamination.
L02 STATE sources of radioactive contamination.
L03 STATE the appropriate response to indicators of potential area contamination or personnel contamination alarms.
L04 IDENTIFY methods used to control radioactive contamination.
L05 IDENTIFY the proper use of protective clothing.
L06 EXPLAIN the purpose and use of personnel contamination monitors.
L07 IDENTIFY the normal methods used for decontamination.

INTRODUCTION

This unit is designed to inform the worker of sources of radioactive contamination. It will also present methods used to control the spread of contamination.

Contamination control is one of the most important aspects of radiological protection. Using proper contamination control practices will help ensure a safe working environment. It is important for all employees to recognize potential sources of contamination as well as to use appropriate contamination prevention methods.

A. COMPARISON OF RADIATION AND RADIOACTIVE CONTAMINATION

Ionizing radiation is the energy (particles or rays) emitted from radioactive atoms that can cause ionization.

Radioactive contamination comes from material that contains radioactive atoms. Even when this radioactive material is properly contained, it may still emit radiation and be an external dose hazard, but it will not be a contamination hazard. When this radioactive material escapes its container, it is then referred to as radioactive contamination.

Radiation is an energy. Contamination is a material.

B. TYPES OF CONTAMINATION

Radioactive contamination can be fixed, removable or airborne.

1. Fixed contamination

Fixed contamination cannot be readily removed from surfaces. It cannot be removed by casual contact. It may be released when the surface is disturbed (buffing, grinding, using volatile liquids for cleaning). Over time it may "weep," leach or otherwise become loose or transferable.

2. Removable/transferable contamination

Contamination that can readily be removed from surfaces. It may be transferred by casual contact, wiping, brushing or washing. Air movement across removable/transferable contamination could cause airborne contamination.

3. Airborne contamination

Contamination suspended in air.

C. SOURCES OF RADIOACTIVE CONTAMINATION

Radioactive material can be spread to unwanted locations. There are several sources and indicators of radioactive contamination.

1. Leaks or breaks in radioactive systems

Hot particles are small, sometimes microscopic pieces of radioactive material that are highly radioactive. They can cause a high, localized radiation dose in a short period of time if they remain in contact with skin/tissue. Hot particles may be present when contaminated systems leak, are opened or when machining, cutting, or grinding highly radioactive materials. Work activities which often present exposure risks to workers from leaks or breaks in radioactive systems include:

- Opening radioactive systems without proper controls.
- Airborne contamination depositing on surfaces.
- Leaks or tears in radiological containers such as barrels, plastic bags or boxes.
- Poor housekeeping in contaminated areas.
- Excessive motion or movement in areas of higher contamination.
- Sloppy work practices such as cross-contamination of tools, equipment or workers.

2. Indicators of possible contamination

- Leaks, spills, standing water
- Dusty, hazy air
- Damaged radiological containers
- Spurious or unexplained personnel contamination at exit points
- Higher than normal background on personnel contamination survey devices
- Airborne monitor alarms

D. CONTAMINATION CONTROL METHODS

Control of radioactive contamination can be achieved by proper personnel radiological practices and engineering controls. By controlling contamination, the potential for internal exposure and personnel contamination can be decreased.

If the presence of loose contamination is discovered, decontamination is a valuable means of control. In some situations, this is not always possible due to:

- Economical conditions: Cost of time and labor to decontaminate location outweigh the hazards of the contamination present.
- Radiological conditions: Radiation dose rates or other radiological conditions present hazards which far exceed the benefits of decontamination.

Therefore, other means of control must be initiated when decontamination is not possible.

1. Employ preventive methods to control radioactive contamination.

- Identify and repair leaks before they become a serious problem.
- Establish adequate work controls before starting jobs.
- Discussing measures that will help reduce or prevent contamination spread before the work begins.
- Change out gloves or protective gear as necessary to prevent cross-contamination of equipment.
- Set-up pre-staging areas to prevent contamination spread from work activities:
  - Cover equipment below a work area to prevent dripping contamination onto cleaner areas.
  - Cover/tape handling tools or equipment used during the job to minimize decontamination after the job (i.e., tape up a pipette before use).
- Good work practices such as good housekeeping and cleaning up after jobs.

"Good Housekeeping" is the prime factor in an effective contamination control program. It involves the interactions of all workers within the laboratory or group. Each individual must be dedicated to keeping "his/her house clean" to control the spread of contamination.

Every possible effort should be made in all operations to confine the spread of radioactive materials to the smallest possible area.

A sound preventive maintenance program can prevent many radioactive material releases.

Control and minimize all material taken into or out of contaminated areas.

Regardless of the precautions taken, radioactive materials will occasionally escape and contaminate an area.

Radiation workers should always be alert for potential violations to the basic principle of contamination control: use of improper contamination control methods, bad work practices, basic rule or standard operating procedure violations, radioactive material releases or liquid spills.

Radiation workers should always ensure that the proper procedures to avoid the spread of contamination are followed or implemented.

2. Engineering control methods

Ventilation is designed to maintain airflow from areas of least contamination to areas of most contamination (e.g., clean to contaminated to highly contaminated areas). Slight negative pressure is maintained on buildings where potential contamination exists.

It is possible to use high efficiency particulate filtration (HEPA) which removes radioactive particles from the air.

3. Containment

Containment generally means using vessels, pipes, cells, glovebags, gloveboxes, tents, huts and plastic coverings to control contamination by containing it.

4. Personnel protective measures

If engineering methods are not adequate then personnel protective measures such as protective clothing and respiratory equipment must be used.

Protective clothing is required to enter areas containing contamination levels above specified limits to prevent contamination of personnel skin and clothing. The degree of clothing required is dependent on the work area, radiological conditions and the nature of the job.

Full protective clothing generally consists of laboratory coats, surgical gloves, and shoe covers.

5. Proper Use

- Inspect all protective clothing for rips, tears or holes prior to use.
- Personal effects such as watches, rings and jewelry should not be worn in contaminated areas.
- Supplemental dosimeters, such as ring badges, should be worn underneath the protective gloves.
- After donning protective clothing and working in contaminated areas, do not go to other locations (i.e., outside the laboratory) with the protective clothing.
- Contact Radiological Control personnel if clothing becomes ripped or torn.
- Respiratory equipment is used to prevent the inhalation of radioactive materials. This training course <u>does not</u> qualify a radiation worker to wear respiratory equipment.

E. CONTAMINATION MONITORING EQUIPMENT

Contamination monitoring equipment is used to detect radioactive contamination on personnel.

<u>Types and use of hand-held contamination monitors</u>.

- Verify the instrument is on, set to the proper scale, and the audio will be heard.
- Survey hands before picking the probe up.
- Hold probe approximately ½" from surface being surveyed for beta/gamma radiation.
- Move probe slowly over surface, approximately 2" per second.
- Proceed to survey in the following typical order (for a complete survey):

- Start at the head (pause at mouth and nose for approximately 5 seconds if airborne contamination is a concern), neck, and shoulders
    - Arms - pause at each elbow
    - Chest, abdomen and back
    - Hips and seat of pants
    - Legs - pause at each knee
    - Shoe tops
    - Shoe bottoms
    - Finally survey the personal and supplementary dosimeters.
- The whole body survey should take 2-3 minutes per survey instrument.
- If the count rate increases during the survey, pause for 5-10 seconds over the area to provide adequate time for instrument response. Carefully return the probe to holder.
- If contamination is indicated, remain in the area and notify Radiation Safety personnel. Minimize cross contamination (such as putting a glove on a contaminated hand) while waiting for Radiation Safety personnel to arrive.

F. DECONTAMINATION

Decontamination is the removal of radioactive materials from locations where it is not wanted. This does not result in the disappearance of radioactive material but involves the removal of the radioactive materials to another location.

- Personnel decontamination is normally accomplished using mild soap and lukewarm water.
- Material decontamination is the removal of radioactive materials from tools, equipment, floors and other surfaces in the work area.

7. RADIOLOGICAL POSTING AND CONTROLS

LEARNING OBJECTIVES:

L01 STATE the purpose of and information found on standard operating procedures.

L02 IDENTIFY the individual's responsibilities in using standard operating procedures.

L03 IDENTIFY the colors and symbols used on radiological postings, signs and labels.

L04 DEFINE all types of Radiation, Contamination, Airborne Radioactivity and Radioactive Material Areas.

L05 STATE the entry requirements for working in and exiting areas controlled for radiological purposes.

L06 STATE the radiological and disciplinary consequences of disregarding radiological postings, signs and labels.

L07 STATE the radiological and disciplinary consequences of unauthorized removal of relocation of radiological postings, signs and labels.

INTRODUCTION

The previous sections discussed some very important background radiological information and radiation dose and contamination control methods. This section will apply this information to the working environment.

A. STANDARD OPERATING PROCEDURES

Standard operating procedures are used to establish radiological controls for areas where radiation sources are handled or stored. They serve to inform workers of area radiological conditions, entry requirements into the areas, special and general radioisotope handling, and provide a means to relate radiation doses received by workers due to specific work activities.

There are two types of Radiological Work Permits depending on the radiological conditions. General operating procedures are used to control routine or repetitive activities such as general handling techniques and inspections in areas with historically stable radiological conditions. Job specific procedures are used to control non-routine operations or work in areas with changing radiological conditions.

1. Information found on Radiological Work Permits consists of:

a. Description/location of work
b. Radiological conditions (this information may also be determined from area radiological survey maps/diagrams or the radiological posting for that area)
c. Dosimeter requirements for the work

d. Pre-job instruction (as applicable). Pre-job instruction generally consist of workers and supervisor(s) discussing various radiological aspects of the job so as to minimize radiological exposure and unplanned situations
e. Required level of training
f. Protective clothing/equipment requirements
g. Radiological Control coverage requirements and stay time controls, as applicable
h. Limiting radiological conditions which may void the operation
i. Special dose or contamination reduction considerations
j. Special personnel surveying considerations
k. Technical work document and other unique information for the task.
l. Date of issue/expiration (if applicable)
m. Authorizing signatures (if applicable)

2. Worker Responsibilities

Workers are responsible to have read and understood the procedure prior to handling radiation sources within the procedure. If, in the judgment of a worker, the procedure is not correct or the information is not clear and understandable, the job should not be started. Instead, the supervisor or Radiation Safety personnel should be contacted. Workers must obey any instructions written in the procedure. Substitutions must never be made for specified requirements.

B. RADIOLOGICAL POSTINGS

1. Purpose

Radiological postings are used to alert personnel to the presence of radiation and radioactive materials. All entrances to the controlled areas shall be clearly marked to indicate that the radioactive materials or radiation producing devices are present.

2. Posting Requirements

Areas Controlled for Radiological Purpose will be designated with a magenta (or black) standard three-bladed radiological warning symbol on a yellow background. Additionally, yellow and magenta ropes, tapes, chains, or other barriers will be used to denote the boundaries.

a. The barriers will be clearly visible from every side. Entrance points to those areas will have signs (or equivalent) stating the entry requirements, such as "Personnel Dosimeters are Required." Additionally, the radiation dose rate, contamination level and/or airborne radioactivity concentration will be included on or near each posting, if applicable when higher levels are experienced.
b. Before entering an area controlled for radiological purposes, read all the signs. Since radiological conditions may change, the signs must also be

changed to reflect the new conditions. Yesterdays sign may be replaced with a new one today.

c. In some cases, more than one radiological hazard may be present in the area. Each must be posted (e.g., Radiation Area, Contamination Area, Airborne Radioactivity Area.)

3. Types of areas controlled for radiological purposes.

The following areas are referred to as radiological areas. Radiological area is a generic term referring to portions of Radiological Buffer Areas.

a. Radiological Buffer Area (BRA) - A boundary area surrounding other radiological areas containing greater radiological hazards such as Radiation, Contamination and Airborne Radioactivity Areas.
   Requirements for entry and working in buffer areas include:
   - Specialized training and personal dosimetry
   - Eating, drinking, smoking or chewing prohibited
   - Obey any posted, written or oral requirements including "Evacuate", or "Stop Work" orders from Radiation Safety personnel

   Stop Work orders are usually a result of one or more of these problems:
   - Inadequate radiological controls
   - Radiological controls not being implemented
   - Sometimes labels or tags are used to warn of specific radiological hazards. Also, radioactive material may be stored in containers which are marked appropriately.

b. Hot Spots
   A hot spot is a localized source of radiation or radioactive material sometimes found in equipment. The radiation levels at that point are typically much higher than the surrounding area. Avoid those areas. The posting will indicate:

CAUTION - HOT SPOT

- Report to Radiation Safety personnel if radiological controls are not adequate or are not being followed.
- In addition, report any unusual conditions such as leaks or spills, dusty, hazy air, and alarming radiation safety instrumentation to Radiation Safety personnel.
- If a spill of radioactive material should occur, it must be controlled immediately to prevent the spread of contamination. To assist in controlling the spill, use the **SWIMS** method:
  - **Stop** or secure the operation causing the spill.
  - **Warn** others in the area.

- **Isolate** the spill if possible
- **Minimize** individual exposure and contamination
- **Secure** unfiltered ventilation, as appropriate
- Notify Radiation Safety personnel and your supervisor

Be aware of changing radiological conditions. Make sure that activities do not create radiological problems for others, and be alert that the activities of others may change the radiological conditions.

<u>Requirements for Exiting</u>

- Monitoring requirements for exiting are site specific
- Before entering a clean area, workers must monitor for contamination per instructions.
- Personal items, such as notebooks, papers or flashlights must also be monitored for contamination and are subject to the same monitoring requirements as the person carrying them.
- Personnel surveying shall be performed prior to washing or showering.

c. Radiation Area

An area is designated a Radiation Area when radiation dose rates are > 5 mrem/hr but ≤ 100 mrem/hr at 30 centimeters from the source of radiation. The postings/signs will indicate:

CAUTION
RADIATION AREA
Personnel Dosimetry Required for Entry

All personnel entering such areas must have completed Radiation Worker Training to include the following established standard operating procedures. Do not loiter. Always practice ALARA. If unanticipated elevated radiation levels are indicated as identified by off scale dosimeter, radiological alarms or other indicators; then:

- Stop work
- Alert others
- Immediately exit the area
- Notify Radiation Safety personnel
- Follow the requirements for exiting

d. High Radiation Area

An area is designated High Radiation Area when radiation dose rates are > 100 mrem/hr at 30 centimeters from the source of radiation, but ≤ 500 rad/hr at 100 centimeters from the source of radiation. The postings/sign will indicate:

DANGER

HIGH RADIATION AREA
Personnel Dosimetry, Supplemental Dosimeters and
Radiological Work Permit Required for Entry

e. Very High Radiation Area
An area is designated Very High Radiation Area when radiation dose rates are >500 rad/hr at 100 centimeters from the source of radiation. The postings/signs will indicate:

GRAVE DANGER - VERY HIGH RADIATION AREA
Special Controls Required for Entry

Entry requirements for High Radiation Area and Very High Radiation Area include specialized training and procedures:
- Personnel and supplemental dosimeters worn.
- Survey meter or dose rate indicating device used.
- Access points secured by control devices.

Additional requirements where dose rates are greater than 0.1 rem/hr are:
- A formal radiological review of nonroutine or complex work activities.
- Determining of worker's current exposure.
- A pre-job brief, as applicable.
- Additional radiological control coverage implemented.

Requirements for working in a Radiation Area also apply when working in High and Very High Radiation Areas.

f. Contamination/Airborne Radioactivity Areas
Contamination Area
An area where contamination levels exceed specific limits is referred to as a Contamination Area. The posting/signs will indicate:

CONTAMINATION AREA

High Contamination Area
An area where contamination levels exceed specific limits is referred to as a High Contamination Area.. The posting/signs will indicate:

DANGER
HIGH CONTAMINATION

Fixed Contamination Area
A Fixed Contamination Area is an area or equipment with no removable contamination but which contains fixed contamination levels exceeding specified limits.

The postings/signs will indicate:

CAUTION
FIXED CONTAMINATION

Airborne Radioactivity Area
An area where airborne radioactivity exceeds specified limits is called an Airborne Radioactivity Area. The postings/signs will indicate:

CAUTION
AIRBORNE RADIOACTIVITY AREA

Requirements for entry into Contamination Areas and Airborne Radioactivity Areas include:

- Radiation Worker Training.
- Personnel dosimeters
- Worker signature on standard operating procedure (if applicable)
- Protective clothing/equipment as required by the standard operating procedure
- A pre-job briefing for High Contamination Area and Airborne Radioactivity Area

Instructions for working in Contamination Areas and Airborne Radioactivity Areas include:

- Avoid unnecessary contact with contaminated surfaces.
- Secure hoses electrical lines, tubes and cables to prevent them from crossing in and out of contamination area.
- When possible, wrap or sleeve materials and equipment.
- Place contaminated tools and equipment inside plastic bags when work is finished.
- DO NOT touch unexposed skin surfaces. Highly contaminated material left on the skin for an extended period of time can cause a significant localized dose to the skin.
- Avoid stirring contamination up since it could become airborne.

Smoking, eating or chewing is not allowed in Contamination, High Contamination and Airborne Radioactivity Areas.
Exit immediately if an injury occurs which allows contamination inside the body.
Requirements for exiting
Exit only at the step-off pad. A step-off pad provides a "barrier" between contaminated and other areas to prevent or control the spread of contamination between areas.

If more than one step-off-pad is used, the final step-off-pad is "clean", it is outside the exit point, and it is adjacent to the control boundary.
Remove protective clothing carefully.
Perform a whole body survey. If contamination is indicated: stay in the area, notify Radiation Safety personnel, and take actions to minimize cross-contamination (e.g., put a glove on a contaminated hand).
After exiting and monitoring, it is a good radiological practice to wash hands prior to performing such activities such as eating, drinking, chewing, applying make-up, etc.

g. Radioactive Materials Area
An area that is established to indicate areas where radioactive materials are used, handled or stored is a Radioactive Materials Area.
Material stored there generally consists of equipment, components and materials which have been exposed to contamination. Sealed or unsealed radioactive sources are also included.
The postings/signs will indicate:

CAUTION
RADIOACTIVE MATERIALS AREA

Requirements for entry/exit
Entry requirements into a Radioactive Materials Area where the whole body dose rate exceeds 5 mrem/hour or contamination levels exceed specified limits will be the same as for entry into a Radiation Area or Contamination Area, depending on the radiological hazard present.

C. RESPONSIBILITIES OF THE WORKER ASSOCIATED WITH POSTINGS, SIGNS, AND LABELS

It is each worker's responsibility to read and comply with all the information identified on radiological postings, signs and labels. Disregarding any of these or removing/relocating them without permission can lead to unnecessary or excessive radiation exposure and/or personal contamination. If any type of material used to identify radiological hazards is found outside an area controlled for radiological purposes, it should be reported to Radiation Safety personnel immediately.

D. FACILITY MAPS

Maps with locations of radiation sources indicate the boundaries of the controlled areas. Boundaries are defined by walls, doorways, and by tape stripes for areas where physical boundaries are not present.

8. RADIOLOGICAL EMERGENCIES

LEARNING OBJECTIVES:

LO1 IDENTIFY the correct responses to emergencies and/or alarms.
LO2 STATE the possible consequences for disregarding radiological alarms.
LO3 STATE the site administrative occupational emergency radiation dose limits.
LO4 IDENTIFY the essential elements of an effective emergency response plan.

INTRODUCTION

Various radiological monitoring systems are used to warn personnel if abnormal radiological conditions exist. It is very important that employees become familiar with these alarms to prevent unnecessary exposure to radiation and contamination.

A. TYPES OF EMERGENCIES

In areas where the exposure levels are above specified limits, equipment that monitors abnormal radiation exposure levels and airborne contamination levels is placed in strategic locations throughout facilities. It is essential for the worker to be able to identify the equipment and alarms and respond appropriately to each.

1. Small Incidents

An incident is small if it meets all of the following conditions:

- A material is released whose nature and potential hazards are known.
- The release presents no actual or potential threat to human health or the environment.
- The release can be cleaned up by one or two people in less than one hour.
- The incident results in nothing more serious than a minor injury requiring simple first aid.

2. Large Incidents

An incident is considered large if any one or more of the following conditions occur:

- Potential contamination of ground water.
- Fire or explosion.
- An incident is regarded by personnel as unsafe to manage without the aid of the Fire Department.
- Release of material that cannot be identified.
- Release of material that cannot be cleaned up by two people in less than one hour.
- Injuries result that require medical treatment other than first aid.
- Incident requires evacuation of the building or the facility.
- Released material migrates to a storm drain or sewer.

B. DISREGARD FOR RADIOLOGICAL ALARMS

Disregarding any of these radiological alarms may lead to possible excessive personal exposure, and the unnecessary spread of contamination.

C. RADIOLOGICAL EMERGENCY SITUATIONS

Working in a radiological environment requires more precautionary measures than performing the same job in a non-radiological setting. This premise holds true especially if an emergency arises during radiological work. Types of emergencies could be:

- Personnel injuries in areas controlled for radiological purposes.
- Situations that require immediate exit from an area controlled for radiological purposes.
- Accidental breach of radioactive system or spill of radioactive material.

D. CONSIDERATIONS IN RESCUE AND RECOVERY OPERATIONS

In extremely rare cases, emergency exposure to high levels of radiation may be necessary to rescue personnel or protect major property.

Rescue and recovery operations that involve radiological hazards can be a very complex issue with regard to the control of personnel exposure. The type of response to these operations is generally left up to the officials in charge of the emergency situation. The judgment of the officials is guided by many variables which include determining the risk versus the benefit of the action, as well as how to involve other personnel in the operation. If the situation involves a substantial personal risk, volunteers will be used. The use of volunteers will be based on their age, experience, and previous exposure.

The regulatory emergency response for these personnel is as follows:

- Protecting major property where the lower dose limit of 5 rem is not practicable - 10 rem
- Lifesaving or protection of large populations where the lower dose limit is not practicable - 25 rem
- Lifesaving or protection of large population - only on a voluntary basis to personnel fully aware of risks involved - greater than 25 rem

  Most facilities establish administrative emergency dose limits which are more conservative than regulatory limits.

E. EMERGENCY PROCEDURES IN ACCIDENTS WITH RADIOACTIVE MATERIALS

Emergencies resulting from accidents caused when working with radioactive materials may range from minor spills of small quantities involving no radiation hazard, to radiation involving serious hazards to personnel and the possibility of bodily injury. Because accidents involving radioactive materials are spontaneous occurrences and often involve complicating factors, set rules for emergency procedures cannot be laid down to cover all possible situations. In any emergency, however, the primary concern is always the protection of laboratory personnel from radiation hazards. Once it is ascertained that no radiation hazard exists to personnel, and existing hazards are under control, the next major concern is confinement of contamination to the immediate area of the accident, and finally, its removal.

If an accident occurs involving radioactive materials (e.g., spill, ingestion, inhalation, or overexposure), notify the Radiation Support Staff (Radiation Safety Officer) and a supervisor as promptly as possible. Take the necessary precautions to avoid involvement of the other personnel in the radiation hazard or spread the contamination. Remain in the immediate area until the Radiation Safety Officer or an appointee arrives.

F. SPILLS AND ACCIDENTS

1. Spills involving no contamination of personnel

a. Notify all other persons in the area at once of the spill.

b. Permit only the minimum number of persons necessary to deal with the spill into the area, making certain that other personnel involved in the accident remain nearby. This will help avoid the possible spread of contamination into the areas.

c. Confine the spill immediately.

Liquid Spills

- Don protective gloves.
- Drop absorbent materials or paper on the spill.

Dry Spills

- Don protective gloves.
- Dampen thoroughly with wet absorbent paper, taking care not to spread the contamination.

d. Notify the Radiation Safety Officer as soon as possible. Do nothing further to remove the contamination until radiation safety personnel arrive.

e. Permit no one to resume work in the area until approval is obtained from the Radiation Safety Officer. The Radiation Safety Officer or the Radiation Support Staff will coordinate the decontamination and monitoring of personnel and the area.

2. Spill involving radiation hazard to personnel

a. Notify all persons not involved in the spill to evacuate the area immediately, but to remain in the local area (hallway or adjacent laboratory) until monitored for contamination. Allow no one except Radiation Support Staff or the Emergency Response Team into the area.

b. Make no immediate attempt to clean up the spill. If the spill is liquid, and the hands are protected, put the container in the upright position.

c. For spills involving contamination of personnel or clothing:

- If the spill is on the skin, flush thoroughly with water.

- If the spill is on clothing, discard outer or protective clothing at once, including shoes. Place these articles on absorbent paper or in plastic bags.
- In the case of internal contamination from ingestion of radioisotopes, contact the Radiation Safety Officer immediately. If ingestion of radioactivity is apparent or suspected, the Radiation Safety Officer will determine whether or not a physician should be consulted.

d. Make sure the fume hood is "on" and the sash is open if the spill is in the room. If the spill is in the fume hood, leave the sash slightly open and make sure the fume hood is left "on".

e. Vacate the room and prohibit entrance into the contaminated area.

f. Do not leave the area.

g. Permit no one to resume work until approval is obtained from the Radiation Safety Officer.

h. Have someone not involved in the accident notify the Radiation Safety Officer as soon as possible, relating all details of the accident.

i. Under no circumstances should an untrained person attempt to examine or decontaminate personnel in the area.

3. Accidents involving radioactive mists, dust, fumes and organic solvents

a. Notify all persons to vacate the room immediately. They should remain in the immediate area (hallway or adjacent laboratory.

b. Ensure that the hood is operating before leaving the room.

c. Leave the room and join the other persons involved in the accident.

d. Have the Radiation Safety Officer notified at once, relating details of the accident.

e. Ascertain that all doors giving access to the room are closed. Under no circumstances should anyone be allowed to enter the room.

f. Report all those suspected or known to have inhaled radioactivity to the Radiation Safety Officer.

g. Do not re-enter the room until approval is obtained from the Radiation Safety Officer.

4. Injuries to personnel involving radiation hazard

a. Wash minor wounds immediately, under running water, spreading the edge of the cut or gash to permit complete flushing. Contact the Radiation Safety Officer. Do not resume work until approval is obtained from the Radiation Safety Officer. The first concern is for the injured individual. If time permits and the injury is minor, attempt to save the water from the washing.

b. If injury is more serious, such as a broken bone or severe burn, have the Radiation Safety Officer notified immediately. Do nothing that would further complicate the injury.

c. In cases involving a radiation injury, a physician qualified to treat radiation injuries should be contacted if necessary.
d. No person involved in a radiation injury is to return to work without the consent of the Radiation Safety Officer.

5. **Fires involving radiation**
   a. Notify all persons in the area at once.
   b. Attempt to extinguish the fire if there is no threat of a radiation hazard, the fire can be fought with no hazard to life, and you have had the appropriate fire extinguisher.
   c. Notify the Radiation Safety Officer as soon as possible.
   d. All fire fighting and other emergency procedures involving radioactivity will be guided by the advice of the Radiation Safety Officer and Radiation Support Staff.

G. Elements of an Emergency Response Plan

Each employer must develop an emergency response plan for emergencies. The plan must be in writing and available for inspection.

1. Pre-planning and preparation before an incident.

Pre-emergency planning and coordination with outside resources, agencies and individuals who may be affected by such emergencies must be accomplished to minimize exposure to people, contamination of the environment, and loss of property.

2. Personnel roles, lines of authority and communications must be established.

3. Emergency recognition and prevention during a response.

Employees participating as an emergency response team must be trained recognize health and safety hazards to protect themselves and others. This training should include:

- Methods used to minimize the risk from safety and health hazards.
- Selection and use of appropriate personnel protective equipment.
- Safe use of control equipment.
- Safe operating procedures to used at the incident scene.
- Techniques of coordination with other employees to minimize risks.
- Appropriate response to overexposures from radiation, health hazards, or injury.
- Recognition of subsequent symptoms which may result from overexposures.

4. Keep safe distances and places of refuge from an incident.

When an evacuation is announced, employees are to stop working and go to the nearest available exit. Employees must leave the facility and report to the designated assembly area for accountability. The assembly area should be at a safe distance from possible radiation exposure.

5. Site security and control during the response.

Site security and control are the methods for controlling activities on the site, determining the hot, warm, and cold zones, controlling site access and traffic. This is a management responsibility which is often designated to security personnel, Radiation Safety personnel and supervisors. Hot, warm and cold zones are buffer control areas which are based on exposure or contamination levels. A cold zone is an area were no exposure or contamination is expected. Warm and hot zones are areas specified by exposure or contamination levels which require different levels of personnel protective equipment.

6. Follow evacuation routes and procedures.

Evacuation route maps should be posted throughout the facility.

7. Decontamination during the response to the incident.

A specific decontamination procedure must be developed, communicated to workers, and implemented before any worker or equipment may enter areas during an emergency response where the potential for exposure to radioactive materials or other hazardous substances exists. Decontamination must be performed in geographical areas that will minimize the exposure of uncontaminated employees or equipment (i.e., upwind and upgrade).

Workers or equipment are not allowed to enter the cold zone without going through decontamination first. Decontamination of workers must also be conducted prior to the removal of personal protective equipment. Decontamination should be monitored by Radiation Safety Personnel to determine the effectiveness and minimize exposure to the individual. If such procedures are found to be ineffective, appropriate steps are then taken to correct any deficiencies.

8. Provide emergency medical treatment and first aid.

The plan must contain directions to the nearest emergency medical facility, and an inventory, quantity, and location of emergency medical equipment within the facility.

9. Follow the emergency alerting and response procedures.

The response shall follow an orderly and comprehensive set of procedures which deal with specific incidents (i.e., radioactive material spill, chemical spill, contaminated worker, earthquake or other unpredicted natural disaster, leaking container and toxic gas leak.).

10. Critique of response and the follow-up procedures.

The plan should be reviewed periodically and, as necessary, be amended to keep it current with new or changing site conditions or information.

11. Selection of Personal Protective Equipment (PPE) and emergency equipment.

PPE is to be selected and used which will protect employees from the hazards which are likely to occur.

9. INTERNAL CONTROLS

LEARNING OBJECTIVES:

LO1 IDENTIFY two individuals identified by name on a radioactive material license.

LO2 IDENTIFY who approves the purchase of radioactive materials.

LO3 IDENTIFY why incoming packages are monitored upon arrival.

LO4 IDENTIFY what must be verified and why when transferring radioactive material to another facility.

LO5 STATE the whole body exposure limits for a pregnant radiation worker.

LO6 IDENTIFY the purpose of an accurate inventory.

LO7 IDENTIFY general procedures for working with radioisotopes in the laboratory.

INTRODUCTION

In an effort to minimize exposures to staff, visitors, and the environment in accordance with established regulations and industry guides of internal controls have been implemented. These controls enable users to maintain control on the radiation sources and minimize the regulatory impact.

A. PERMISSION TO USE RADIOISOTOPES

The use of radioisotopes requires authorization from the Radiation Safety Officer and the Radiation Safety Committee. In general an application is submitted to the Radiation Safety Officer who will review it for completeness. The Radiation Safety Officer will submit the application with recommendations to the Radiation Safety Committee for approval or denial with his/her recommendations. Persons who are granted this permission are designated as "Principal Users". Only individuals designated "Principal Users" or working under the direct supervision of a Principal User are permitted to possess or use radioisotopes. Each Principal User completes a "Statement of Training and Experience" with each application.

Permission to use radioisotopes may be withdrawn for reasons including, but not limited to dosimetry, bioassay results indicating exposure at or near maximum permissible levels, or excessive levels of contamination on uncontrolled surfaces. In such an event, an investigation will be conducted, and the Principal User will be required to furnish an explanation of the incident and action taken to prevent recurrence.

B. ORDERING RADIOISOTOPES FROM COMMERCIAL VENDORS

To purchase radioisotopes, a requester will have to submit information on the Principal User, the isotope requested, the vendor, the order number and the amount. The Radiation Safety Officer or a designee will review the request against established limits for the Principal User, and the facility license inventory against the license limits. Once approved by the Radiation Safety Officer, the material may be ordered.

C. HANDLING INCOMING RADIOACTIVE MATERIAL

All incoming radioisotopes are delivered to the Radiation Safety Officer or Radiation Safety Assistant before they are delivered to the requester. If the Radiation Safety Officer or Assistant is not available, the package will be stored in a controlled area with appropriate shielding prior to inspection. Incoming packages will be tested for external radiation with a survey meter and inspected visually for damage with might indicate possible leakage. A wipe test will be carried out on the package and properly assayed. The package will then be opened, and the innermost container examined for damage and wipe tested. If no contamination is apparent, it may be provided to the Principal User.

A wipe test is a sample made for the purpose of determining the presence of removable radioactive contamination on a surface. It is done by wiping, with slight pressure, a piece of soft filter paper over a representative type of surface area. The sample is analyzed in a radiation counting system appropriate for the type of radioactivity expected on the sample.

Under circumstances where the nature of the radioisotope dictates that special services or instructions are required by the user, the radioisotope is kept until time of use by the Radiation Safety Officer. The Radiation Safety Officer then delivers the isotope and supervises the operation, provides special instructions and performs radiation monitoring as needed.

D. TRANSFER OF RADIOISOTOPES

Radioactive material license allows a Principal User to make the following transfers:

- Transfer radioactive materials to persons outside the facility who are specifically licensed by the US Nuclear Regulatory commission or a State Licensing authority to receive the radioactive materials.
- All outgoing radioactive materials must be processed through the Radiation Safety officer.

This will ensure that (first), the recipient is properly licensed, and (second), the radioactive material is properly packaged and meets all appropriate shipping and labeling regulations.

If transfer of radioactive materials to another authorized Principal User is to be done, the recipient must be authorized for the specific radioisotope being transferred for the appropriate quantities. The sender will notify the Radiation Safety Officer in writing of said transfer.

E. RADIOISOTOPE INVENTORY

Periodically all radioactive material in the possession of each Principal User will be inventoried, indicating the new total millicurie amount of each radioisotope. This physical data is compiled and summarized by the Radiation Safety Officer. This inventory data (as well as the radioisotope ordering system) ensures that the total radioisotope quantities do not exceed those authorized by the license.

F. DISPOSAL OF RADIOACTIVE WASTE MATERIALS

Regulations permit disposal of radioactive waste. It typically is handled by transference to a person holding a specific license to receive the radioactive waste (vendor). The facility does not lose liability for the waste after it has been transferred to this vendor. The facility continues some level of liability for radioactive waste after it has been received by the disposal site.

Each facility will develop internal procedures for disposing of radioactive waste from laboratory facilities. The waste must be segregated and packaged according to specific regulations. Internal procedures are normally designed to enable the support staff to package waste according to these regulations.

G. PRENATAL RADIATION POLICY

The US Nuclear Regulatory Commission states that the whole body exposure during the term of pregnancy (of the mother) be kept below 0.5 rem for the entire gestation period and no more than 0.05 rem in any single month. An information package on the risks of radiation exposure should be provided to all employees who may become pregnant. Pregnant employees are encouraged to take all possible steps to minimize their exposure to penetrating radiation.

H. LABORATORY PROCEDURE WITH RADIOISOTOPES

Specific laboratory handling and operating procedures for radioactive materials will vary with the particular radionuclides, quantity, and chemical form. However, some general laboratory responsibilities and rules are presented below for use by the Radiation User (Radiation Worker) as a guideline for the safe handling of radioactive materials:

- Disposable gloves, safety glasses and a lab coat must be used whenever handling, pippetting, or dispensing radioactive solutions.
- Keep exposure to radiation as low as reasonably achievable (ALARA), and specifically below the regulatory exposure limits. Most licensees have a regulatory commitment to maintain exposures below a specific limit. This limit is enforceable during regulatory inspections.
- Wear the prescribed dosimeters while working with radioactive material.
- NEVER pipette radioactive substances by mouth.
- ABSOLUTELY NO eating, drinking, smoking, applying cosmetics, or storing of food or beverages is permitted in areas controlled for the use of radioisotopes.
- Use disposable plastic-backed absorbent sheets on all laboratory benches where radioisotopes are used. Change these frequently and whenever they are determined to be contaminated.

- Use disposable glass or plastic-ware whenever practical when working with radioisotopes. Any reusable labware must be thoroughly decontaminated prior to being sent to central glass washing area.
- Use a survey meter during and after all radioisotope operations to follow the progress of radioactive material and to identify contamination. H-3 cannot be monitored in this manner and a wipe test should be performed after each use. C-14 and S-35 are difficult to monitor with a survey meter. Therefore, a wipe test may be necessary when working with microcurie amounts.
- Radioisotope work should be done in a certified fume hood whenever possible. This is due to the possibility of airborne contamination (evaporation, flaking, dust, or aerosol formation).
- Use protective barriers and other shields whenever possible.
- All stored radioactive materials must be labeled with the radionuclide, quantity, date, and words "Caution, Radioactive Material", and the radiation caution symbol. When appropriate, include the user's name.
- Stored radioisotopes must be secured from unauthorized use.
- Notify the Radiation Safety Officer immediately of all spills.
- A radiological clean-up must be performed after each major operation that involves radioactive materials. All lab areas, equipment, glassware, etc. should be monitored and decontaminated.
- Survey hands, shoes, and body for radioactivity and remove all loose contamination before leaving the laboratory for any reason.
- All radioactive liquids must be stored and transported in double containment to minimize the threat of spills. Trays sufficiently deep to contain the entire volume which could be spilled, make good secondary containment for bags, bottles, or vials of radioactive liquid.
- Maintain good personal hygiene:
    - Keep fingernails short and clean.
    - Do not work with radioactive materials if there is a break in the skin below the wrist.
    - Wash hands and arms thoroughly before handling any object which goes to the mouth, nose or eyes.
    - It is strongly recommended that open-toed shoes or shorts not be worn in the radioisotope laboratory.
- Containment control, distance from the radiation source, shielding and the minimizing time near the radiation source are the best tools for limiting radiation exposure.

I. RADIATION SAFETY MANUAL

Most licensees must maintain some type of Radiation Safety Manual. This manual should be reviewed as a part of training. In general the Radiation Safety Manual contains information about the Radiation Safety Program vital to controlling the radiation sources and minimizing exposures. In addition it is designed to minimize the regulatory impact and provide flexibility in the administration of a good Radiation Safety Program.

B. Module B - General Laboratory Materials

Module B contains ten (10) sections which discuss the concept of safe handling of unsealed radioactive sources and which the worker must know to minimize contamination and exposures. Each section is designed to be an independent lesson. The module is designed to be an entire course. This course builds upon the fundamentals and will require some duplication of concepts previously presented.

1. RADIOLOGICAL CONTAMINATION

LEARNING OBJECTIVES:

LO1 DISTINGUISH between ionizing radiation and radioactive contamination.
LO2 DEFINE fixed, removable and airborne contamination.
LO3 IDENTIFY the units used to measure radioactive contamination.
LO4 IDENTIFY causes of radioactive contamination.
LO5 STATE the appropriate response to indicators of potential area contamination or personnel contamination alarms.
LO6 IDENTIFY indicators of possible area contamination.

INTRODUCTION

This unit is designed to inform the worker about sources of radioactive contamination encountered in the laboratory environment. Contamination control is one of the most important aspects of radiological protection. Using proper contamination control practices will help ensure a safe working environment.

A. COMPARISON OF RADIATION AND RADIOACTIVE CONTAMINATION

Ionizing radiation: The energy (particles or rays) emitted from radioactive atoms that can cause ionization is termed ionizing radiation.

Radioactive contamination: Radioactive material is material that contains radioactive atoms. Even when this radioactive material is properly contained, it may still emit radiation and be an external dose hazard, but it will not be a contamination hazard. When this radioactive material escapes its container, it is then referred to as radioactive contamination.

Radiation is an energy. Contamination is a material. See figure B.1.1.

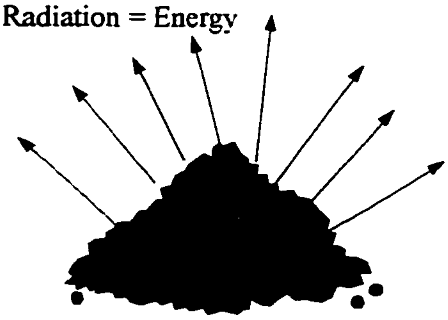


FIGURE B.1.1 - RADIATION VERSUS RADIOACTIVE MATERIAL

B. TYPES OF CONTAMINATION

Radioactive contamination can be fixed, removable or airborne.

1. Fixed contamination

Fixed contamination cannot be readily removed from surfaces. It cannot be removed by casual contact. It may be released when the surface is disturbed (buffing, grinding and using volatile liquids for cleaning) Over time it may "weep", leach or otherwise become loose or transferable.

2. Removable/transferable contamination

Removable or transferable contamination can readily be removed from surfaces. It may be transferred by casual contact, wiping, brushing or washing.

3. Airborne contamination

Radioactive material which is suspended in the air. Air movement across removable/transferable contamination could cause airborne contamination.

C. UNITS OF RADIOACTIVE CONTAMINATION

Because radioactive contamination is radioactive material, the units are expressed in activity. When measuring the amount of radioactive contamination (material) on a surface (area) or contained within a specific space (volume), the units most commonly used are disintegrations per minute (dpm) or activity per volumetric measurement (i.e., μCi/ml).

1. Direct reading

Contamination monitors measure radiation emitted by the radioactive material. The radiation may enter the detector and be counted as a single event. The units are normally seen by the monitor (through the detector) as counts per minute (cpm).

2. Counts per minute (cpm) versus disintegrations per minute (dpm).

There is a direct relationship between the counts recorded and the actual activity (disintegrations) present. A multiplication factor is used to convert the cpm to dpm. This is called the efficiency.

$$cpm/dpm = efficiency$$

3. Removable contamination

Removable contamination is measured by swiping or smearing a surface and counting the amount of activity which is lifted (removed) from the surface.

D. CAUSES OF RADIOACTIVE CONTAMINATION

Radioactive material can be spread to unwanted locations. There are several sources and indicators of radioactive contamination.

1. Leaks or breaks in radioactive systems

Hot particles, which are small, sometimes microscopic pieces of radioactive material that are highly radioactive, they can cause a high, localized radiation dose in a short period of time if they remain in contact with skin/tissue. Hot particles may be present when contaminated systems leak, are opened or when machining, cutting, or grinding is performed on highly radioactive materials. These processes include:

- Opening radioactive systems without proper controls
- Airborne contamination depositing on surfaces
- Leaks or tears in radiological containers (barrels, plastic bags or boxes)
- Poor housekeeping in contaminated areas
- Excessive motion or movement in areas of higher contamination
- Sloppy work practices, such as cross-contamination of tools, equipment or workers

E. INDICATORS OF POSSIBLE AREA CONTAMINATION

1. Visual indicators:

- Leaks, spills, standing water
- Dusty, hazy air
- Damaged radiological containers

2. Detection of contamination or elevated radiation levels:

- Spurious or unexplained personnel contamination
- Radioactivity observed in bioassay samples collected
- Higher than normal background during personnel contamination surveys
- Airborne monitor alarms

F. PRIMARY REASONS FOR CONTAMINATION CONTROL MEASURES

1. Protection of the worker

Measures to control radioactive contamination are implemented to protection workers:

- Minimizing the chance of inhalation or ingestion of radioactive/hazardous material.
- Eliminating or reducing external radiation dose rates.
- Reducing worker discomfort by minimizing the use of personal protective clothing and/or respirators.

2. Radioactive materials may enter the body by:

- Inhalation (the most common pathway)
- Cuts/wounds (concern with sharps) punctures
- Absorption (skin, mucous membranes, eyes)
- Ingestion (biting nails, applying makeup, eating, drinking, etc.)

3. Protection of the environment

Measures to control radioactive contamination are implemented to protect the environment by:

- Controlling the release of radioactivity in the environment
- Minimizing the amount of radioactive waste generated

4. Protection of the facility and programs

Measures to control radioactive contamination are implemented to protect facilities and programs by:

- Eliminating or minimizing the spread of contamination
- Preventing cross-contamination and the loss of experimental results
- Meeting regulatory requirements

G. CONTAMINATION CONTROL MEASURES

Contamination control measures should address:

Knowledge of the characteristics of radionuclides used.

Preparation of areas and materials which include:

- Marking, labeling, and posting of areas and materials.
- Personnel protective equipment; type, availability, and use.
- Storage and containment of radioactive/hazardous materials.

Good work practices which include:

- Special precautions for handling liquids.
- Special precautions for handling sharps.

Radioactive waste management.

Radiation monitoring (including interpretation of meter readings) during and at completion of work.
Decontamination of personnel and equipment.
Regulatory requirements which are imposed or implied.
Training requirements necessary to control the material used.

2. COMMONLY USED RADIOISOTOPES

LEARNING OBJECTIVES:

LO1 DEFINE how radioisotopes are classified for toxic effects.

LO2 IDENTIFY the difference between the physical half-life, biological half-life and the effective biological half-life.

LO3 DEFINE what is the critical body organ and the method of personnel monitoring.

INTRODUCTION

Each radioisotope has specific characteristics which are unique. These help define the hazards associated with the radioactive source. Understanding these characteristics will enable the worker to identify and take the appropriate protective measures to minimize exposure to ionizing radiation.

A. RANGE

The energy of the radiation emitted determines the maximum range (penetration) of the radiation emitted. The range depends upon the media it is traveling through. To penetrate the dead layers of the skin requires energies of 70 keV or more for beta emitters.

B. RADIOTOXICITY

Radioisotopes are classified according to their radiotoxicity by the International Atomic Energy Agency (IAEA).

C. PHYSICAL HALF-LIFE

The physical half-life is the statistical estimate of the time for one half of the radioactive material to decay to a lower energy state (commonly to a non-radioactive state).

D. BIOLOGICAL HALF-LIFE

The biological half-life is the estimated time it takes for the body to eliminate one half of the initial material from the body by normal methods of elimination (assuming reference man is the individual of interest). Reference man is a hypothetical aggregation of human physical and physiological characteristics arrived at by international consensus. These characteristics are used by researchers and public health workers to standardize results of experiments and to relate biological insult to a common base.

E. EFFECTIVE HALF-LIFE

The effective half-life is the required for the amount of a radioactive element deposited in a living organism to be diminished 50 percent as a result of the combined action of radioactive decay and biological elimination. Elimination is the removal of material from the body via urine, feces, sweat or exhalation. Excretion usually refers to elimination via urine or feces.

$$T_{eff} = \frac{T_{bio} \times T_{1/2}}{T_{bio} + T_{1/2}}$$

F. CRITICAL ORGAN

The critical organ is that part of the body where the most effective dose equivalent is delivered. The body organ receiving a radionuclide or radiation dose that results in the greatest overall damage to the body. Effective dose equivalent is the sum of the products of the dose equivalent to the organ or tissue and the weighting factors applicable to each of the body organs or tissues that are irradiated.

G. MONITORING

The recommended personnel monitoring will provide useful information to determine the dose delivered.

H. ANNUAL LIMIT OF INTAKE (ALI)

The Annual Limit of Intake defines the amount of the radioisotope which will deliver the maximum dose to the critical organ according to regulatory standard (a regulatory overexposure, not observable biological damage). It is the derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year.

I. SHIELDING

The recommended shielding is the amount of material suggested to reduce the dose rate. It is any material or obstruction that absorbs radiation and thus tends to protect personnel or materials from the effects of ionizing radiation.

TRITIUM (H-3)

Tritium is a low energy beta emitter and cannot be monitored directly with portable survey meters. Monitoring is normally performed by taking a swipe of the area and counting the swipe in a liquid scintillation counter.

1. Maximum energy: 0.018 MeV (average energy is 0.006 MeV)
2. Maximum range in air: 0.25 inches (6 mm)
3. Maximum range in water: 6×10^{-3} mm
4. IAEA Radiotoxicity classification: Low
5. Physical half-life: 12.35 years
6. Effective biological half-life: 10 days
7. Critical Organ: whole body
8. Personnel Monitoring: Bioassay - urinalysis, NOT detected with a dosimeter (TLD or film badge
9. ALI : 80 mCi (3×10^9 Bq) tritiated water (the maximum amount of radioactive material which will deliver the dose to the critical organ of interest exceeding regulatory limits of a radiation worker during a working year)
10. Shielding: None (the penetration of the beta is extremely low)
11. Special considerations:
    a. It cannot be monitored directly.
    b. Many compounds readily penetrate gloves and the skin.
    c. Bremsstrahlung may be a consideration for large quantities of tritium.
    d. Tritiated DNA precursors are considered more toxic than tritiated water but are generally less volatile and do not present a significantly greater hazard.

CARBON -14 (C-14)

Carbon-14 is a low energy beta emitter which is about 10 times more energetic than tritium. C-14 may be detected with the proper radiation survey instrument and with proper care in conducting the survey.

1. Maximum energy: 0.156 MeV (the average energy is 0.052 MeV)
2. Maximum range in air: 9 inches (24 cm)
3. IAEA Radiotoxicity classification: Medium-low
4. Physical half-life: 5730 years
5. Effective biological half-life: 12 days
6. Critical Organ: Whole body and the body fat
7. Personnel Monitoring: Bioassay - urinalysis and/or breath measurements (CO_2), NOT detected with a dosimeter (TLD or film badges)
8. ALI: 2 Ci (7 x 10^{10} Bq) CO by inhalation
   200 mCi (7 x 10^9 Bq) CO_2 by inhalation
9. Shielding: 3 mm of Plexiglas but 1 cm required for rigidity
10. Special Considerations:
    a. Detection of C-14 by radiation survey instruments requires special care due to the low efficiency of detection.
    b. Some C-14 labeled compounds may penetrate gloves and skin.
    c. Special caution should be observed when handling C-14 labeled halogenated acids.

SODIUM-22 (Na-22)

Sodium-22 is a positron emitter (positive beta particle/electron) and high energy gamma emitter. It also emits an annihilation photon when the positive electron is annihilated with a negative electron, producing pure energy. Sodium-22 is detected with a thin end-window G-M probe, sodium-iodide scintillation counter or liquid scintillation detector.

1. Maximum energy:
   maximum beta energy: 0.546 MeV (average energy 0.182 MeV)
   gamma energy 1.275 MeV; annihilation photon: 0.511 MeV
2. Maximum range in air: 4.7 feet (1.4 m)
3. Unshielded dose rate from 1 mCi point source at 0.5 inches (1 cm): 11.8 rad/hr
4. IAEA Radiotoxicity Classification: High-medium;
5. Physical half-life: 950 days
6. Effective biological half-life: 10.9 days
7. Critical Organ:
   Whole body for intake of transportable compounds
   Lungs for inhalation; and Lower large intestine for ingestion
8. Personnel Monitoring: Dosimeter, finger rings, uptakes determined by urinalysis
9. ALI: 0.6 mCi (2 x 10^7 Bq) by inhalation, clearance in weeks
   0.4 mCi (1 x 10^7 Bq) by ingestion
10. Shielding: 6.5 mm of lead is the first half value layer (thickness of lead which will reduce the dose rate by one half).
    Multi-hundred mCi quantities need to be completely surrounded by beta shielding material to prevent the betas from escaping and creating a source of secondary annihilation radiation outside the shielding.
11. Special Considerations:
    a. Near an unshielded Na-22 source, dose rates due to beta radiation can be much higher than dose rates due to gamma radiation.
    b. Avoid direct eye exposure by interposing transparent shielding or indirect viewing.
    c. Avoid skin dose by indirect handling.

PHOSPHORUS-32 (P-32)

Phosphorus-32 is a high energy beta emitter which may create a whole body, skin and eye hazard. Most common means of detection is with a thin window probe or liquid scintillation.

1. Maximum energy: 1.71 MeV (the average energy is 0.570 MeV)
2. Maximum range in air: 19 feet (6 m)
3. Maximum range in tissue: 8 mm
4. IAEA Radiotoxicity Classification: Medium-low
5. Physical half-life: 14.29 days
6. Effective biological half-life: 10-14 days
7. Critical Organ:
   a. Bone - for transportable compounds
   b. The lung and lower large intestine are critical organs for inhalation and ingestion.
   8. Personnel Monitoring: Dosimeter for the external exposures and urinalysis for uptakes
   9. ALI: 4 mCi (1×10^7 Bq) by inhalation, clearance in weeks
   4 mCi (1×10^7 Bq) by ingestion
10. Shielding: 0.5 inch (0.7 cm) of Plexiglas
11. Special Considerations:
    a. Safety glasses can provide eye protection.
    b. Contamination is easily detected with G-M thin window probe.
    c. Bremsstrahlung radiation may be a consideration for larger quantities.
    d. Radioactive waste containers may need to be shielded with Plexiglas.
    e. A high local dose can be received if the radioactive material is touched and allowed to remain in contact with the skin.
    f. Safety glasses can provide eye protection.
12. Typical dose rates from 100 μCi (3.7 MBq):
    a. 3 mrad/hr at 1 cm
    b. 0.03 mrad/hr at 10 cm
    c. 0.002 mrad/hr at 40 cm

PHOSPHORUS-33 (P-33)

Phosphorus-33 is a low energy beta emitter. Most common means of detection is with a thin window probe or liquid scintillation.

1. Maximum energy: 0.248 MeV (the average energy is 0.083 MeV)
2. Maximum range in air: 1.59 feet (0.5 m)
3. Maximum range in tissue: 1 mm
4. IAEA Radiotoxicity Classification: Medium-low
5. Physical half-life: 24.4 days
6. Effective biological half-life: 10-14 days
7. Critical Organ:
   a. Bone - for transportable compounds
   b. The lung and lower large intestine are critical organs for inhalation and ingestion
8. Personnel Monitoring: NOT detected with a dosimeter (TLD or film badge), dosimeter and finger rings, uptakes may be determined by urinalysis
9. ALI: 3 mCi (1×10^8 Bq) by inhalation, clearance in weeks
   6 mCi (2×10^8 Bq) by ingestion
10. Shielding: 0.25 inch (0.3 cm) of Plexiglas
11. Special Considerations:
    Detection of P-33 by radiation survey instruments requires special care due to the low efficiency of detection.

SULFUR-35 (S-35)

Sulfur-35 is a low energy beta emitter similar to Carbon-14. Most common means of detection is with a thin window probe or liquid scintillation.

1. Maximum energy: 0.167 MeV (the average energy is 0.056 MeV)
2. Maximum range in air: 10 inches (24 cm)
3. Maximum range in tissue: 0.32 mm
4. IAEA Radiotoxicity Classification: Medium-low
5. Physical half-life: 87.4 days
6. Effective biological half-life: 77 days
7. Critical Organ: Whole body and testis
8. Personnel Monitoring: Bioassay - urinalysis, NOT detected with a dosimeter (TLD or film badge)
9. ALI:
   a. 10 mCi (4 x 10^8 Bq) inorganic compounds
   b. 5 mCi (2 x 10^8 Bq) elemental sulfur
10. Shielding: 3 mm of Plexiglas but 1 cm required for rigidity
11. Special considerations:
    Detection of S-35 by radiation survey instruments requires special care due to the low efficiency of detection.

CHLORINE-36 (Cl-36)

Chlorine-36 is a medium energy beta emitter. Use a thin-end window G-M detector or liquid scintillation counter for detection.

1. Maximum energy: 0.71 MeV (the average energy is 0.233 MeV)
2. Maximum range in air: 7 feet (2 m)
3. Maximum range in tissue: 2.6 mm
4. IAEA Radiotoxicity Classification: High-medium
5. Physical half-life: 300,000 years
6. Effective biological half-life: 10-29 days
7. Critical Organ:
   a. Whole body for transportable compounds
   b. Lung for inhalation
   c. Lower large intestine for ingestion
8. Personnel Monitoring: Urinalysis, finger rings
9. ALI: 0.2 mCi (7×10^6 Bq) by inhalation, clearance in weeks
   2 mCi (1×10^7 Bq) by ingestion
10. Shielding: 0.25 inch (0.6 cm) of Plexiglas
11. Special Considerations:
    a. Cl-36 beta particles have sufficient energy to penetrate gloves and skin.
    b. Contamination is easily detected with G-M thin window probe.
    c. When handling millicurie quantities, do not work over an open container
    d. Avoid glove and skin contamination or ensure that it is promptly detected and removed.
    e. A high local dose can be received if the radioactive material is touched and allowed to remain in contact with the skin.
    f. Safety glasses can provide eye protection.

CALCIUM-45 (Ca-45)

Calcium-45 is a low energy beta emitter and may be detected with a thin window probe. Calcium-45 is commonly used with animal studies.

1. Maximum energy: 0.257 MeV
2. Maximum range in air: 20 inches (52 cm)
3. Maximum range in tissue: 0.62 mm
4. IAEA Radiotoxicity Classification: High
5. Physical half-life: 163 days
6. Effective biological half-life: 163 days
7. Critical Organ: Bone
8. Personnel Monitoring: Bioassay - initially by urine, later by feces
9. ALI: 8 mCi (3 x 10^7 Bq) by inhalation
   2 mCi (7 x 10^7 Bq) by ingestion
10. Shielding: 3 mm of Plexiglas but 1 cm required for rigidity
11. Special Considerations:
    Detection of Ca-45 by radiation survey instruments requires special care due to the low efficiency of detection.

CHROMIUM-51 (Cr-51)

Chromium-51 is a gamma and a x ray emitter. Most common means of detection is by scintillation.

1. Maximum energy: 0.32 MeV (9.8 %) very low energy (0.005 MeV) x ray (22 %) and 0.004 MeV (66.9 %) auger electron
2. Maximum range in air: Data not available
3. Maximum range in tissue: Data not available
4. IAEA Radiotoxicity Classification: Medium -low
5. Physical half-life: 27.7 days
6. Effective biological half-life: 27 days;
7. Critical Organ: Lower large intestine and lungs
8. Personnel Monitoring: Dosimeter, internal uptakes may be determined by urine or fecal sampling
9. ALI: 20 mCi (7×10^8 Bq) by inhalation, yearly clearance
   20 mCi (7×10^8 Bq) by ingestion
10. Shielding: 3.2 mm of lead is the first half value layer (thickness of lead which will reduce the dose rate by one half
11. Special Considerations:
    Use thin-end window G-M or solid scintillation detectors or liquid scintillation counting.

IRON-55 (Fe-55)

Iron-55 is a x ray emitter. Most common means of detection is by a G-M probe looking at the Mn x rays which are emitted. Manganese is formed when the iron nucleus captures an electron. The manganese emits an x ray. Liquid scintillation counting may also be used.

1. Maximum energy: electron capture with an average low energy of 0.0006 MeV
2. Maximum range in air: Data not available
3. Maximum range in tissue: Data not available
4. IAEA Radiotoxicity Classification: Medium-low
5. Physical half-life: 2.6 years
6. Effective biological half-life: 370 days
7. Critical Organ:
   Liver and spleen for inhalation
   Lower large intestine for ingestion
8. Personnel Monitoring: Bioassay - uptakes evaluated by analysis of blood
9. ALI: 2 mCi (7 x 10^7 Bq) by inhalation, daily clearance
   9 mCi (3 x 10^7 Bq) by ingestion
10. Shielding: None (the penetration is extremely low).

COBALT-57 (Co-57)

Cobalt-57 is a gamma emitter. Most common means of detection is with a thin window G-M probe.

1. Maximum energy: Gamma radiation from, 0.014 to 0.692 MeV (0.122 MeV emitted 85.5 % of the time)
2. Maximum range in air: Data not available
3. Maximum range in tissue: Data not available
4. IAEA Radiotoxicity Classification: Medium-low
5. Physical half-life: 270.9 days
6. Effective biological half-life: 9 days
7. Critical Organ: Lower large intestine
8. Personnel Monitoring: Dosimeter, uptakes may be evaluated by whole body counting
9. ALI: 7 mCi (3×10^7 Bq) by inhalation, yearly clearance
   4 mCi (2×10^8 Bq) by ingestion;
10. Shielding: 3.2 mm of lead is the first half value layer.

IRON-59 (Fe-59)

Iron-59 is a beta and gamma emitter, which can create an external, internal, and skin and eye hazard. Iron-59 is detected with a thin-window end G-M probe, solid scintillator, or liquid scintillation counter.

1. Maximum beta energy:
   0.466 MeV (average energy is 0.155 MeV)
   0.273 MeV (average energy is 0.091 MeV)
   0.131 MeV (average energy is 0.044 MeV)
   Gamma energies:
   1.292 MeV; 1.099 MeV; 0.192 MeV; 0.143 MeV
2. Maximum range in air: 45 inches (115 cm
3. Unshielded dose rate from 1 mCi point source at 0.5 inch (1 cm): 6.18 rad/hr
4. IAEA Radiotoxicity Classification: Medium-high
5. Physical half-life: 44.6 days
6. Effective biological half-life: 42 days
7. Critical Organ:
   Liver and spleen for inhalation; lower large intestine for ingestion
8. Personnel Monitoring: Dosimeter, finger rings - Fecal analysis may be used to determine uptake for weeks or months after handling. urinalysis is recommended form 4-24 hours after handling;
9. ALI: 0.3 mCi (1 x 10^7 Bq) by inhalation
   0.8 mCi (3 x 10^7 Bq) by ingestion
10. Shielding: 9.7 mm of lead is the first half value layer
11. Special considerations:
    a. Near an unshielded Fe-59 source, dose rates from beta radiation can be much higher than dose rates due to gamma radiation.
    b. Avoid direct eye exposure.
    c. Avoid skin exposure.

IODINE-125 (I-125)

Iodine-125 is a gamma and x ray emitter. Most common means of detection is by scintillation.

1. Maximum energy: 0.035 MeV gamma (6.5 %)
0.027 MeV x ray (112.5 %)
0.031 MeV x ray (25.4 %);
2. Maximum range in air: Data not available;
3. Maximum range in tissue: Data not available
4. IAEA Radiotoxicity Classification: Medium-high
5. Physical half-life: 60.0 days
6. Effective biological half-life: 42 days
7. Critical Organ: Thyroid gland
8. Personnel Monitoring: Dosimeter, internal uptakes evaluated by thyroid scan
9. ALI: 0.06 mCi (2×10^6 Bq) by inhalation, daily clearance
0.04 mCi (1×10^6 Bq) by ingestion
10. Shielding: 0.25 mm of lead is the first half value layer
11. Special considerations:
Volatilization of iodine (NaI) is the most significant hazard.
    a. Simply opening a vial of sodium iodide at high radioactive concentrations can cause minute droplets to become airborne.
    b. Solutions containing iodide ions should not be made acidic nor stored frozen.
    c. Wear two pairs of gloves or polyethylene gloves over rubber. Some iodide compounds can penetrate surgical rubber gloves.

IODINE-131 (I-131)

Iodine-131 is a gamma, x ray and beta emitter. Most common means of detection is by scintillation.

1. Maximum energy: 0.248 - 0.606 MeV
   Primary gamma energies: 0.364 MeV
   0.637 MeV
   0.284 MeV
2. Maximum range in air: Data not available
3. Maximum range in tissue: Data not available
4. IAEA Radiotoxicity Classification: Medium-high
5. Physical half-life: 8 days;
6. Effective biological half-life: 7.6 days
7. Critical Organ: Thyroid gland
8. Personnel Monitoring: Dosimeter, internal uptakes evaluated by thyroid scan
9. ALI: 0.05 mCi (2×10^6 Bq) by inhalation, daily clearance
   0.03 mCi (1×10^6 Bq) by ingestion
10. Shielding: 2.3 mm of lead is the first half value layer
11. Special considerations:
    Volatilization of Iodine (NaI) is the most significant hazard.
    a. Simply opening a vial of sodium iodide at high radioactive concentrations can cause minute droplets to become airborne.
    b. Solutions containing iodide ions should not be made acidic nor stored frozen.
    c. Wear two pairs of gloves or polyethylene gloves over rubber. Some iodide compounds can penetrate surgical rubber gloves.

3. PREPARATION OF WORK AREAS AND MATERIALS

LEARNING OBJECTIVES:

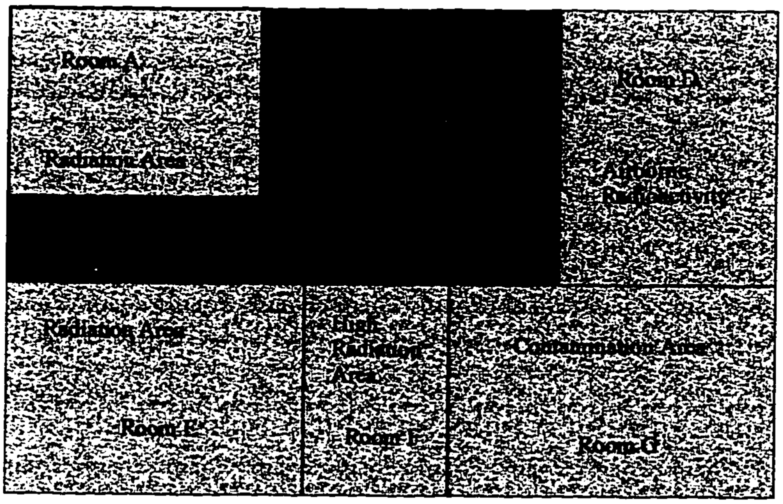
LO1 STATE the preparation work areas and equipment.
LO2 IDENTIFY methods used to control radioactive contamination.
LO3 IDENTIFY the proper use of protective clothing.
LO4 EXPLAIN the purpose and use of personnel contamination monitors.

INTRODUCTION

This unit is designed to assist the worker in preparing the work station such that spread of contamination will be minimized.

A. APPROPRIATE SELECTION OF WORK AREA

The work station should not present an exposure potential to another individual within the laboratory or to the adjacent rooms and spaces (other laboratories, offices or occupied spaces). The work station should not conflict with the other work within the laboratory (such as a strong gamma emitters near low background counting equipment or a strong gamma emitter adjacent to office space where exposures are observed in the office area). Only workers with the appropriate level of training should be authorized to enter areas controlled for radiological purposes. The area which are restricted should be clearly identified to all workers frequently the area, see figure B.3.1.



Untrained workers may enter dark

FIGURE B.3.1 - LOCATION WHERE UNTRAINED WORKERS MAY ENTER

B. PREPARATION OF WORK AREAS

1. Minimize area:
Confine operations involving radioactive materials to as small a space as practicable.

2. Preparation of work area may include: (See figure B.3.2)
- Clearing area of extraneous items and material
- Covering area as appropriate
- Marking and labeling area and materials

FIGURE B.3.2 - WORKPLACE SETUP

3. Work surface:
Diaper paper (absorbent paper) should be placed absorbent side up. Use trays when appropriate.

4. Personnel contamination monitors
Personnel contamination monitors are used to detect radioactive materials on the skin and clothing. These are generally portable survey meters. This equipment should be calibrated and operational.

C. PREPARATION OF EQUIPMENT

1. Assemble survey meters:
The survey meter should be turned on and located in close proximity to the work station. Position the detector such that it is directed toward the work area. This will enable workers to conveniently monitor hands during work and recognize when sources are open. Always work with the audio turned on. Personal safety and the safety of others must take priority over the concept that the sound may be disturbing to visitors or other workers.

2. Equipment preparation:

Use dedicated tools when appropriate. Cover or tape tools or equipment used during the job to minimize decontamination after the job when tools cannot be easily wiped down.

3. Assemble waste receptacles:
Receptacles for waste should be located by the work station such that waste may be conveniently disposed of without contaminating the work station.

4. Assemble materials and supplies:
Those supplies which would minimize small spills should also be within arms reach while handling unsealed radioactive materials.

D. SHIELDING (IF APPROPRIATE)

Placement of shielding materials is critical to both personal safety and that of other colleagues. Work stations which require the use of shields should be located in corners or against walls so no worker on the opposite side of the will receive an exposure. However, if this cannot be accommodated, then shielding for the work station on the opposite side of the workbench where another person may be working should be considered.

When shielding for both beta and gamma emitters, the shielding should be for the beta emitters first. The beta shield should be closer to the radiation source to minimize the production of x rays from the beta emitter interacting with the lead (gamma) shield.

Beta Emitters

Optimum visibility and shielding needs are met with the use of Lucite "L" blocks. Remember all shields should be marked with the radiation symbol to prevent accidental exposure. Table 6 contains thickness of Lucite which will stop all of the beta particles for commonly used beta emitters.

Caution: Do not use dense materials such as lead to shield beta emitters. Use of such materials may cause Bremsstrahlung (x ray) exposure.

Table 6
Beta Shielding for Common Radionuclides

Radioisotope	Minimum thickness (cm) of Lucite to stop all beta particles
H-3	None needed
C-14	<2 feet use 0.1 >2 feet - none needed
S-35	Same as C-14
Ca-45	0.1
P-32	0.8

Gamma Emitters:

Although lead glass gives the best visibility, lead sheets or bricks provide better attenuation. Lead "L" blocks with lead glass in the 45 degree angle top plate are a good compromise when visibility is the prime concern. Any lead glass or other shielding used (such as steel) should have a lead equivalency value specified below. In general, ten times the half value is adequate, as this will reduce the exposure by three orders of magnitude. By dividing the initial dose rate by one half, tens times, you will be left with less than 0.1 percent of the initial value. Table 7 contains half value layers of lead (Pb) for radionulcides commonly used in a general laboratory.

Table 7
Half Value Layers (Pb)

Radioisotope	Half Value Layer (Pb)
Na-22	1.00
Cr-51	0.20
Se-75	0.20
Rb-86	0.90
I-125	0.01
I-131	0.30

E. VENTILATION CONTROL

1. **Airflow direction**
Designed to maintain airflow from areas of least contamination to areas of most contamination (e.g., clean to contaminated to highly contaminated areas) such as fume hoods or glove boxes.

2. **Negative pressure**
Slight negative pressure is maintained in buildings/rooms where potential contamination exists.

3. **Filtration**
High efficiency filtration (HEPA) which removes radioactive particles from the air may be used. This is commonly required for high levels of radioactivity such as 10 percent of the DAC. Charcoal filters are required for specific nuclides such as iodide.

4. **Flow rate**
Always check the flow rate or pressure in ventilated enclosures before starting operations. The flow rates of fume hoods must also go from least contaminated to most contaminated, see figure B.3.3.

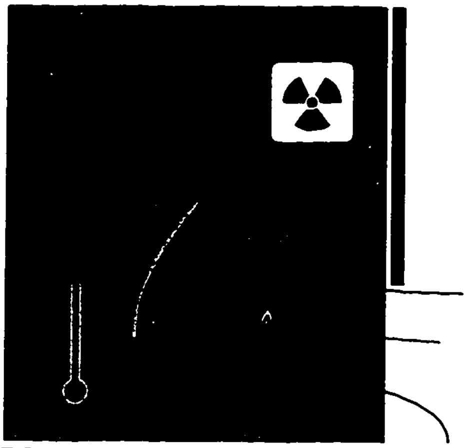


FIGURE B.3.3 - FUME HOOD FLOW RATE

F. MARKING, LABELING, AND POSTING

1. Marking and Labeling

a. Mark and label area/materials as appropriate. Other workers should not have to guess what is contaminated or where the radioactive materials are located.

b. Do not discard intact radioactive labels/markings in normal trash!

Figure B.3.4 is an illustration of the labeling.

- Mark and label area and materials as appropriate.
- Designation of areas

FIGURE B.3.4 - LABELING

2. Designation of Areas

a. A radioactive materials area is an area or structure where radioactive material is used, handled, or stored.

b. A contamination area is any area where contamination levels exceed values listed in the appropriate regulation, but are less than or equal to 100 times those values.

The posting/signs will indicate:

CAUTION
CONTAMINATION AREA

3. **High Contamination Area**
Any area where contamination levels are greater than 100 times the values listed in the appropriate regulation is called a High Contamination Area.

4. **Fixed Contamination**
Fixed contamination designates levels greater than release values but not removable contamination.

5. **Airborne Radioactivity Area**
An airborne radiation area is where the measured concentration of airborne radioactivity, above natural background, exceeds either (1) 10 percent of the DAC averaged over 8 hours or (2) a peak concentration of 1 DAC.
Derived Air Concentration (DAC): Breathing an air concentration of one DAC for one working year (2000 hours) will result in a committed dose equivalent equal to an annual limit (i.e., 5 rem whole-body, 50 rem target organ).

6. **Radiation Area**
A radiation area is any area accessible to personnel where an individual could receive to a major portion of the whole body, a dose equivalent greater than 5 mrem in one hour at 30 cm (approximately one foot) from the radiation source or any surface through which the radiation penetrates.

G. PERSONNEL PROTECTIVE EQUIPMENT

Laboratory coats are intended to prevent contamination from spreading onto your personal clothing. If the coat is not buttoned-up, it will not prevent the spread of contamination. Approximately 1/3 of the contamination experienced by laboratory personnel is due to improper use of the personnel protective equipment.

Some compounds may be absorbed through the skin very easily. Wearing double gloves is advisable. Change the outside pair of gloves often. Hands should always be surveyed when changing gloves.

1. **Personnel Protective Clothing (Anti-Contamination or Anti-C)**
   a. Personnel protective clothing is used to protect your skin and personal clothing.
   b. It does not provide protection from penetrating radiation such as gamma rays.
   c. The degree of clothing required is dependent on the work area, radiological conditions and the nature of the job. Standard clothing requirements for low-level laboratory work are:
      - Lab coat

- Surgeon's gloves
- Shoes without open toes
- Pants (provides increased protection of the legs compared to dresses)
- Safety glasses or equivalent for eye protection (i.e., from P-32)

2. Proper use of protective clothing

a. Inspect all protective clothing for rips, tears or holes prior to use.
b. Personal effects such as watches, rings or jewelry should not be worn in areas where contamination is expected.
c. After donning protective clothing such as anti-contamination clothing, proceed directly from the dress-out area to the work area. Most low-level laboratories do not require the use of anti-contamination clothing. In general, a lab coat is sufficient to protect the individual.
d. Avoid getting lab coats "wet". "Wet" lab coats provide a means for contamination to reach the skin/clothing.
e. Contact Radiation Safety Personnel if clothing becomes ripped or torn during operations and contamination is observed or suspected.

3. Eye protection

Safety glasses, goggles, or face shields may be used to protect the eyes from moderate to high energy beta radiation, such as betas emitted from P-32.

4. Respiratory equipment

Respiratory equipment is used to prevent the inhalation of radioactive materials. Ventilation design should eliminate the need to use respiratory equipment except in extreme cases. This training course does not qualify a worker to wear respiratory equipment.

4. CONDUCT OF WORK - GOOD PRACTICE

LEARNING OBJECTIVES:

LO1 IDENTIFY the requirements for entry, working in and exiting Contamination Areas and Airborne Radioactivity Areas.

LO2 IDENTIFY the proper use of protective clothing.

LO3 IDENTIFY methods used to control radioactive contamination.

LO4 STATE the appropriate response to a spill of radioactive material.

INTRODUCTION

This unit is designed to inform the worker of sources of radioactive contamination. It will also present methods used to control the spread of contamination.
Contamination control is one of the most important aspects of radiological protection. Using proper contamination control practices will help ensure a safe working environment. It is important for all employees to recognize potential sources of contamination as well as to use appropriate contamination prevention methods.

A. PERSONAL PREPARATION

Before beginning a task each worker must make sure he/she is ready to work has the following:

- Training to meet entry requirements.
- Knowledge of the standard operating procedures.
- Appropriate dosimetry.
- Personal Protective Equipment.

B. REQUIREMENTS OF POSTED CONTAMINATION AREAS

1. Requirements for entry

Meet the minimum requirements for entry into contamination areas, including:

- Radiation Worker training.
- Understanding of the specific procedures of the job/task.
- Personnel Protective clothing/equipment required for the job/task.
- Personnel dosimetry.
- Pre-job briefing for High Contamination Area and Airborne Radioactivity Areas.

2. Requirements for working in the area

- Avoid unnecessary contact with contaminated surfaces.
- When possible wrap or sleeve materials and/or equipment brought into the area.
- Do not touch unexposed skin surfaces.
- No smoking, eating, chewing, drinking or applying cosmetic.

3. **Requirements for exiting the area**
   a. Exit only at step-off pad (if provided). A step-off pad provides a "barrier" between contaminated and other areas to prevent or control the spread of contamination between areas. If more than one step-off pad is used, the final step-off pad is "clean" and is outside the exit point and is adjacent to the boundary of the contamination area.
   b. Remove protective clothing carefully and slowly. Loose contamination on the clothing can be dislodged causing a possible spread of contamination or even inhalation if it becomes airborne.
   c. Perform a personal survey. If contamination is indicated:
   - Stay in the area
   - Notify Radiation Safety Personnel
   - Take action to minimize cross-contamination (e.g., put a glove on a contaminated hand or tape over contamination on clothing to prevent the spread of the contamination).

   d. Tools or equipment being removed from a posted area must be monitored for release. This is typically performed with a portable survey meter.
   e. After exiting and monitoring yourself, it is a good practice to wash hands.

C. DOSIMETRY

Always have proper personnel monitoring which might include:

1. **Whole body**

   The whole-body dosimeter, such as a thermoluminescent dosimeter (TLD), is worn outside of routine clothing (i.e., lab coat) between the collar and the waist. Whole body areas are identified as the major blood forming organs. See figure B.4.1.

2. **Extremity monitoring**

Finger rings if handling high contact dose rate materials such P-32. Ring badges should be worn on the hand which is expected to receive the greatest exposure. If exposures are experienced on a routine basis, the hand with the ring badge should always be the same. The badge should be underneath disposal gloves to prevent the dosimeter from becoming contaminated. Extremities are identified as the area from the elbows (most commonly the hands) and lower and the knees and lower, see figure B.4.1.

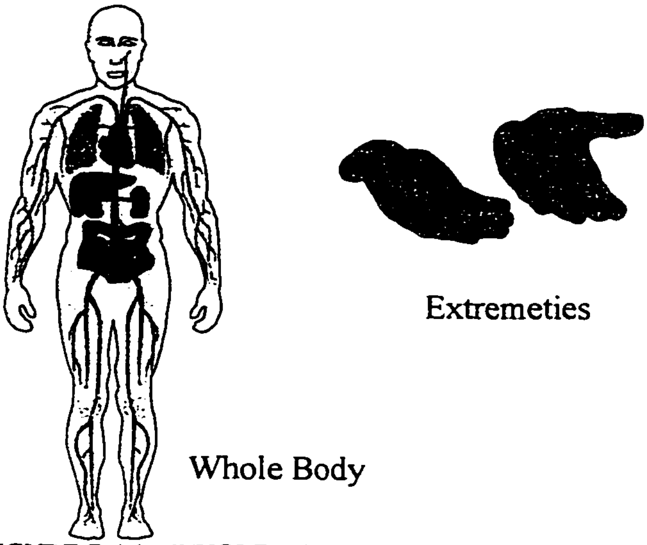


FIGURE B.4.1 - WHOLE BODY AND EXTREMITIES

D. PERSONNEL PROTECTIVE CLOTHING (ANTI-CONTAMINATION)

The degree of clothing required is dependent on the work area, radiological conditions and the nature of the job. Standard clothing in most low level radioisotope laboratories are (see figure B.4.2.):

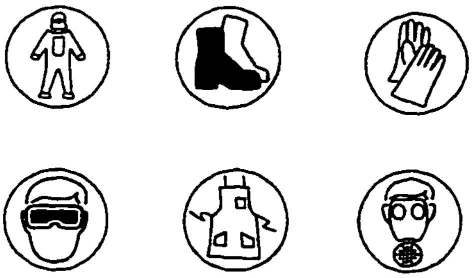


FIGURE B.4.2 - PERSONNEL PROTECTIVE CLOTHING

Lab coat with long sleeves and buttoned or otherwise closed.
Surgeon's type disposal gloves.
Shoes without open toes.
Safety glasses or equivalent for eye protection from high energy beta emitters.

1. Proper use of protective clothing.

Inspect all protective clothing for rips, tears or holes prior to use. Personal effects such as watches, rings or jewelry should not be worn in laboratories where contamination is eminent. Protective clothing should not leave the laboratory if contamination is eminent or known. Avoid getting lab coats "wet". "Wet" lab coats provide a means for contamination to reach the skin/clothing. Contact Radiation

Safety Personnel if clothing becomes ripped or torn during operations and contamination is likely.

2. Eye protection

Safety glasses, goggles, or face shields must be worn to prevent eye contamination in the event of splashes or droplet contamination. In addition, eye protection will provide protection from moderate to high energy beta radiation such as betas emitted from P-32.

3. Respiratory equipment

Respiratory equipment is used to prevent the inhalation of radioactive materials. Ventilation design should eliminate the need to use respiratory equipment except in extreme cases. This training course does not qualify a worker to wear respiratory equipment.

E STORAGE AND CONTAINMENT OF RADIOACTIVE MATERIAL

Containment generally means using vessels, trays, absorbent paper or bench tops to contain contamination.

1. Storage areas

Store large bottles and containers close to the floor.
Shelves should be:

- Secured (bolted) to a wall
- Have lips to restraining cords to prevent bottles from falling
- Storage area should be well lit, properly ventilated, and have an even temperature

2. Radioactive materials should be properly stored

Store in an unbreakable container. If this is not possible, secondary containment (which is able to contain the entire volume of the primary container) should be used.

- In stable containers with secure means of closing.
- Away from sinks and drains or other possible pathways.
- Protected from adverse environmental factors.
- Away from combustibles and other fire sources.
- Protected from "unauthorized relocation", including locked refrigerators and storage cabinets.
- Clearly label outside of container with contents, especially if stored overnight.
- Provide instructions to open containers.

3. Posting of storage area

Room access and cabinets, refrigerators or freezers which house the container should be labeled "Caution: Radioactive Material" or "Caution: Radioactive Material Storage Area".

4. **Chemical considerations for storage**
Segregate incompatibles and store by hazard classification.

F. GOOD HOUSE KEEPING

"Good Housekeeping" is the prime factor in an effective contamination control program. It involves the interactions of all groups within the facility. Each individual must be dedicated to keeping his/her "house clean" to help control the spread of contamination.

G. GOOD PRACTICES

- <u>**Believe**</u> labels and posted areas.
- Avoid contamination and airborne radioactive areas. These areas should be isolated from routine operations.
- Treat radiological areas as if everything were contaminated.
- Minimize the number of items carried or placed into potentially contaminated areas.
- Use proper and functional radiation detection instrumentation.
- Do not eat, drink, apply makeup or chew gum.
- Always wash hands upon completion of work.

H. SPECIAL PRECAUTIONS FOR LIQUIDS

Radioactive solutions are a potential source of radioactive contamination if they are spilled or allowed to evaporate. A particular concern of a spill is that it may be a source of airborne radioactivity. In addition, when radioactive material is in a solution it can be carried to places not normally accessible, like under equipment.

1. **Handling liquids**
Standard good practices for handling liquids include:
- Using appropriate gloves for liquids being handled
- Protecting personal clothing
- Working in a tray with absorbent paper
- Using mechanical pipettes and dilutors. NEVER pipette by mouth!
- Working in a properly vented area
- Reporting any spills or suspected spills

2. **Prevent spills**
The best way to handle a spill is to prevent it in the first place by:
- Storing materials unless in use
- Limiting quantities to what is needed
- Keeping work area clean and free of obstructions
- Using stable containers with secure means of closing
- Avoiding unstable (top heavy) containers or arrangements

- Using secondary containment for liquids

3. Leaking containers

- Report all suspected leaks immediately to Radiation Safety Personnel.
- If the material is highly toxic, evacuate everyone from the area.
- Leaking containers should be placed in a fume hood if it can be done safely.

4. Handling spills

One simple method utilized for response to spills is the acronym SWIMS which stands for:

- Stop the spill
- Warn others
- Isolate the area
- Minimize exposure
- Secure the ventilation system. If the spill involves a volatile chemical or volatile or gaseous radionuclides, the ventilation may need to be left on.

5. PERSONAL PROTECTIVE EQUIPMENT

LEARNING OBJECTIVES:

LO1 DEFINE the limitations of Personal Protective Equipment.
LO2 DEFINE control points.
LO3 DISCUSS radiological control including contamination and dose rate.
LO4 DISCUSS the Donning and Doffing of protective clothing.
LO5 DISCUSS the selection factors of Personal Protective Equipment.
LO6 DISCUSS and demonstrate the methods for a personnel survey.
LO7 DISCUSS contamination control techniques.

INTRODUCTION

This unit is designed to inform the worker of proper use of Personnel Protective Equipment. Personnel Protective Equipment is intended to prevent contamination from spreading onto personal clothing and skin. If it is not used properly, it will not provide the level of protection intended.

A. BASIC CONSIDERATIONS

Personal Protective Equipment - There are two basic considerations when choosing Personal Protective Equipment (PPE):

- It should provide protection from external radiation such as gamma radiation (i.e., lead apron, lead gloves or leaded glasses). The Radiation Safety Personnel should advise when this equipment is necessary.
- It should provide protection from radioactive contamination to minimize the potential for the contamination from getting onto skin or clothes and from entering the body. This is the most common PPE used in general laboratories. This equipment is NOT designed to provide protection from external radiation exposure. The criteria for selection is normally for chemical considerations.

B. LIMITATIONS OF PERSONAL PROTECTIVE EQUIPMENT

Personal Protective Equipment has limitations. PPE is not designed for all hazards. The primary considerations in the design are for chemical and physical hazards/resistance.

1. Degradation

The obvious physical damage occurs at the areas where a chemical and/or physical substance agent has come into contact with the protective equipment and results in a chemical reaction with the material.

2. Penetration

The leakage due to design and construction faults. This may occur around seams or openings in the garment (i.e., zippers, buttons, etc.)

3. Permeation

The migration of a challenge chemical through a protective barrier permeation. When liquid or vapor permeates through rubber or plastic material there is a three-step process:

- Sorption of the chemical at the outside of the PPE.
- Diffusion of the chemical through the PPE material
- Desorption of the chemical from the inside surface of the PPE to the wearer

4. Breakthrough time

Breakthrough time is defined as the amount of time it takes for the chemical to travel from the outside surface to the inside surface.

5. Factors which influence permeation

- Temperature - The rate of permeation increases in direction proportion to the temperature.
- PPE thickness:
  - Permeation is proportional to 1/thickness
  - Breakthrough time is proportional to $(\text{thickness})^2$

- Solubility effect - Solubility is the amount of chemical that can be absorbed by a given amount of PPE material.
  - Note: Low solubility does not necessarily mean low permeation rate.
  - Example: gases have low solubility but a high diffusion coefficient.
- Multi-component liquids - A mixture can be significantly more aggressive towards plastics and rubbers than single components.
- Persistent permeation - After a chemical has begun to diffuse into a plastic or rubber material, it will continue to diffuse after the chemical has been removed from outside surface.
- Chemicals will move from areas of high concentration to areas of low concentration.
- Concentration - The amount of material available to challenge the protective barrier is the concentration.

C. DESIGN AND CONSTRUCTION FACTORS TO BE CONSIDERED:

1. Durability (thickness, strength, lifetime)

Does the material have sufficient strength to withstand the physical stress of the task(s) at hand?

Will the material resist tears, punctures, and abrasions?

Will the material withstand repeated use after contamination/decontamination?
Can the required task be accomplished before contamination breakthrough occurs, or degradation of the PPE becomes significant?

2. Penetration related

How likely is it that chemicals will move through zippers, stitched seams or imperfections such as pinholes in the protective clothing?

3. Flexibility

Will the material and design allow sufficient flexibility of motion to perform the task?

4. Thermal limits

Will the material maintain its protective integrity and flexibility under hot and cold extremes?

5. Lot to Lot variations

Is the garment quality consistently good?
Is there great variability with certain manufacturers, models or clothing types?

D. SELECTION DECISION FACTORS

1. Work Function/Application

Compatibility with other equipment - Does the clothing preclude the use of another necessary piece of protective equipment?

2. Chemicals Involved

The individual components of clothing and equipment must be assembled into a full protective ensemble that protects both the worker from the hazards and minimizes the hazards and drawbacks of the PPE ensemble itself.

3. Degree of Exposure Contact

EPA has established four "Levels" (A, B, C, & D) of protective clothing to be worn by personnel when involved in the response to and/or mitigation of a hazardous waste emergency. The criteria established for the wearing of the various levels of protective clothing are:

Level "A" - Represents the highest available level of respiratory, skin and eye protection.

Level "B" -Provides the same level of respiratory protection but less skin protection than "A".

Level "C" - Provides the same skin protection as "B", but less respiratory protection.

Level "D" - Provides minimal skin protection, but not respiratory protection.

4. **Reuse/Decontamination**
   Ease of decontamination:
   Are decontamination procedures available on site?
   Will the material pose any decontamination problems?
   Should disposable clothing be used?

5. **Cost Availability**
   Comparisons of cost and availability should be performed.

6. **Responsibilities**

- Identify the proper type of PPE to be used for a specific hazardous situation.
- Ensure that all affected employees have their own PPE.
- Monitor the integrity of PPE employees are using.
- Ensure that damaged or contaminated PPE is not used.
- Ensure that the PPE is used properly. A laboratory coat not buttoned up will not provide the intended level of protection.

E. GENERAL LABORATORY PERSONAL PROTECTIVE EQUIPMENT

- Personnel Protective Clothing (lab coat, gloves, shoe covers)
- Proper use of the protective clothing (use as designed)
- Eye protection (high energy beta emitters, chemicals)
- Respiratory protection
- Standard operating procedure
- Training

F. LABORATORIES WITH HIGHER LEVELS OF POTENTIAL CONTAMINATION

- Radiological areas which require protective clothing.
- Control points (location where access to and from contamination areas is controlled to minimize the spread of the contamination outside the area)
- Donning of protective clothing (putting on the protective clothing)
  - Inspect clothing for holes, rips or tears
  - Taping - on edges of pants, sleeves, front closure, and hood
  - No bunches or gaps permitted
  - Removal tabs on the taping
  - Start feet first and work up
  - Pants and sleeves go outside boots and gloves
  - Face piece must be under the hood
- Doffing of protective clothing (taking off the protective clothing)
  - Tape removal working from the top to the bottom

- SCBA harness removal keeping face piece on (if applicable)
- Jacket removal (inside out)
- Face piece
- Gloves (inside out)
- Bib/overall removal (inside out to ankles)
- Boot removal (step out to clean area)
- Do not touch any of the outside surfaces of the protective clothing with hand, feet or body. It may be contaminated.

- Personnel surveys
  - Survey from the top to the bottom
  - Survey around the eyes, nose and mouth

6. MONITORING FOR CONTAMINATION

LEARNING OBJECTIVES:

LO1 DEFINE the types of contamination to be monitored.
LO2 STATE when surveys should be performed.
LO3 IDENTIFY the typical methods of beta/gamma monitoring with portable survey meters.
LO4 STATE the information which must be documented during contamination monitoring.
LO5 DESCRIBE a whole body survey.
LO6 DEFINE the information required to document a survey.

INTRODUCTION

This unit is designed to inform the worker of basic monitoring techniques for radioactive contamination. It will also present methods used to control the spread of contamination.

Contamination monitoring is one of the most important aspects of controlling contamination. Using proper monitoring methods will help ensure a safe working environment. It is important for all employees to identify sources of contamination as well as to use appropriate contamination prevention methods to minimize exposures to personnel and the environment.

A. CONTAMINATION MONITORING EQUIPMENT

Contamination monitoring equipment is used to detect radioactive contamination on personnel and work areas. There are two basic types of monitoring equipment, portable survey meters and counting equipment. Portable survey meters are generally used to identify the location of contamination and to differentiate between fixed and removable contamination. Generally, portable survey meters are qualitative. Counting equipment is used to quantify contamination and is generally referred to as quantitative.

For fixed contamination, always use radiation survey meters to identify the contamination. Tritium is the exception as it cannot by readily detected with a portable survey meter.

For removable contamination, use both portable survey meters and wipe testing to identify contamination. Counting equipment, such as gamma counters and liquid scintillation counters is used to quantify the contamination levels, if they are removable. For tritium, portable survey meters (in general) are not used to identify contamination due to the low energy of the beta. A wipe test are required which is counted in a liquid scintillation counter.

While handling unsealed radioactive materials, monitor hands frequently during work. Monitor your hands and feet when leaving the workstation. Do personnel monitoring before leaving the laboratory. It is common to find contamination on the lab coat in the vicinity where it touched the workstation.

B. CONDUCTING SURVEYS - GENERAL

Regulatory agencies have provided general action levels for removable and fixed contamination above which specified control measures should be taken to protect against internal and external radiation exposure. For workers, the action levels are usually many orders of magnitude lower than those that, if the material were re-suspended, would produce maximum permissible concentration in air.

Good laboratory practice dictates that radiation surveys be made during and after experiments to ensure that sources are adequately shielded and that contamination is controlled. As a part of regulatory conditions (i.e. radioactive material license) facilities are required to survey their areas periodically and to document all surveys performed. The frequency of the surveys is dependent on the radioisotopes used, activity, physical properties, working conditions, and commitment to the regulatory agency. Typically a schedule would be weekly or monthly. When the responsible user surveys weekly, the support group, such as Health Physics or Radiation Safety, would typically survey monthly.

Most radioisotopes used in research laboratories primarily involve the use of beta/gamma emitters. The following is typical for beta/gamma direct monitoring with portable survey meters:

- **Window**: Use a thin window probe. Detector window thickness (mylar) should be not more than 2.0 mg/cm^2. Use a NaI detector when microcurie amounts are used of low energy gamma emitters.
- **Scanning**: Scan the surface. In most cases scanning will cover nearly 100% of accessible surfaces.
- **Distance**: Maintain detector window no more than 1/2 inch from surface.
- **Speed**: The number of counts produced in the detector is inversely proportional to the scanning speed. ANSI 13.12 (1987) describes a formula for calculating scan speed.
- **Audio**: If at any point, a perceivable audible or visual response is detected, perform a stationary evaluation of count rate.

Most surveys require additional monitoring with counting equipment to measure removable contamination. These are referred to as smear or wipe surveys. Specifically, smear surveys differ from wipe surveys only by a known surface area. Wipe surveys are performed over a surface area of 100 cm^2. Smear surveys are performed over an undefined surface area. These tests should be expressed in counts per minute (cpm) or disintegration's per minute (dpm). Background samples shall always be prepared and counted along the area wipe tests. Areas found to be contaminated in excess of two to three times background are to be decontaminated and resurveyed.

- An initial screening evaluation (not for final release) may be conducted by wiping 100% of surface.

- These large area wipes may be evaluated by holding the probe on to the wipe media (~ 5 seconds).
- Take representative disk smears (100 cm^2 area) of up to 100% of accessible surface areas.
- Wipe and smear surveys are counted in liquid scintillation counters, beta counters, or gamma counters. Sample preparation depends upon the counting system used.

C. AREA SURVEYS (See figure B.6.1)

- Frequently monitor work areas.
- Monitor at the end of each shift.
- Monitor upon completion of work (or prior to taking a break and leaving the work).
- Monitor at least every 2 hours for work in progress.
- Wipe surveys should be performed on equipment and areas where survey instruments are not adequate to monitor contamination.

- Area Surveys
  - Frequently monitor work areas.
  - Monitor at the end of each shift.
  - Monitor upon completion of work or prior to taking a break and leaving the work.
  - Monitor at least every 2 hours.
  - Wipe surveys should be performed for contamination.

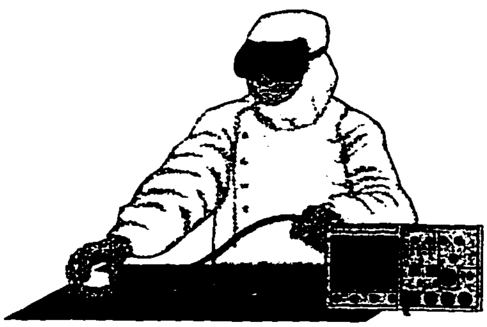


FIGURE B.6.1 - AREA SURVEYS

D. PERSONNEL SURVEYS

A whole-body survey should take approximately 3 to 5 minutes. A full whole body frisk is not generally necessary for routine bench top operations unless a spill occurs or contamination is found on the hands or face. The survey should be done before removing the laboratory coat and repeated if contamination is found.

The potential for personnel contamination, either external or internal, is normally identified through one of five monitoring methods:

- Count rate meter stations: external monitoring
- Personnel contamination monitors: external monitoring
- Partial monitors: external monitoring
- Whole body counts: internal (in vivo)
- Excreta analysis: internal (in vitro)

1. Work conditions:

In some cases the presence of contamination is assumed prior to personnel monitoring:

- Exposure of individual to known contaminated liquid.
- Exposure of individual to airborne contamination without proper protective devices.
- Improper work practices within contamination area:
  - Improper removal of protective clothing or devices
  - Improper work practices with contaminated material
  - Failure to follow the radiological control requirements
  - Unknowingly working with material discovered to be contaminated

2. Proceed to survey in the following typical order:

- Head - Face/nose/mouth (pause at mouth and nose for approximately 5 seconds - concern for intake);
- Neck and shoulders
- Arms (pause at each elbow), hands and wrists; especially where gloves end
- Chest and abdomen
- Back, hips and seat of pants
- Legs and cuffs
- Shoe tops
- Shoe bottoms (pause at sole and heel)

If the count rate increases during frisking (such as the audible signal), pause for 5-10 seconds over the area to provide adequate time for instrument response.

If contamination is indicated (routinely identified as two times background):

- Remain in the immediate area
- Notify Radiation Safety Personnel
- Minimize cross contamination (such as putting a glove on a contaminated hand until decontamination can be attempted).

3. When monitoring, check hands before picking up meter.

- Hold the probe approximately 1/2 inches from surface
- Move probe slowly, 2 inches per second

E. DETECTION OF CONTAMINATION

Decontamination is the removal of radioactive materials from locations where it is not wanted. This does not result in the disappearance of radioactive material but involves the removal of the radioactive materials to another location. You must use the appropriate detection systems and methods to identify possible contamination.

F. DECONTAMINATION OR NOT

If the presence of loose contamination is discovered, decontamination is a valuable means of control. There are special techniques used for decontamination which were derived from experience. In some situations, that is not always possible. There is an excellent list contained in National Council on Radiation Protection and Measurements (NCRP) Report Number 65; Management of Persons Accidentally Contaminated with Radionuclides, Bethesda, MD; 1980

1. **Economical conditions:**
   Cost of time and labor to decontaminate location outweigh the hazards of the contamination present.

2. **Radiological conditions**
   Radiation dose rates or other radiological conditions present hazards which far exceed the benefits of decontamination.

G. SURVEY DOCUMENTATION

A user survey log of each required survey (e.g. monthly) must be maintained in the appropriate file(s). A check-list is provided in the file which lists the compliance items Radiation Safety inspects during laboratory surveys. Review of these items for compliance with current practice within any laboratory is recommended. The survey information generally includes the following:

- **A sketch of the laboratory**
- **Survey locations indicated on the laboratory sketch**
- **Survey instrument**
- Identification of the meter (or counting system) used (e.g. manufacturer, model, serial number). Note: survey meters must not be used if out of calibration.
- **Background measurement**
- Background radiation survey meter reading and/or counting of a "blank" sample during liquid scintillation counting.
- **Levels of contamination observed (including zeros)**
- **The date of the survey**
- **The name of the surveyor**

7. RELEASE OF MATERIALS

LEARNING OBJECTIVES:

LO1 DEFINE releases to controlled and unrestricted areas.
LO2 DEFINE what background levels should be present during surveys and why.
LO3 EXPLAIN the method for direct monitoring of beta/gamma sources.
LO4 DEFINE the areas to be monitored for wipe surveys per sample.
LO5 DEFINE the proper method to perform swipe surveys (area, pressure).
LO6 EXPLAIN the proper method for packaging and submittal of swipes.
LO7 EXPLAIN the proper method for preparation of tritium swipes.

INTRODUCTION

This unit is designed to inform the worker of the various methods used to allow for the release of equipment and other sources which were previously contaminated. It will also present methods used to control the spread of contamination.

Contamination control is one of the most important aspects of radiological protection. It is important for all employees to recognize when equipment and other sources of previously contamination can be released and when they cannot.

A. RELEASE TO CONTROLLED AREAS

Prior to being released, property must be surveyed to determine whether both removable and total surface contamination (including contamination present on and under any coating) is greater than the regulatory limits.

Property shall be considered to be potentially contaminated if it has been used or stored in radiation areas that could contain unconfined radioactive material or that are exposed to beams of particles capable of causing activation.

Material and equipment in radiological areas established to control surface or airborne radioactive material shall be treated as potentially contaminated, see Table 8.

B. UNRESTRICTED RELEASE

The release of property to uncontrolled areas must be in accordance with established regulations and guidelines, such that possession and utilization is granted without regard or concern for residual radioactivity content. Items identified for release should be surveyed for fixed/removable contamination to determine the highest level of contamination.

C. MONITORING TECHNIQUES - GENERAL

Monitoring for release of materials is addressed in regulatory guidance. The following techniques apply for G-M detectors (^{3}H cannot be measured by this method). Particular attention should be paid to areas where radioactive dirt, fluids, or particles could impinge, settle, or accumulate. Also, areas where surfaces mate (e.g. flanges), equipment with moving parts (e.g. fans, or pump internals), and equipment used to transport or store radioactive liquids or gases should be thoroughly surveyed.

TABLE 8
Surface Radioactivity Guides

NUCLIDE (1)	REMOVABLE(2,4)	Total (2,3) FIXED PLUS REMOVABLE
U-natural, U-235, U-338 and associated decay products	1,000 dpm α/100 cm^2	5,000 dpm α/100 cm^2
Transuranics (including Pu), Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	20 dpm/100 cm^2	300 dpm/100 cm^2
Th-natural, Th-232, Sr-90, Ra-224 U-232, I-126, I-131, I-133	20 dpm/100 cm^2	1,000 dpm/100 cm^2
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except for Sr-90 and other noted above (5)	1,000 dpm β-γ/100 cm^2	5,000 dpm β-γ/100 cm^2

(1) Where surface contamination by both alpha and beta-gamma-emitting nuclides exists, the limits established for alpha and beta-gamma-emitting nuclides should apply independently.
(2) As used in this table, dpm (disintegrations per minutes) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background and efficiency and geometric factors associated with the instrumentation.
(3) The levels may be averaged over one square meter provided the maximum surface activity in any area of 100 cm^2 is less than three times the guide values.
(4) The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area should be based on the actual area, and the entire surface should be wiped.
(5) This category of radionuclides includes mixed fission products, including the Sr-90 which is present in them. If does not apply to Sr-90 which has been separated from the other fission products or mixtures where the Sr-90 has been enriched.

1. **General Guidance**
   a. Surveys should be conducted in a low background area (background levels are not to exceed 100 cpm).
   b. Direct measurement shall be made prior to smear or wipe surveys.
   c. Materials or equipment with inaccessible surface areas should be disassembled for survey or the inaccessible areas evaluated for contamination with special survey techniques or by review of process knowledge.
   d. An audible response shall be utilized as the principal indicator for initial detection of surface radioactivity.
   e. The assigned instrument/detector efficiencies shall reflect a prior evaluation of facility wastes.

   Typical efficiencies for a thin window probe.

   - ^{14}C 10%
   - ^{35}S 10%
   - ^{32}P 50%

2. **Swipes for Release or Transportation (does not apply to tritium)**
   a. Prior to taking a wipe for release purposes, the item should be swiped according to the instructions below.
   b. If contamination is detected, the item should be decontaminated and resurveyed prior to taking official wipes.
   c. Items wiped for release should be surveyed for fixed/removable contamination to determine the highest level of contamination.
   d. Transportation packages may exhibit radiation levels due to the contents. Therefore, direct surveys for highest radiation levels have little correlation with removable contamination. If removable contamination is detected, the item should be decontaminated and resurveyed prior to taking official wipes. Under certain conditions, packages can be offered for transportation with residual contamination (49 CFR 173.443).

3. **Swipes on Suspected Contaminated Surfaces (does not apply to tritium)**
   a. Perform a general survey for fixed/removable contamination to prevent swiping in areas of gross contamination.
   b. For surfaces likely to be contaminated use a portable G-M meter with a thin window beta/gamma probe to screen for elevated levels of radioactive contamination and prevent cross contamination.
   c. Removable contamination may be checked by taking area swipes using tissue swipes or other absorbent materials and counting directly with a portable G-M meter with a beta/gamma probe (HP-210 pancake probe).

d. If contamination is detected, it may be prudent to decontaminate before taking a swipe. If the existing contamination level must be determined, be very careful not to spread contamination or produce any airborne radioactivity.

D. BETA/GAMMA DIRECT MONITORING

1. Window

Use a thin window probe. The detector window thickness (mylar) should be not more than 2.0 mg/cm^2.

2. Scanning

Scan the surface. In most cases scanning will cover nearly 100% of accessible surfaces.

3. Distance

Maintain detector window no more than 1/2 inch from surface.

4. Speed

The number of counts produced in the detector is inversely proportional to the scanning speed.

5. Audio

If at any point, a perceivable audible or visual response is detected, perform a stationary evaluation of the count rate.

E. WIPE (SWIPE) SURVEYS AND TECHNIQUES

Wipes are taken to detect the presence of removable contamination on a material. Wipes can provide official documentation for release of items to uncontrolled areas and packages submitted for transportation. In general a wipe is an absorbent material smeared over a 100 cm^2 area and counted for removable radioactivity. A swipe is the same activity, however the surface area is undefined and more limited.

1. Wipe Area

a. An initial screening evaluation (not for final release) may be conducted by wiping 100% of the surface.

b. These large area wipes may be evaluated by holding the probe up to the swipe (≈ 5 seconds).

c. Take representative disc smears (100 cm^2 area) of up to 100% of accessible surface areas.

2. Materials

Any soft absorbent material can be used, such as Kimwipes or cheese cloth.

3. **Pressure Area**

The wiping material should be folded over and the pressure area (the area that will be in contact with the surface) should approximate the area of the detector. This does not work for all situations depending on the size and configuration of the item.

4. **Inaccessible areas**

If portions of the item are inaccessible and there is potential for internal contamination, efforts must be made to survey the internal surfaces either by disassembly or some other method such as sampling internal fluids or flushing internal surfaces and counting the effluent. If this is not possible or feasible, the item cannot be released for unrestricted use. If there are any questions, contact Radiation Safety personnel.

F. DOCUMENTATION

<u>All surveys for unrestricted release shall be documented in writing</u>.

1. **Official Wipes for Release Surveys**

Areas of 100 cm^2 should be selected either on individual surfaces or a combination of surfaces. A surface area of 100 cm^2 is equivalent to the surface area of a dollar bill. As a general rule, one to five wipes should be taken for every square meter of representative surface area to be surveyed.

2. **Surfaces Greater than or Equal to 100 Square Centimeters**

If the total surface area of the item to be wiped is greater than 100 cm^2 representative areas should be wiped on all surfaces.

3. **Representative Area**

Setting specific criteria as to what constitutes a representative area in each case is extremely difficult. The item, material or equipment and its history must be known sufficiently to determine the number of wipes required to adequately document that all portions of the item, material or equipment are not contaminated. If that information is not available or unknown, more wipes should be taken. A thorough survey with a thin window detector or area wipe could be used to provide a general idea of contamination levels before using swipe tabs.

4. **Official Wipes for Packages Submitted for Transportation**

To determine the removable contamination levels on packages submitted for transportation, an area of 300 cm^2 per wipe should be taken.

8. DECONTAMINATION

LEARNING OBJECTIVES:

L01 IDENTIFY when decontamination may not be recommended.
L02 IDENTIFY methods for preventing contamination.
L03 DEFINE the control factors for actions to be considered during skin contamination.
L04 DEFINE the method of skin decontamination.
L05 DEFINE material decontamination.
L06 IDENTIFY the normal methods used for decontamination.

INTRODUCTION

Contamination control is one of the most important aspects of radiological protection. Using proper contamination control practices will help ensure a safe working environment. It is important for all employees to recognize potential sources of contamination as well as to use appropriate contamination prevention methods.

This unit is designed to inform the worker of sources of radioactive contamination. It will also present methods used to control the spread of contamination.

A. DECONTAMINATION OR NOT

If the presence of loose contamination is discovered, decontamination is a valuable means of control. Decontamination is the removal of radioactive materials from locations where it is not wanted. This does not result in the disappearance of radioactive material but involves the removal of the radioactive materials to another location. In some situations, this is not always possible.

1. Economical conditions

Cost of time and labor to decontaminate location outweigh the hazards of the contamination present.

2. Radiological conditions

Radiation dose rates or other radiological conditions present hazards which far exceed the benefits of decontamination.

B. PREVENTIVE METHODS

- Identifying and repairing leaks before they become a serious problem.
- Changing out gloves or protective gear as necessary to prevent cross-contamination of equipment.
- Good housekeeping is the best method of prevention. If the material and equipment is not available to become contaminated, there will be less to decontaminate in the event of a spill.

C. SKIN DECONTAMINATION

Once it is determined that the worker is contaminated, the actions taken will be controlled by three basic radiological control factors:

- Physical condition of the worker.
- Location of the contamination on the worker.
- Activity of the nuclide(s) present.

Primary consideration should be given to the physical condition of the worker. All action taken by the Radiation Safety personnel will be based on the workers physical condition. The major concern should be whether or not the worker has a serious injury. When a worker sustains a serious injury, the primary concern is the first aid or assistance the worker needs. When a worker sustains an injury, the extent of the injury needs to be determined. Conditions that should be investigated include open/puncture wounds, bruises, sprains, strains and fractures.

Once the physical condition of the worker has been identified, the location of the contamination needs to be determined. Some of the items to pay particular attention to include:

- Is contamination localized on skin surface?
- Is contamination located on or near a body orifice?
- Is contamination located near a break in the skin?
- Is there a skin condition present in the vicinity of the contamination?

Include a determination of the type of activity (alphas, beta or gamma) and save some type of sample for laboratory analysis.

Skin contamination normally does not cause physical injury to the skin. Some nuclides and chemical forms allow absorption through the skin (i.e., iodide and tritium). Strong beta emitters may present a hazard to the skin.

Intact skin is an excellent barrier, so use gentle methods to decontaminate. Normally, mild soap and lukewarm water is used to decontaminate personnel. There are several guidelines to follow:

- Do not abrade skin
- Do not chap skin by cold water or harsh chemicals
- Do not spread the contamination
- Avoid hot water because it will open pores
- Use mild soap, not detergents or abrasives

1. **Notify the Radiation Safety personnel for assistance in monitoring and decontamination.**
   Stay put so as not to spread contamination.

2. **Cover area if possible to prevent airborne and cross contamination.**
   Put on a glove.
   Put on booties to keep from tracking contamination.

Tape loose contamination on lab coat or coveralls.

3. **Carefully remove clothing by rolling inside out, and place in contaminated laundry.**

4. **Often some skin contamination remains. A common procedure is to wear surgeon's gloves overnight to induce sweat that will lift contamination from the skin.**

D. MATERIAL DECONTAMINATION

Material decontamination is the removal of radioactive materials from tools, equipment, floors and other surfaces in the work area, see figure B.8.1.

- Establish control to prevent the spread of contamination.
- A high priority is the prevention of airborne contamination.
- Decontaminate from area of low to high contamination. An exception is when potential for airborne contamination is high.
- Decontaminate from top to bottom so that contamination will not run down on the clean surface.
- Only make one pass, then discard or turn wipe to a clean surface. Do not decontaminate an area).

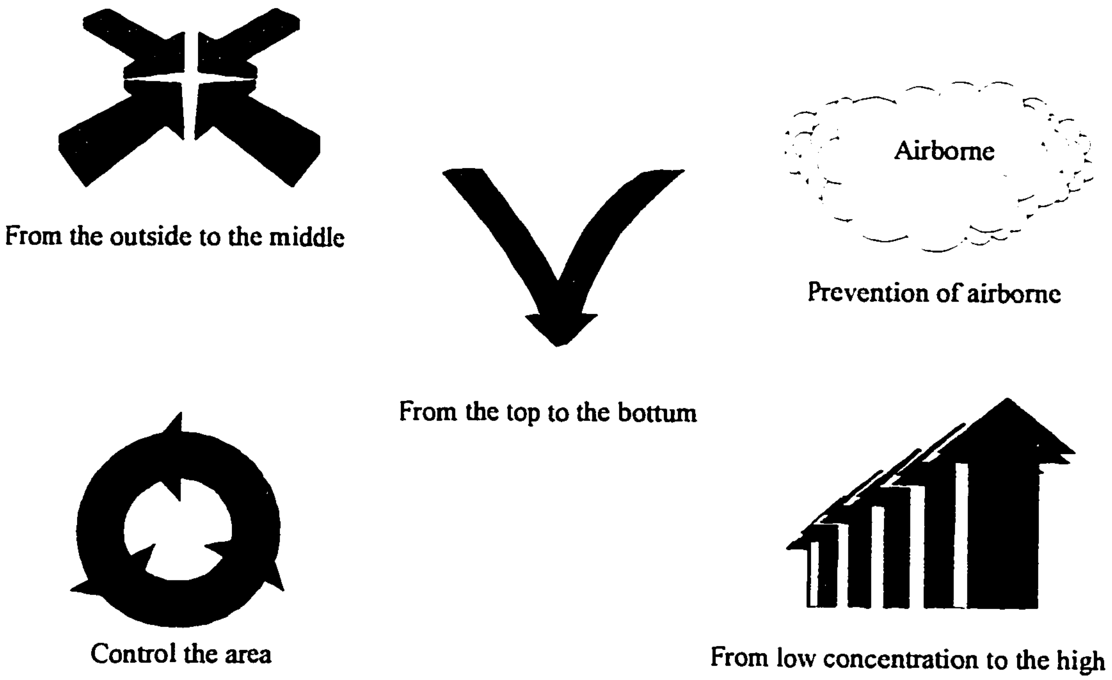


FIGURE B.8.1 - DECONTAMINATION TECHNIQUES

9. PORTABLE SURVEY METERS

LEARNING OBJECTIVES:

LO1 IDENTIFY the correct instrument (from a list of common types of radiation survey instruments) for the detection and measurement of the basic types of ionizing radiation.

LO2 IDENTIFY the response characteristics and limitation of the radiation survey instruments commonly used.

LO3 IDENTIFY the proper operational checks for portable survey meters.

LO4 EXPLAIN the methods of calibration, source checks and background measurements.

LO5 EXPLAIN the basic techniques for surveying areas and personnel.

INTRODUCTION

This unit is designed to inform the worker of use of survey instruments commonly found in basic research laboratories. It will also present methods used to perform basic surveys of areas and personnel, primarily when radioactive contamination is a concern.

Contamination control is one of the most important aspects of radiological protection. Using the survey instrument properly is paramount to contamination control practices and will help ensure a safe working environment.

A. BASIC SELECTION

1. Exposure

To measure exposures, instruments should be calibrated in R/hr or mR/hr. In general, this is looking at the energy deposited by unit mass.

2. Contamination

To measure material, instruments should be calibrated in counts per minute (cpm). This contamination can be removable, fixed, or a combination of the two. Removable contamination represents a greater hazard. Methods of detection should be used which can detect fixed or removable contamination, and differentiate between the two. The two most common portable survey meters are those with a Geiger-Mueller (G-M) detector and with a scintillation detector.

The table 9 below provides basic guidance in the selection of appropriate instruments to measure or detect radioactive contamination. Identify those radionuclides which are handled. Select the appropriate instrument(s) based on both the need for portability and the sensitivity of the instrument for the characteristic radiation emitted by the radionuclide in question.

TABLE 9
Selection of Appropriate Instruments

Characteristic Radiation	Portable Instruments	Non-Portable Instruments
Low energy beta ^{3}H, ^{63}Ni		H, E, F
Medium energy beta ^{14}C, ^{35}S, ^{45}Ca	A, (C, D) for associated Bremsstrahlung	G, H, E, F
High energy beta ^{32}P	A, B, (C, D) for associated Bremsstrahlung	G, H, E, F
Low energy gamma (or x ray) ^{125}I	C, D	I, H, (E, F, G)
Medium-high energy gamma ^{131}I, ^{22}Na	D, A, B, C	I, G, E, F, H, I

A = Ratemeter with end window or pancake G-M probe.
B = Ratemeter with thin wall G-M probe.
C = Ratemeter thin NaI(Tl) scintillation probe.
D = Ratemeter thick thin NaI(TL) scintillation probe.
E = Ratemeter with gas-flow proportional counter.
F = Open window gas-flow proportional counter.
G = Closed window gas-flow proportional counter.
H = Liquid scintillation counter (LSC).
I = Gamma spectrometer with semiconductor or scintillation detectors.
__ = Superior.
( ) = Limited usefulness.

3. Desirable features of G-M survey instruments

a. Paralysis protection: sometimes an option at extra cost
b. Audible output: sometimes an option at extra cost
c. Coil cord, if detachable probe: sometimes an option
d. Large diameter probe: extra cost for most instruments
e. Response data for different radiation
f. Available service and parts
g. Reliability
h. Commonly used batteries

B. OPERATIONAL CHECKS

1. Obtaining the activity

The amount of radioactivity that has been detected by direct monitoring or by wipe survey can be readily estimated by subtracting the background count rate (background cpm) from the observed count rate (gross cpm) and then dividing the net count rate by the counting efficiency (c/d) for the radionuclide in question.

$$\frac{\text{(gross cpm)} - \text{(background cpm)}}{\text{efficiency}} = \text{net dpm}$$

Always express contamination levels in standard units, such as dpm or microcuries/100 cm^2. If the identity of the radionuclide detected is not known, the most conservative (lowest) efficiency of the possible radionuclides should be used. Table 10 provides efficiencies for portable survey meters for selected radionulcides.

TABLE 10
Conservative Survey Instrument Efficiencies

Radionuclide	Beta Energy MeV maximum	Beta Energy MeV average	Range in air	Efficiency %
Tritium	0.0186	0.0057	1/4 inch	0
Carbon-14	0.156	0.045	9 inches	10
Sulfur-35	0.167	0.0488	12 inches	10
Strontium-90	0.546			45
Phosphorous-32	1.71	0.69	20 feet	50 approximate

2. Pre-operational checks should always be performed

a. Check the **calibration** sticker to ensure that the instrument's calibration is valid. Because the calibration is not valid does not mean that the instrument is not operational. It does mean that it cannot officially be used for health and safety purposes. Regulations dictate how to calibrate and when to calibrate portable survey meters. Most calibration cycles are one year.

b. **Check the battery**.
With most programs this is the only feature which the operator may change without invalidating the calibration.
If the batteries have expired, replace them. An occasional check during the days activities will identify if the instrument is still operational.

c. **Turn on the audio.**

The audio on the instrument has a faster response time than the dial reading. By using the audio as an indicator for possible contamination, the operator is left free to visually concentrate on the location of the probe rather than on the meter. This should help prevent placing the probe in the contamination and reducing the effectiveness of the instrument.

d. **Source check** - make sure that the instrument responds.
The source check should have a known response on the instrument. It is not recommended to use short-lived radionuclides as a source check. The response on the instrument should not vary over time. When the instrument is checked with the source at one time of the year, it should respond the same any other time of the year.

e. **Check the background.**
Know the background radiation levels. This should be twice when using the instrument, both at the beginning and end. In general, most laboratories try to identify low levels of contamination. For most operations, this is about two times the background.

3. Periodical checks

Operational checks and source checks will identify problems while the instrument is in use.

4. Post-operational checks

Source check and battery check should be performed at the completion of the work. This will identify if the instrument battery expired or if the instrument malfunctioned. If the instrument is no longer functional for either reason, there may be potential contamination spreading which the operator was not aware.

C. LIMITATIONS

To measure the activity, the radiation must somehow get into the detector. Radioactivity is emitted randomly in every direction. Charged particles, such as alpha and beta particles, have a finite range of travel in air.

1. Range dependent for charged particles.

The detector must be close to the source to be observed. Weak beta sources (^{3}H) will not penetrate the window of portable survey meters routinely used in general laboratories.

2. Instruments are normally calibrated with a gamma source (^{137}Cs).

Beta sources under respond with G-M detectors.
Alpha sources over respond with G-M detectors.

3. **Instruments may be subjected to environmental sources (i.e. RF, Pulses, magnetic field interference, position to earth).**

4. **The probes of G-M detectors are very thin and can be easily punctured.**
5. **The meter dial and the audio do not respond at the same rate.** The audio is much faster at responding to observed activity. The meter dial requires a specific time for the electronics to respond.

6. **Survey instrument are normally qualitative and not quantitative.**

7. **Window may be too thick and provide a low response or no response at all.**

8. **Batteries may die or be low at inopportune times.**

9. **Calibration may drift.**

10. **Short in cable or other electronic problems may occur.**

11. **A high radiation field may peg the dial and respond as a low radiation field.**

12. **Poor survey techniques may cause problems.** The angle of the probe to the source may result in only partial detection of the activity. Radiation is absorbed by air if the probe is too far from the source.

D. CALIBRATION, SOURCE CHECKS AND BACKGROUND

Portable survey meters are calibrated by subjecting the instrument to a known gamma field. The electronics are adjusted (as much as possible) to the field to obtain a reading which can normally vary +/- 10 to 15 percent (depending on the manufacturers recommendations).

1. **Instruments are routinely calibrated on a periodic schedule, most often annually.**

2. **Only calibrated instruments are authorized to be used for health and safety purposes.**

3. **The operational status of the instrument should be verified by comparing it to a known source of radiation (source check).** This source should be a long-lived source such that the response on the instrument should be the same over time.

4. A background check should be performed at the beginning and end of the work period or day. An increase in the background would suggest contamination may be spreading.

E. BASIC SURVEY TECHNIQUES (AREA AND PERSONNEL)

Surveys are required to be conducted periodically according to the use of radioactive materials. The frequency is dependent upon the license commitment. The technique is dependent upon:

1. **Characteristics of the radionuclide**
   What is the most appropriate instrument for contamination surveys?

2. **Chemical characteristics of the compound.**
   To what location will the compound be transported?
   Does the chemical preclude observation and relocation?
   Does the compound present any other risks (e.g. biohazard)?

3. **Fixed, removable or airborne contamination**
   Wipe test versus survey instruments.

4. **Physical properties**
   Is the contamination a liquid, dry powder or gas?
   Where is the contamination?

5. **The activity being surveyed**
   Are you surveying low background areas being surveyed?
   Instruments may be a screening technique and counting equipment a primary discriminator for contamination.
   Is surveying for high gross contamination being done?
   The survey instrument may be the primary discriminator for contamination.
   Is the sensitivity of the instrument sufficient for the task?

6. **Other considerations:**
   a. Risk to the surveyor
   b. Instruments available
   c. Counting statistics

When surveying for contamination on people, always start by removing the clothing in the area where the contamination is located. If the contamination engulfs the entire individual, by removing the clothing most of the contamination is removed. The survey should then proceed at the head, concentrating around the mouth and nose to determine if radioactive material entered the body by inhalation. Then proceed to survey the front of the body from the top to the bottom followed by the survey of the back of the body from the top to the bottom. A whole body survey should take 3 to 5 minutes.

10. USE OF FUME HOODS AND GLOVEBOXES

LEARNING OBJECTIVES:

- LO1 STATE three types of airborne hazards against which fume hoods are effective.
- LO2 STATE two types of physical hazards against which fume hoods are effective.
- LO3 IDENTIFY what the air circulation is called that takes place around a fume hood.
- LO4 DEFINE face velocity.
- LO5 IDENTIFY the minimum distance from the front of a fume hood where experiments should be performed.
- LO6 IDENTIFY the reasons and criteria for using a glovebox.
- LO7 IDENTIFY 5 components of a glovebox.

INTRODUCTION

Many of the materials used in laboratories give off fumes, mists, vapors, particulates and aerosols that are hazards. To minimize exposure to these materials special precautions need to taken. In many laboratories this often means working within a fume hood or working with a glovebox.

A. WHY LABORATORY HOODS ARE NEEDED

The most efficient and cost effective form of contaminant control is local exhaust ventilation. This involves capture of the chemical contaminant at its source of generation. The laboratory chemical fume hood is a specialized form of capture hood that totally encloses the emission source.

Hoods are necessary for controlling possible airborne contamination arising from work with radioactive materials. The airflow into the hood must be adequate, and the hood must be designed such that the lines of air flow are all directed into the hood and away from the operator. Airflow into the hood should be between 100 and 125 linear feet per minute when the hood sash is at its normal open position during use. A recommended opening is 14 inches to give eye protection as well as effective ventilation. Flows above 125 feet per minute may lead to turbulence and some release of hood air to the laboratory.

Even the best hoods do not completely isolate the area inside the hood from the laboratory, so there is a limit to the maximum amount of activity that can be handled. Careful solutions can be processed that contain up to 100 mCi of the less hazardous beta emitters in the hood without serious contamination to personnel or surroundings. However, if complex wet operations with risk of serious spills, or dry and dusty operations must be performed, a completely isolating system such as a glovebox may need to be used. If massive shielding is needed, a more elaborate system such as a hot cell is required.

Provisions should be made for HEPA filters and/or activated charcoal absorbers to be installed at the hood air outlet when required by NRC regulations. The fan should be selected to handle the increased static pressure produced by the air filtration system.

B. PROTECTIONS AFFORDED BY FUME HOODS

The simplest type of confinement and enclosure may be accomplished by limiting the handling of radioactive materials to well-defined, separated areas within a laboratory, and by the use of sub-isolating units such as trays. For low-level work where there is no likelihood of atmospheric contamination this may be sufficient. If the possibility exists of the release to the atmosphere, either as a gas or an aerosol, of amounts of activity between 1 and 10 times the maximum recommended body burden, the usual practice is to use a ventilated hood.

- HEPA filters have unique characteristics.
    - Disposable, dry-type filters
    - Constructed of Boron Silicate microfibers
    - Be able to capture particles as small as 0.3 of a micron with 99.9% success rates.
- Remember: HEPA filters do not guard against hazardous "gases".
  If substances give off both particles and gases talk to a supervisor or the Radiation Safety Officer about the proper hood to use.
- When working with radioactive material, a radioisotope hood should be used which:
    - Is impermeable to such materials.
    - Will minimize dangerous exposure.
- No matter what sort of hood is being used, and what precautions are taken, things can still go wrong.
    - It is important to "be prepared" for accidents.
    - Spills need to be dealt with immediately.
    - Follow the facility's clean-up procedures.
    - Soak up spills with absorbent materials.
    - Dispose of resulting residues properly.
- Small fires can also occur in hoods.
    - If possible, put out fire with extinguishers or through suffocation.
    - If uncontrollable, close the sash and evacuate.
    - Sound alarms and call for assistance, if needed.
- Ventilation failures can also occur with hoods which:
    - Can be caused by malfunctions in electrical lines.
    - May result in the release of harmful fumes, vapors or particles.

C. HOW HOODS FUNCTION MECHANICALLY

The function of hoods may be studied by using the chemical exhaust hood as an example. They:

- Prevent contaminants within the hood from entering the "breathing zone".
- Create a protective barrier by pulling air into and through the hood.
- "Inward" airflow keeps hazards from escaping.

Captured contaminants are filtered, diluted and exhausted through a duct system.

Hoods can also provide protection from "physical" threats.

The sash protects workers from hazards such as chemical splashes, sprays, fires and minor explosions.

To make sure they are operating safely, hoods are thoroughly at several junctures:

- When first installed.
- Whenever a change is made in the lab's ventilation system.
- Periodically throughout the year.

D. TESTING HOODS FOR CORRECT OPERATION

Factors to consider when choosing a performance test include (1) reason for testing, (2) type and quantity of chemicals or biological agents to be used in hood, (3) types of operations and equipment to be used in hood, (4) number and type of users, (5) diversification of hood use, both in the short term (months) and long term (years), (6) location of hood within the facility, (7) type of hood (conventional or auxiliary air), and (8) ease of performance of test.

Performance tests involve measurement of the hood flow characteristics (face velocity and air quantity) and the efficiency of the hood in containing an artificial challenge gas or aerosol generated within the hood.

Fume hoods should be tested to verify adequate performance. Generally, this involves measurement of total volume flow and face velocity across the hood opening and comparison to design guidelines. Face velocity measurements should be made at 9 to 12 points equally distributed across the opening of the hood. In addition, observation of airflow patterns should be made by generating a source of smoke across the face opening. It has been common practice to conduct these tests at regular intervals throughout the year on operational hoods.

There are specific steps to follow to determine if a hood is operating correctly.

Air circulation around the hood ("CROSS DRAFT") should be checked first.

- Measure six inches from the front of the hood.
- Should not be greater than 20 linear feet per minutes.

Next a smoke tube should be used to make sure airflow within the hood is correct.

- Smoke should head for the ventilation ducts.

Then measure the face velocity, the rate of air coming through the face of the hood.

- Open the sash.
- Use instruments such as anemometers or velometers.
- Do not use sheets of tissue or other paper as a substitute.

Measuring this "Face Velocity" requires great precision.

- The hood face is divided into a grid patter.
- Velocity of the air is measured in each quadrant.

- Values for specific points can vary +/- 25%.
- No measurement should be below 60 feet per minute.

Face Velocity is also compared to Cross draft.

- Cross draft should never be greater then 20% of Face Velocity.

If problems are apparent, several things will be checked or adjusted:

- Interior hood baffles.
- Laboratory ventilation systems.

Checking for turbulence within a hood is also important.

- Use "smoke patterns" for this purpose.

If excessive turbulence is seen (or smoke is not captured) a number of things will be checked:

- Location of equipment within the hood.
- The hood's Face Velocity.
- Location of air-input ports.
- Physical location of the hood itself.
- Volume of air coming into the hood.

E. PROPER USE OF LABORATORY HOODS

Hoods must be used correctly to be effective, see figures B.10.1 through B.10.4.

- Maintain proper airflow within the hood.
- Perform experiments at least six inches inside the hood.
- Elevate equipment (especially large pieces) if necessary.

- Objects placed too close to the front of the hood can obstruct airflow and increase the risk releasing hazardous fumes the worker's breathing

- Eddy currents caused by the worker can add to the problem.

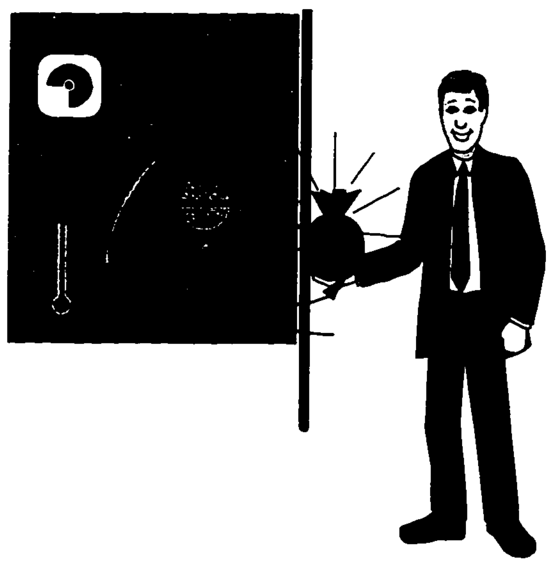


FIGURE B.10.1 - PROPER USE OF FUME HOOD

- Too large an opening will reduce the hood flow to dangerously low levels.

- Air velocity will not be adequate to prevent escape of hazardous fumes.

FIGURE B.10.2 - FUME HOOD SASH OPEN

- Pull the sash down as far as possible when working. keep it at a comfortable level.

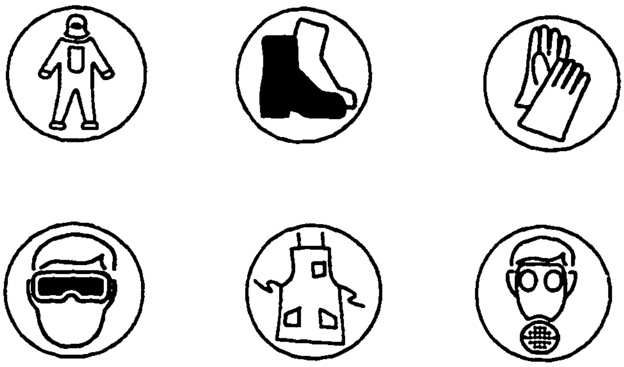


FIGURE B.10.3 - PERSONNEL PROTECTIVE EQUIPMENT

- When working with a hood, personal protective equipment is still required.
  - Safety eyewear.
  - Lab coats.
  - Gloves.
  - Other protection if necessary.
- Hoods should not be used as storage cabinets.
  - Overloading restricts the airflow.
  - This can result in dangerous build-up of hazardous vapors.
  - Chemicals stored in hoods can make an emergency or fire worse.
  - When not actively working with a material in the hood, put it away.
- Take steps to prevent contaminated air in hoods from entering the laboratory. Keep the sash closed as much as possible.
- Pay attention to air monitors.

- Maintain hood face openings to one square foot or less at all times to keep air velocity above 100 linear feet per minute (100 lfm).

- Keep containers sealed to minimize releases.

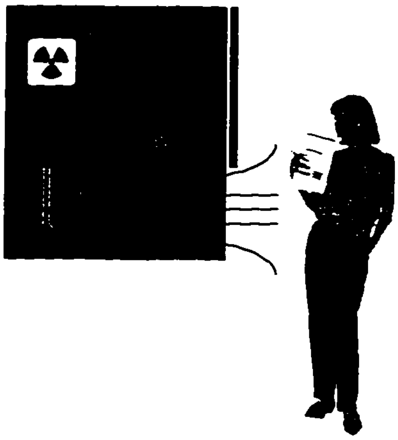


FIGURE B.10.4 - FUME HOOD FACE OPENING

- It is also important to exercise caution around hoods.
  - Airflow must not be disrupted.
  - Even velocities of 100 linear feet per minute can be overcome by rapid movements in front of the hood.
- Solid objects should be kept from entering a hood's exhaust ducts because they:
  - Can lodge in a duct or fan.
  - Adversely affect airflow.
  - Can change the filtration characteristics of the system.
- Never place your head inside an exhaust hood.
  - They disrupt airflow.
  - There is a risks of being overcome by potentially hazardous fumes/vapors.

F. WHY GLOVEBOXES ARE USED

There are two reasons to use a glovebox.

1. To contain hazardous materials which are radioactive, chemically toxic, carcinogenic or a biohazard.

2. To keep oxygen and/or moisture away from material.

The need for a glovebox is based on:

- Toxicity of the substance being handled.
- Quantity needed in an operation.
- Chemical nature of the substance.
- Dispersibility.
- Type of work being done.

When the toxicity, radioactivity level, or oxygen reactivity of the substances under study is too great to permit safe operation in a chemical fume hood, resort must be made to a totally enclosed, controlled-atmosphere glovebox must be used. The special feature of a glovebox, as the name suggests, is the total isolation of the interior of the box from the surrounding environment. Items can be manipulated inside the box by means of full-length gloves sealed into a sidewall of the box. To prevent loss of materials from the inside of the glovebox to the laboratory, the box is maintained under substantial negative pressure relative to the laboratory.

- What requirements do you have for a glovebox?
  - Is a stainless steel box required?
  - What type of atmosphere - air or inert?
  - Visibility and accessibility - how much?
  - Is shielding and remote handling required?
- What are the general glove requirements?

  There are general requirements for specific radionuclides being handled. Tritium can be especially difficult to control. Under some chemical conditions, half of the uptake from tritium is provided by absorption through the skin. These compounds and quantities should be handled in a glovebox with the appropriate support equipment installed. Basic requirements for working with tritium are given in Table 11 below.

TABLE 11
Requirement for working with tritium

Glove	Type	Use	Change
Inner	Cotton	Absorbs moisture	15 minutes
Second	Pylox	Second barrier	15 minutes
Third	Pylox	Third barrier	15 minutes
***	Gauntlets	Arm protection	15 minutes
Glovebox glove	Butisol or Hypolon	Primary protection hand & arm	Yearly

- What special safety features should be installed?
  - A pressure drop gauge measures differential pressure between room and box or airlock. The normal range is 0.5 to 1.0 inches of water.
  - Positive gas pressure control system is present on inert boxes.
  - Some working station HEPA filtered hoods are equipped with flow indicators.
  - An alarm which is sensitive to excessive heat or heat loss.
- What utilities are needed such as lights, power or gas? Ground interrupt circuits should be installed. In some cases, explosion proof conditions need to be met.
- Ergonomics are very important. This is the person to machine interface. The set up should be specific to the individual. For example, the glovebox needs to be at a height where the operator can handle the samples and equipment inside the box with as much comfort as possible. It should not be too high or too low for the operator.

- Gloveboxes must be seismically secured. In certain parts of the country, there is a significant concern that the glovebox will be relocated by environmental conditions such as an earthquake.

G. BASIC COMPONENTS OF A GLOVEBOX

Basic components of a glovebox are:

- Exhaust filters to capture effluent
- Intake filter to control humidity
- Heat detector
- Pressure gauge to verify direction of flow
- Bag-out port to input and exit samples, waste, and equipment
- Glove ports for manipulating samples and equipment
- Window to observe work
- Box to contain hazardous materials

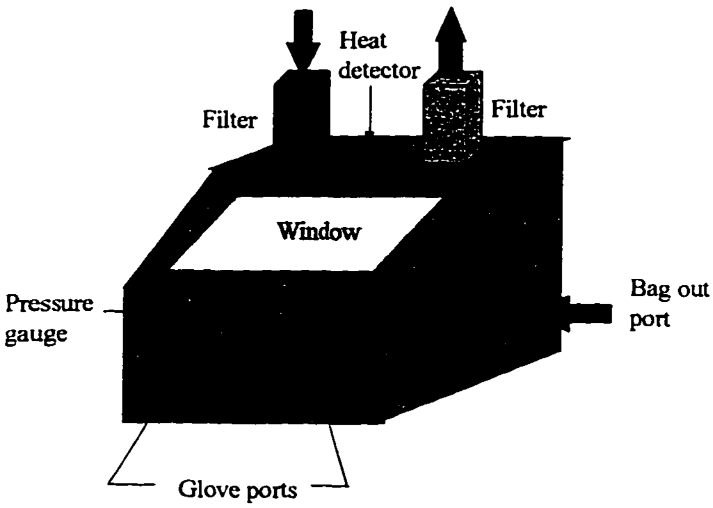


FIGURE B.10.5 - COMPONENTS OF A GLOVEBOX

H. PROPER USE OF GLOVEBOXES

Always understand the procedure before starting an operation.

1. **Perform a self-safety check.**

- Is the appropriate protective clothing being worn?
- Is the operator certified to perform the work?
- Check the laboratory for:
  - Any leaks.
  - Strange noises.
- Review procedures.
- Obtain all necessary supplies.
- Check ventilation before starting.

- Check for hazards before starting work.
  - In case of atmospherically sensitive material, it is good practice to have secondary contaminant.
  - Minimize the amount of powder which could be exposed to the glovebox atmosphere.
- Check status of gloves
  - Put on inner gloves.
  - Loosen the gloveport cover and check for leaks.
  - Check the rolled up glovebox glove. Check the gloves for breaks as they are unrolled or untied.
  - If leaks or breaks are detected, close port and call for assistance.
- Check for puncture hazards.
  - Sharp objects could puncture glove or hand, by injecting material directly into bloodstream.
  - Hot objects could melt the glove.
  - Glass objects could be hit and broken.
- Minimize the amount of hazardous material in a glovebox.
  - Package and transfer trash as it accumulates.
  - Limit quantities of hazardous materials to what is necessary.
  - Do not use glovebox for unnecessary storage.
  - Use secondary containment.
- Always close out operations in a routine manner.
  - Clean up and bag-out all trash.
  - Turn off any utilities.
  - If anything is left on, notify the appropriate individuals. Also, leave a note with emergency instructions.
  - Double check that everything is off.
  - Secure the gloves and replace the gloveport covers.
  - Turn off survey meter, if applicable.
  - Complete paper work as appropriate.

I. TYPES OF EMERGENCIES WHICH MAY INVOLVE GLOVEBOXES

The are five basic types of emergencies which may involve gloveboxes, failure of the glove, contamination incidents, excessive pressure in the glovebox, excessive negative pressure in the glovebox and a fire in the glove box.

1. Serious failure of glove - what to do.

a. Do not withdraw the hand.
b. Shout for help.
c. Get respirator and don.
d. When protected, withdraw hand leaving glove in box.
e. Place contaminated hand in plastic bag until decontaminated.

f. Secure gloveport cover.
g. Call for assistance in decontamination.

2. **Contaminated inner glove - what to do.**
   a Remove glove by turning the glove inside out.
   b. Check hand for contamination.
   c. If contaminated, bag hand.
   d. Call for assistance.

3. **Personnel contamination - what to do.**
   a. Call for assistance.
   b. Local skin contamination:
   - Any methods used must not abrade skin.
   - Waste water is considered contaminated.

   c. Wound contamination:
   - Do not attempt to decontaminate, medical advice must be obtained.
   - Do not stop bleeding unless it is life-threatening.

4. **Excessive pressure in glovebox - what to do:**
- Alarm should sounded.
- Put on respiratory protection.
- For airbox - adjust dampers to obtain proper negative pressure.
- Call for assistance.
- Exhaust filters may need changing.

5. **Excessive negative pressure in a glovebox - what to do:**
- Shut exhaust damper.
- Adjust intake damper.
- If glove fails, respiratory protection is needed.
- Call for assistance.

6. **A fire in a glovebox may release hazardous material and result in:**
- Loss of filtration and other controls.
- Loss of shielding.
- Emission of toxic vapors or fumes.
- Explosion.
- Electrical shock hazards.

7. **In case of fire, the primary concern is your safety.**
- Don respirator.
- Notify fellow workers and call for emergency services.
- Use extinguisher.

C. *Module C - Supplemental Materials*

Module C contains six (6) sections which discuss additional training area for support operations and/or special sources or equipment that would significantly benefit the worker. The concepts presented in this module provide instruction in subject areas common to many general laboratories. The instructor is encouraged to select the sections appropriate for the workers based upon the need of the facility. Each section is designed to be an independent lesson. The module is designed to be an entire course.

1. STORAGE AND CONTAINMENT

LEARNING OBJECTIVES:

LO1 DEFINE containment.
LO2 STATE the general hazards' classes for storage of materials.
LO3 STATE the general guidelines for storage of hazardous materials.
LO4 DEFINE the proper storage for radioactive materials.

INTRODUCTION

This unit is designed to inform the worker of storage methods for hazardous material commonly found in the general laboratory. In the general laboratory, the storage of chemicals will take priority over the concept of radioactivity.

Everything in the world is made of chemicals. Some chemicals are made by nature and some are made by people. Both natural and man-made chemicals may have hazards.

Chemicals have three main types of hazards:

- Fire
- Reactivity
- Health

Anyone working with dangerously reactive liquids and solids should always practice good personal hygiene.

- Wash hands and exposed skin before going home.
- Wash hands and exposed skin before eating, smoking or using the toilet.
- Launder work clothing regularly and separately from non-work clothing.
- Keep food, drink and cigarettes away from storage and handling areas.

A. CONTAINMENT OF MATERIAL

Containment generally means using vessels, trays, blotting paper and bench tops to contain contamination. Secondary containment means that the primary container is within another container in the event the primary container fails, such as from breaking. Secondary containers should be at least the same volume as the primary container see figure C.1.1.

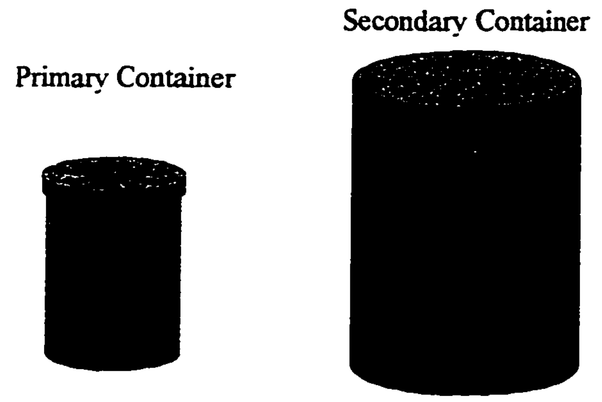


FIGURE C.1.1 - DOUBLE CONTAINMENT

B. SEGREGATION AND STORAGE

Many chemicals may be dangerous, even common chemicals used every day.

1. Fire Hazards

Flammable chemicals catch fire easily. Flammable liquids produce vapors. These vapors are often heavier than air. They can sink to the floor and travel long distances through buildings. When the vapors catch fire, the fire can flash back to the container of flammable liquid. This may cause an explosion.

2. Reactivity Hazards

Reactive materials may explode and catch fire:

- If they are knocked over or dropped
- If pressure or temperature is increased
- If they mix with air, water or other chemicals

3. Health Hazards

Exposure to some chemicals may result in health problems such as:

- Itchy skin
- Irritation of the eyes and nose
- Allergies
- Skin burns
- Eye damage

If enough of a hazardous chemical enters the body, a person may be poisoned. Symptoms can include headache, dizziness and nausea.

Some chemicals may cause serious diseases. Repeated exposure to some chemicals, or exposure over a long time, may even cause serious diseases such as cancer.

Segregate incompatible materials and store them by hazard class. This will minimize the possibility of the materials reacting with each other in general storage and during emergency conditions such as fires. Recommended general hazard classes for storage are:

- Caustics (bases)
- Acids (mineral)
- Flammables; (including organic acids)
- Poisons (toxic)
- Oxidizers
- Water reactives

C. GENERAL GUIDELINES

Keep flammables by themselves in approved storage cans or cabinets.

- Keep acids away from bases.
- Separate organics from inorganics.
- Store oxidizers away from flammables.
- Provide as much physical separation as possible between classes.

Biohazards should be properly labeled and may be stored as one group.

- Class A and B carcinogens should be properly labeled and stored with their chemical family.
- Store Class C carcinogens in the glovebox or another regulated area.

D. STORAGE AREAS

Store large bottles and containers close to the floor.

Shelves should:

- Secured (bolted) to a wall
- Have lips or restraining cords to prevent bottles from falling

Storage area should be well lit, properly ventilated, and have an even temperature.

Secondary containment of chemical containers in polyethylene trays is recommended for spill protection.

E. FORMATION OF ORGANIC PEROXIDES

Organic peroxides are a class of compounds that has unusual stability problems. This makes them among the most hazardous substances found in the laboratory. As a class, organic peroxides are considered to be powerful explosives and are sensitive to heat, friction, impact, and light, as well as to strong oxidizing and reducing agents. Common compounds that form peroxides during storage include:

- ethyl ether
- isopropyl ether
- potassium metal
- vinyl chloride
- cyclohexene
- dicyclopentadiene
- vinyl acetylene

- dioxane
- acetal
- butadiene
- vinyl ethers
- styrene
- diacetylene
- vinyl acetate
- tetrahydrofuran
- divinyidene chloride
- cumene
- sodium amide
- methyl acetylene
- methylcyclopentene

F. STORAGE OF RADIOACTIVE MATERIALS

Radioactive materials must be properly stored. They must not be stored in the same room with chemical waste. Below is a list of guidelines for the storage of radioactive materials.

- Store in unbreakable containers. If not possible, use secondary containment.
- Use stable containers with secure means of closing.
- Keep away from sinks and drains or other possible pathways.
- Protect them from adverse environmental factors.
- Keep away from combustibles and other fire sources.
- Ensure protection from "unauthorized relocation".
- If more than 100 times the ALI is handled, contaminant should be resistant to fire.
- Clearly label outside of container with contents especially if stored overnight.
- Provide instructions to open containers.
- Separate waste from usable radioactive materials.
- Monitor storage locations for possible contamination frequently, especially when storing tritium.

2. RADIOACTIVE WASTE MANAGEMENT

LEARNING OBJECTIVES:

LO1 DEFINE how waste should be segregated.
LO2 STATE where radioactive waste should be stored.
LO3 STATE how sharps should be handled.
LO4 IDENTIFY methods of waste minimization.
LO5 IDENTIFY the various waste disposal methods and their controls.
LO6 EXPLAIN waste volume reduction techniques.
LO7 IDENTIFY mixed waste and the appropriate disposal methods.

INTRODUCTION

This unit is designed to inform the worker of waste control concepts. It will also present methods used to minimize radioactive waste.

Radioactive waste management is an important aspect of radiological protection. Using proper control practices will help ensure a safe working environment and minimize exposure to workers and the environment. It is important for all employees to recognize waste management techniques to keep exposures as low as possible and to minimize cost.

A. SEGREGATION

Segregate waste by type to facilitate storage, waste minimization and disposal. Waste is segregated to prevent fires, explosions, spills, reactions, and other events that potentially endanger human health and the environment. Waste segregation requires constant attention and monitoring. Proper waste segregation is heavily emphasized in regulations and is a common focus of inspections.

B. WASTE STORAGE

Each laboratory should have a designated location in which to store waste. Radioactive waste should be stored separately from hazardous waste. This location should be out of the way of normal lab activities, but easily accessible and recognizable. The waste accumulation area is a temporary location for waste until it can be picked up by waste processing staff for storage, treatment, or disposal.

Waste materials should be kept in secondary containers and segregated by hazard class. The waste must be properly labeled. Secondary containers may be lab trays or any device that will contain 110% of the largest container.

Check for:

- Properly completed label (activity, quantity, date).
- Proper containment (integrity).
- Waste separated in the appropriate containers (shielding, capped).
- Waste separated by type and radionuclide (half-life, liquid, animal).

Containers should always be arranged so that labels are visible without having to move the container. Containers showing signs of leakage or deterioration are addressed immediately. Secondary containment for liquids waste must be adequate (at least 100 per cent of the initial volume). Documentation and recordkeeping are needed for disposal and license inventories.

C. SHARPS

Contaminated syringes, glass pipettes and other sharp items must be placed in a specifically designed, rigid container. This minimizes the risk to laboratory personnel and those individuals processing waste.

D. MINIMIZE WASTE GENERATION

- Confine operations with radioactive materials to as small an area as possible.
- Minimize materials introduced into radioactive material handling areas. Restrict materials entering areas where unsealed radioactive materials are handled to only the materials needed for the performance of work.
- Segregate clean materials from radioactive materials. Do not dispose of clean materials in radioactive waste containers. This may seem like it is obvious, BUT it takes extra effort to remove labels from materials such as clean packing boxes, etc.
- Reserve an assortment of tools and supplies primarily for use in contamination areas.
- Contamination control measures such as covering benches generate waste. On the other hand, decontamination generates a great deal of waste. Good housekeeping, minimizing bench areas and secondary containment can reduce the amount of coverings required.

E. STORAGE FOR DECAY

- Storage: Some radionuclides have a short half-life and can be stored for decay. Generally, radionuclides with a half-life less than 90 days are stored separately. These are decayed between 7 to 10 half-lives. They are then surveyed and disposed as non-radioactive waste.
- Substitution: Substitute for shorter-lived radionuclides if possible, i.e. ^{33}P for ^{35}S.

F. DISPOSAL VIA SANITARY SEWER

Some regulatory agencies allow for discharge via sanitary sewer. NRC licenses allow limited quantities of radionuclides to be disposed via the sanitary sewer per 10 CFR 20.2003. Many businesses do not allow for such discharge due to other liability issues.

In general, only tritiated wastes are released to the sanitary sewer. Other isotopes are released, but only under the direct supervision of the Radiation Safety Officers for those facilities. No radioactive liquids are released to the sanitary sewer without the written permission of the Radiation Safety officer. The Radiation Safety Officer shall maintain accurate and complete records on all releases to the sanitary sewer system, and shall ensure that regulatory guidelines are not violated.

There are limits as to the quantities which are allowed to be released into the sanitary sewer specific to each radioisotope via 10 CFR 20.2003. Most states have adopted the same limits within their respective regulations.

G. DISPOSAL VIA FUME HOOD

Most regulatory agencies allow for discharge via exhaust fume hoods. These limits are also dictated as to the limits via 10 CFR 20.2003. Most states have adopted the same limits within their respective regulations.

H. DISPOSAL OF SPECIFIC WASTE PER 10 CFR 20.2005

Safety in transport of radioactive materials is accomplished mainly by requiring the proper type of packaging, depending upon the type, quantity and form of the material. Waste generators and waste processors must record on shipment manifests a description of the transferred waste, and must also carry out a quality control program to assure that classification of waste is carried out in a proper manner. The manifest must also indicate as completely as practicable: a physical description of the waste, the volume, radionuclide identity and quantity, the total radioactivity, and the principal chemical form. The solidification agent must be specified. Additional information may be required for shipment to a particular disposal facility depending upon facility specific license conditions.

In accordance with Part 20.2005, NRC licensees may dispose of the following without regard to its radioactivity:

- Liquid scintillation counting media containing 0.05 microcuries or less of ^{3}H or ^{14}C per gram of medium
- Animal carcasses containing 0.05 microcuries or less of ^{3}H or ^{14}C per gram of animal tissue averaged over the weight of the entire animal

I. MIXED WASTE

Mixed waste is exceedingly difficult if not impossible at this time to dispose of. Currently there are no commercial disposal sites accepting mixed waste. Mixed waste is defined as hazardous chemical waste banned from land burial and is radioactive.

1. Ways to avoid generating mixed waste

a. Use non-hazardous cleaning materials for decontamination whenever possible.
b. Segregate radioactive waste from other hazardous waste at the source.
c. Explore the use of other materials which are non-hazardous for use in radiological areas to prevent the generation of mixed waste.

d. Discontinue use of non-biodegradable (organic solvent based) liquid scintillation fluid. Organic scintillation fluids create a mixed waste disposal of which may not be possible.

2. **Other methods of facilitating disposal:**
   a. Do not combine solvents with metals. Disposal is very difficult. Examples are lead or mercury combined with solvents.
   b. Generally it is a good idea to separate organic and inorganic waste whenever possible.

J. VOLUME REDUCTION

Radioactive waste cost is directly related to the volume. Chemical waste cost is based upon the weight of the chemicals being disposed. Radioactive waste is based upon volume. Reduction techniques will significantly reduce cost.

1. Compacting

Compacting may produce reduction factors of 5 to 1. Only dry solid waste (primarily laboratory trash) may be compacted. Liquids, animals, and solids (such as machinery) cannot be compacted.

2. Shredding

Shredding may produce reduction factors of 12 to 1. Plastic vials and other materials with a memory can be effectively reduced in volume by shredding. This techniques removes the memory.

3. Incineration

Incineration is difficult under present regulation and political climate. This method would be effective for many types of radioactive waste. Obtaining permits and going beyond public opinion is the most difficult aspect of incineration operations.

3. ANIMAL FACILITIES

LEARNING OBJECTIVES:

L01 IDENTIFY what training, if any, is required by animal handlers.
L02 IDENTIFY what areas should be surveyed when handling animals and radioactive materials.
L03 STATE the appropriate posting of animal facilities and equipment.
L04 IDENTIFY methods used to prepare the workstation where animals are handled.
L05 IDENTIFY the proper handling of specimens.
L06 EXPLAIN the method of labeling cages.
L07 STATE the methods of waste disposal and storage of animal carcasses.

INTRODUCTION

This unit is designed to inform the worker of sources of radioactive contamination when working with animals and for the animal handler. It will also present methods used to control the spread of contamination.

A. TRAINING OF ANIMAL HANDLERS

All persons who work with animals that have received radioactive materials, through injections or infusions, are required to be trained in areas of radiation safety.

Protocol studies involve specials procedures and require special training relative to the procedures. Different animals also require different procedures based upon the needed animal handling techniques. The animal handler should be experienced with the specific animal types and techniques before introducing radioisotopes.

If researchers are required to wear personnel dosimeters, such as film badges during animal experiments, the animal handlers may need dosimeters as well. Personnel dosimeters are not necessary for all work with radioactive materials. For example, they are inappropriate for ^{3}H and ^{14}C. Internal dosimetry may be a special concern in the event of animal bites.

1. Laboratory Practices

a. Do not eat, drink, chew gum, apply cosmetics, or store food in areas where radioactive materials are utilized.
b. All personnel need to wash hands immediately after completion of any procedure which utilizes radioactive materials.
c. Animal rooms containing radioactive materials shall be marked with the radiation warning symbol and shall be kept locked when unattended.
d. Each cage should be individually labeled with the radioactive warning symbol.

e. All procedures shall be in accordance with the established protocol and written facility safety guidelines.

2. **Personal protective clothing**

Personal protective clothing shall be worn when working in rooms containing radioactive materials and experimental animals:

- Regular work clothes and footwear without open toes
- Disposable shoe coverings
- Laboratory coat or coveralls
- Personal exposure monitor as appropriate for the isotopes and amounts in use
- Gloves and booties
- Safety glasses

B. MONITORING, SURVEYING AND POSTING

Monitoring for radioactive contamination should be conducted after each experiment involving the use of radioisotopes according to the method prescribed by the facility. Caging and lab surfaces with the potential to be contaminated must be monitored prior to release. Areas contaminated to a level in excess of two times background must be decontaminated. Records of caging and monitoring must also be provided to the animal facility manager.

- The room in which the animal receives the radioactive material and the room in which the animal is housed afterwards must be posted with a "CAUTION RADIOACTIVE MATERIALS" sign.
- If radioactive materials are not going to be used again in the near future, close-out surveys of the rooms should be performed and the signs removed.
- Geiger counters or G-M meters are used to look for gross contamination of certain high energy beta and some gamma emitting radionuclides.
- Use meter to check hands, shoes, clothing, floor, bench and cage.
- Use wipes and count in a liquid scintillation or gamma counter for contamination check to determine counts or disintegrations per minute.
- All cages housing or transporting radioactive animals must be labeled "CAUTION RADIOACTIVE MATERIAL," with the radionuclide, activity, and date indicated.
- Cages must be monitored and decontaminated, and labels must be removed before the cages are sent to the cage wash area or are released for general use. Never use cages which have not be decontaminated for other use because there is a danger of exposures to other staff.

C. WORKSTATION PREPARATION

1. Absorbent paper

a. Absorbent paper must be placed underneath the animals throughout the radioactive injection or infusion procedure.

b. Cages used to transport and house the animals must be lined with absorbent paper.
c. If it is likely that the animal will excrete on the floor in the housing area, absorbent paper should also be placed under the cage.
d. All soiled absorbent paper must be disposed of as radioactive waste.

2. **Booties**
   a. If it is likely that the floor will become contaminated during the radioactive procedure, it should be covered with absorbent paper, and disposable booties should be worn to prevent tracking of the contamination.
   b. Booties must be disposed of as radioactive waste before leaving the potentially contaminated area.

3. **Labeling of specimens**
   a. Any specimens collected from the animal after it has received radioactive materials must be labeled "CAUTION RADIOACTIVE MATERIAL".
   b. If the specimen is to be taken to another room, double containment must be used.
   c. Depending on the type and quantity of radioactive material in the specimens, shielding may be needed.

4. **Radioactive waste disposal**
   a. Collection and disposal of excreta
      1) Animal excreta must be collected and disposed of as radioactive waste.
      2) The excreta should be collected and sealed in plastic bags using absorbent material like absorbent paper or animal bedding.
      3) The bags must be packaged in medical pathological waste containers.
      4) The box must be labeled "CAUTION RADIOACTIVE MATERIAL" and a tag indicating the radionuclide, activity, and date must be attached.
   b. Disposal of animal carcasses
      1) Remove all intravenous lines, needles and absorbent paper and dispose of them separately, before packaging carcasses for disposal.
      2) The needles and other sharps must be placed in a separate labeled plastic box.
      3) Carcasses must be sealed in a leakproof plastic bag.
      4) Carcasses must be refrigerated if stored for 4 hours.
      5) Carcasses must be frozen if stored for 24 hours or more.

5. **Necropsy**

If an animal dies unexpectedly after receiving an injection or infusion of radioactive material and a necropsy is needed, coordinate with Radiation Safety personnel.

4. GAMMA-CELL IRRADIATORS

LEARNING OBJECTIVES:

LO1 STATE who may use the irradiator and what training they must have.
LO2 STATE the types of monitoring performed when using gamma-cell irradiators.
LO3 DEFINE the expected dose rates to the operator of gamma-cell irradiators.
LO4 EXPLAIN the emergency procedure to be followed.
LO5 STATE how to obtain authorization to use gamma-cell irradiators.
LO6 EXPLAIN the responsibilities of the custodian and the user.

INTRODUCTION

This unit is designed to inform those who work with gamma-cell irradiators which are commonly used in general laboratories. Gamma-cell irradiators are designed to provide a large uniform gamma field for irradiation of samples.

For radiation protection purposes, external dose shall be the primary concern of the operator when using the gamma-cell irradiation.

A. DOSE RATES ASSOCIATED WITH GAMMA-CELL IRRADIATORS

Gamma-cell irradiators provide a large gamma dose to samples. The most common radioisotopes used are ^{60}Co or ^{137}Cs. The sources are sealed sources, normally comprised of stainless steel encapsulation. Due to the encapsulation, only the gamma radiation is emitted.

Sources are commonly provided as a line source, similar in shape to a pencil. Within a sample chamber, this shape enables the exposure to be provided as a uniform dose over a larger distance. A point source projects the dose differently, as radiation coming from a single small point. When the distance from a line sources is increased (about three times the length of the source) the line sources acts as a point source. The exposure to the operator would be considered a point source due to the distance from the source itself.

The containment vessel of the system is normally heavily shielded, typically with lead. The dose rates on the outside of most systems, approximately one foot from the source, is normally 2.5 mR/hr or less when the source is in the expose position. This is the highest potential for an exposure of the operator. When the source is in the safe position, the source is more heavily shielded. When the system is in the expose position, the level of exposure to the operator, one foot from the source calculated for a working year would not exceed the regulatory limit of a whole body exposure to gamma radiation.

2.5 mR/hour x 40 hour/week x 50 weeks/year = 5,000 mrem/year

Routinely, the operator is only at this location for a few minutes at any one time. The systems are designed with interlocks and other safety features to minimize any potential exposure to operators. These are designed to move the source into the safe position if the chamber is opened or other situations arise. Commonly the system is designed with alarms in the room to detect the changes in the system and exposure rates. The system includes visible and audible alarms. Administrative controls are established to make sure the area is clear and ensure that the operators have the appropriate training. This control normally includes control of the key to the system. Workers using the system must be monitored for whole body gamma exposures.

B. MONITORING

Check to be sure that the area radiation monitoring system, normally mounted on the wall adjacent to the gamma-cell irradiator unit, is operating as evidenced by an audible clicking (background radiation) and lighted panel.

Ensure that the portable radiation monitor is operational by performing the pre-operational checks for the instrument. Place the portable radiation monitor on the floor near the door of the irradiator in the "ON" position. This is a secondary check for potential exposures to the operator in the form of an area monitor.

Ensure that whole-body dosimeter is worn. Do not enter without proper dosimetry.

C. SYSTEM OPERATION

Ensure that the interlocks are operational according to the instructions posted in the room. Verify that the source is in the "OFF" position before attempting to open the chamber door. After placing the sample into the chamber, recheck the interlocks again before placing the source in the active position.

After using the irradiator, document in the Irradiator Safety Manual Use Log that interlock checks have been completed in accordance with the Health Physics instructions posted for the equipment.

The operator should stay behind the designated point, normally identified on the floor, or outside the room when the unit has the source in the active position. If the sample will be left in the irradiator for an extended period of time while operator is not attending the system, a notification should be posted. In the event of a problem with the system, there will be a point of contact to evaluate system failures and to return any samples left in the system.

Never leave the unit or room unlocked or unsecured!

D. EMERGENCY PROCEDURES

In the event of malfunction during loading, unloading or use of the irradiator or if the wall-mounted radiation monitor should give an alarm signal, the unit is to be taken out of service immediately. Evidence of malfunction includes binding or moving parts, the presence of metal shavings or chips, or any abnormal condition or functions. **IN NO**

CASE SHOULD THE USER ATTEMPT TO REPAIR OR MODIFY THE IRRADIATOR!

- Log and describe any abnormal occurrences in the use log.
- Should the "RELEASE SOURCE" fail, an audible alarm will be triggered in a short period of time, typically 10 seconds. Should this alarm sound, leave/secure the room and immediately contact the Radiation Safety personnel.
- If at any time it is possible to open the cavity door without pressing the door release button, the interlock assembly is malfunctioning. DO NOT USE THE UNIT! Lock it with the padlock, leave/secure the room and contact Radiation Safety personnel.
- If at any time it is impossible to raise the source with the door closed or to open the door with source in the "OFF" position, either the interlock switches or interlock solenoids are malfunctioning. DO NOT USE THE UNIT! Lock it with the padlock, leave/secure the room and contact Radiation Safety personnel.

E. PROCEDURES FOR GAINING AUTHORIZATION FOR USE

Irradiators are used under the supervision of individuals so authorized by the Radiation Safety Officer, Radiation Safety Committee or the Radiological Control Manager. Those individuals are commonly referred to as the "Irradiator Custodians."

An individual may become an Irradiator Custodian by submitting the appropriate request to the organization which manages or oversees the Radiation Safety Program.

Typically what is included in the request is:

- Evidence of meeting the training requirements for such sources.
- Specific information about the irradiator: location, source strength, operating procedures, others who will be supervised during such use.

Typical Irradiation Procedures:

- The irradiator may ONLY be operated by the custodian (individual responsible for supervision of use, approved by name under the Radiation Safety Program) or by his/her designees (previously approved individuals).
- Users must be familiar with the operating instructions and adequately trained in the proper operation and emergency procedures specific to the unit.
- Obtain the key from the custodian.
- Place the key in the unit, and turn it on.
- Place samples to be irradiated into the chamber, then actuate "Irradiate" position.
- At the end of the irradiation period, be sure the source(s) are in its shielded position, then remove the irradiated samples.
- Record the required information in the Use Log.
- Secure the irradiator, and return the key to the custodian.

F. TRAINING REQUIREMENTS

The custodian must:

- Completion of basic Radiation Safety with an emphasis on biological effects with gamma sources and external monitoring of exposures.

- Demonstration of the proper operation of the specific irradiator to be authorized.
- The exposure rates for the unit or system to be authorized and how to perform the appropriate calculations for dose estimates (primarily for the samples to be irradiated).
- Emergency procedures for the unit or system.

G. RESPONSIBILITIES

1. The custodian must:

a. Maintain the irradiator in a clean and mechanically functional conditions.
b. Notify the Radiation Safety personnel of any anticipated changes in configuration, location or operation in a timely manner.
c. Ensure that designated users receive training as required.
d. Ensure that designated users wear whole body radiation monitors when operating the irradiator.
e. List and certify designated users.
f. Ensure physical security of the key to the unit and prevent unauthorized use of the irradiator.
g. Notify the Radiation Safety personnel immediately of any malfunctions or problems with the irradiator.
h. Arrange for repairs or maintenance of the unit by appropriate persons.

2. Designated Users must:

a. Operate the unit in accordance with the established procedures at all times.
b. Wear a whole body radiation monitor when operating the irradiator.
c. Notify the Custodian and the Radiation Safety personnel of any malfunctions or other problems with the irradiator.
d. Ensure that the key is returned to secure storage following irradiation.

3. Radiation Safety Branch/Personnel must:

a. Maintain the license/authorization issued to the facility by regulatory agency for operation of the irradiator.
b. Conduct leak tests and other safety inspections as described by the manufacturer and the regulatory agency.
c. Provide the appropriate training.

H. SYSTEMS CONTROLS

1. Installation

Relocation of an irradiator shall be permitted only after authorization is granted by the regulatory agency. The request normally includes:

a. A description of the new facilities, including an annotated sketch of the floor plan of the room and adjoining areas, showing the planned location of the irradiator and identifying the types of activities to be conducted in the adjoining areas. Adjoining areas include rooms and corridors surrounding the room as well as above and below the room.
b. A description of the security measures to be taken to prevent unauthorized access to the irradiator.
c. Verification that the floor of the proposed facility is rated to support the weight of the irradiator. Sufficient evidence may be obtained and submitted.
d. A description of the methods to be utilized in moving the irradiator.

2. Change of Custodian

If transfer of responsibility for the irradiator is contemplated, the new applicant must apply for authorization.

3. Removal

If removal of decommissioning of the irradiator is contemplated, contact the regulatory agency. The irradiator can only be transferred to another appropriately licensed institution or individual. In the event that the sealed source(s) are to be disposed, the manufacturer or others who are appropriately licensed must be involved in their removal and disposition.

4. Maintenance

a. In the event of malfunction of the irradiator, the custodian shall be responsible for notifying the internal regulatory authority (typically the Radiation Safety Manager).
b. Under no conditions shall irradiator operators or the custodian attempt to:
- Repair or modify source positioning mechanisms, shutters, interlocks, shielding or other systems designed to maintain the irradiator in a safe condition.
- Attempt to gain access to or remove the sealed source.
- Replace the source.
- These procedures may be performed only by the manufacturer or other duly licensed agent.

c. If maintenance of the above types is contemplated, the custodian shall be responsible for notifying the Radiation Safety Manager so that the necessary inspections and safety procedures can be performed.

I. OTHER SAFETY PROCEDURES

The Radiation Safety Manager will be responsible for ensuring that leak tests are performed. Personnel under direction of the Radiation Safety Manager will perform leak tests on the sealed sources at intervals not to exceed 6 months. Any leak test indicating

0.005 μCi or more of removable contamination shall result in the immediate removal from service of the irradiator. Notification will be made to the appropriate authorities as required by regulation. The performance of the leak tests shall be recorded in the Use Log.

The Radiation Safety Manager will be responsible to ensure routine compliance surveys are performed at least semi-annually, such as:

- Checking for proper operation of all interlocks on the irradiator.
- Measuring exposure rates at all accessible points around the irradiator using a portable ionization chamber, and ensuring that radiation levels are within regulatory limits.
- Checking for compliance with provisions of the irradiation operating procedures, including adherence to the proper training of users.
- Documenting completion of survey in the Use Log.

5. SEALED SOURCES

LEARNING OBJECTIVES:

L01 DEFINE the process for determining if a sealed source is accountable or exempt.

L02 STATE the frequency for performing an inventory and leak check for sealed sources.

L03 STATE the actions if a source listed on the inventory cannot be accounted for.

L04 STATE the wipe activity level at which action must be taken by the individual performing the leak check.

L05 IDENTIFY the type of hazard presented by sealed sources.

INTRODUCTION

What is a sealed source? A sealed source is a radioactive material that is contained in a sealed capsule, sealed between layers of nonradioactive material, or firmly fixed to a nonradioactive surface by electroplating or other means. The confining barrier prevents dispersion of the radioactive material under normal and most accidental conditions related to the use of the source. In a general laboratory a sealed source can be calibration sources, check sources, internal standards, plated sources or irradiators. They are generally gamma emitters. However, some plated sources are beta emitters such as ^{63}Ni used in gas chromatography.

The inventory and leak testing of radioactive sources is a federally regulated process. The process begins and the paper trail for the source starts when the source is requested for purchase. Once the source has been received and classified the source custodian will add the source to the inventory.

A. GENERAL HAZARD

Sealed sources are primarily an external hazard. They present an exposure potential to individuals close to the source. They are used in a variety of ways from gas chromatography to calibration sources. Sources are used to check portable survey meters, personnel survey devices (both portable and fixed), and counting instruments. These sources are used to verify that the instruments are operating properly.

They should always be handled as if they were contaminated materials (i.e. gloves, remote handling tools). There are four basic means of protection with sealed sources:

- **Time** The less the time the less the exposure.
- **Distance** The exposure rate is reduced by $1/D^2$ (point source).
- **Shielding** Absorption of the radiation will reduce the dose.
- **Source Reduction** The dose rate is directly proportional to the source activity.

B. SOURCE CLASSIFICATION

A sealed source is defined as radioactive material that is contained in a sealed capsule, sealed between layers of nonradioactive material, or firmly fixed to a non radioactive surface by electroplating or other means. The confining barrier prevents dispersion of the radioactive material under normal and most accidental conditions related to use of the source.

C. ACCOUNTABLE SOURCES

An accountable radioactive source is a sealed source with an activity level equal to or greater than values listed in Table 12 below:

1. Exempted Sources

An exempt source is a sealed source with a half-life of less than 30 days or an activity less than the sources for radionulcides listed in Table 12.

2. Inventory

Sealed sources must be inventoried on some routine frequency. Most facilities are required to perform the source inventory at least every 6 months. Larger sources and specific radioactive materials must be inventoried every 3 months.

3. Inventory Process

The inventory process not only determines if the source is in the proper location but verifies such things as:

a. Proper labeling and identification
b. Source isotope, activity, and date activity was determined

TABLE 12
Values for Exemption of Sealed Sources from Inventory

Less than 300 μCi

^{3}H	^{55}Fe	^{113}Cd	^{180}Ta
^{7}Be	^{59}Ni	^{115}In	^{181}W
^{14}C	^{63}Ni	^{123}Te	^{185}W
^{35}S	^{73}As	^{135}Cs	^{187}Re
^{41}Ca	^{79}Se	^{141}Ce	^{204}Tl
^{45}Ca	^{87}Rb	^{152}Gd	
^{49}V	^{99}Tc	^{157}Tb	
^{53}Mn	^{107}Pd	^{171}Tm	

Less than 30 μCi

^{36}Cl	^{105}Ag	^{145}Pm	^{175}Hf
^{40}K	^{114m}In	^{147}Pm	^{181}Hf
^{59}Fe	^{113}Sn	^{145}Sm	^{179}Ta
^{57}Co	^{119m}Sn	^{151}Sm	^{184}Re
^{75}Se	^{121m}Sn	^{149}Eu	^{186}Re
^{84}Rb	^{123}Sn	^{155}Eu	^{192}Ir
^{85}Sr	^{123m}Te	^{151}Gd	^{193}Pt
^{89}Sr	^{125m}Te	^{153}Gd	^{195}Au
^{91}Y	^{127m}Te	^{159}Dy	^{203}Hg
^{95}Zr	^{129m}Te	^{170}Tm	^{205}Pb
^{93m}Nb	^{125}I	^{169}Yb	^{235}Np
^{95}Nb	^{137}La	^{173}Lu	^{237}Pu
^{97m}Tc	^{139}Ce	^{174}Lu	
^{103}Ru	^{143}Pm	^{174m}Lu	

Less than 3 μCi

^{10}Be	^{93}Zr	^{121m}Te	^{166m}Ho
^{22}Na	^{94}Nb	^{129}I	^{176}Lu
^{26}Al	^{93}Mo	^{134}Cs	^{177m}Lu
^{32}Si	^{95m}Tc	^{137}Cs	^{172}Hf
^{46}Sc	^{97}Tc	^{133}Ba	^{182}Ta
^{44}Ti	^{98}Tc	^{144}Ce	^{184m}Re
^{54}Mn	^{106}Ru	^{144}Pm	^{185}Os
^{60}Fe	^{101}Rh	^{146}Pm	^{194}Os
^{56}Co	^{102}Rh	^{148m}Pm	^{192m}Ir
^{58}Co	^{102m}Rh	^{148}Eu	^{194m}Ir
^{60}Co	^{108m}Ag	^{150}Eu	^{194}Hg
^{65}Zn	^{110m}Ag	^{152}Eu	^{202}Pb
^{68}Ge	^{109}Cd	^{154}Eu	^{207}Bi
^{83}Rb	^{126}Sn	^{146}Gd	^{210m}Bi
^{88}Y	^{124}Sb	^{158}Tb	^{241}Cm
^{88}Zr	^{125}Sb	^{160}Tb	

Less than 0.3 μCi

^{90}Sr	^{178m}Hf	^{226}Ra	^{249}Bk
^{113m}Cd	^{182}Hf	^{228}Ra	^{254}Es
^{138}La	^{210}Po	^{241}Pu	

Less than 0.03 μCi

^{146}Sm	^{210}Pb	^{242}Cm	^{257}Fm
^{147}Sm	^{236}Np	^{248}Cf	^{258}Md

Less than 0.003 μCi

^{148}Gd	^{238}U	^{241}Am	^{247}Bk
^{228}Th	^{237}Np	^{242m}Am	^{249}Cf
^{230}Th	^{236}Pu	^{243}Am	^{250}Cf
^{232}U	^{238}Pu	^{243}Cm	^{251}Cf
^{233}U	^{239}Pu	^{244}Cm	^{252}Cf
^{234}U	^{240}Pu	^{245}Cm	^{254}Cf
^{235}U	^{242}Pu	^{246}Cm	
^{236}U	^{244}Pu	^{247}Cm	

Less than 0.0003 μCi

^{227}Ac	^{232}Th	^{248}Cm	^{250}Cm
^{229}Th	^{231}Pa		

D. LEAK TESTING OF SEALED SOURCES

Sources must also be leak tested to determine if the encapsulation is still intact. No sources are allowed to show leakage of more than 0.005 μCi. If the levels of removable contamination are not in excess of the required standards, the unit will be allowed to remain in service until the next leak test.

1. Precautions for Leak Testing

a. A sealed source shall not be removed from its container solely for the purpose of leak testing if it could produce a whole body dose rate of greater than 100 mrem/hr, unless the source can be removed remotely.
b. An exemption from leak testing may be granted if the source custodian prepares a letter describing the situation, and concurrence has been obtained from the regulatory agency. The source shall then be leak tested the next time it is removed from its container.
c. Sources in storage for periods longer than 6 months, need only to have their integrity determined when they are removed from storage and before being placed in use.

2. Leak Test Performance

To determine if the source is leaking, the surface of the source or the inner surface of the container must be smeared and counted on instruments capable of detecting activity below the established limit.

3. Determining the Wipe Activity
Count the source and container wipes to determine if the sealed source is leaking.

4. Report Unsatisfactory Leak Test Results.

E. CALCULATING THE SOURCE ACTIVITY OR DOSE RATE

The dose rate is determined to warn the user of the hazards associated with source. The dose rate as determined by an actual meter reading or estimation is recorded. The dose rate and activity calculations can be accomplished in one of several ways.

1. Calculating the dose rate: Use the 6CEN Rule.

The dose rate expected from the source at 1 foot may be approximated using the D=6CEN rule if the activity and isotope are known. This formula can only be used for gamma energies greater than 0.07 MeV, but less than 2 MeV.

D = (6) (C) (E) (N) where:

D	=	dose rate in R/hr at 1 foot
(6)	=	conversion constant (5.91 rounded up to 6)
(C)	=	activity of the source in Curies
(E)	=	total gamma energy (MeV)
(N)	=	gamma's per disintegrations

Example: A 100 µCi ^{137}Cs source equals what dose rate at 1 foot? The energy of ^{137}Cs gamma's is 0.662 MeV and is produced 85 percent of the time during decay.

D = (6) (C) (E) (N)

D = (6) (1 E-4) (0.662) (0.85)

D = 3.38 E-4 R/hr or 0.3 mR/hr at 1 foot.

The activity of the source can be determined using this formula if the dose rate at one foot is known and isotopic content of the sources is known:

$$C = \frac{D}{(6)(E)(N)}$$

Example: A ^{137}Cs source with a 1 foot dose rate of 1.5 mR/hr contains approximately how many Curies of activity?

$$C = \frac{1.53E\text{-}3}{(6)\,(0.662)\,(0.85)} = 4.44E\text{-}4 \text{ Ci}$$

2. Decay corrected activity method: To determine the current activity of a source, the following information must be known:

- The original source activity
- Source isotopic content
- Date the original activity was determined

Once all the information is known use the following formula to calculate the current source activity:

$$A = \frac{A_0}{2^n}$$

Where:	A_0	=	original activity
	A	=	activity left after n half lives
	n	=	elapsed time ($T_{1/2}$)
	elapsed time	=	time elapsed between the original source activity determination and the current date in the same units as the $T_{1/2}$
	$T_{1/2}$	=	half-life of isotope

Example: A 100 µCi ^{60}Co source was manufactured on 1/1/81, what will the source activity be as of 1/1/89? The $T_{1/2}$ for 60Co is 5.271 years.

A_0	=	100 µCi
A	=	?
n	=	8 years/5.271 years

$$A = \frac{100}{2^{1.52}} = 34.87 \ \mu\text{Ci}$$

The calculations must now be documented for each of the sources.

6. X RAY SOURCES

LEARNING OBJECTIVES:

L01 IDENTIFY the dose rates produced by various x ray producing equipment and the time required to sustain sever damage from these units.

L02 IDENTIFY which senses can or cannot detect an x ray beam.

L03 IDENTIFY three ways to reduce exposures to patients and the operator from medical x rays.

L04 LIST two short-term effects from very high exposures to x rays.

INTRODUCTION

This unit is designed to inform the worker of sources of radiation exposure from x ray sources. It will present methods used to control such exposures.

A. CHARACTERISTICS OF X RAYS

X rays are produced when a high speed electron is slowed down and/or stopped. The penetrating ability of x rays depends on their energy and the absorber. Higher energy x rays penetrate much further than low energy x rays.

Radiation safety concerns include:

- Sources of x rays from external hazards.
- Highly collimated and intense source of radiation emitted.
- X rays may scatter and not be where expected. X rays can turn corners.
- X rays are not detected by the five senses.
- X rays may be produced in machines designed for other purposes.

Analytical x ray machines may produce dose rates in excess of 100,000 rad/min. These present a significant hazard to the operator.

Details of incidents:

- Injury from placing fingers in sample chamber, most commonly from diffraction x ray systems
- Replacement of leaded glass with ordinary glass
- Improper survey for x ray leakage
- Working in enclosure with beam "ON" because of interlock bypass
- Hand in the beam area with the beam on

X rays are an external hazard. There are several primary means of protection.

Time

Distance

Shielding

X rays systems also present an electrical shock hazard due to the high voltage.

Most Radiation Safety Programs Include:

Engineered Controls - Interlocks, shields, mazes, barriers, shutters

Administrative Control - Training, procedures, manuals, signs, lights
Monitoring - Area, personnel, x ray safety box, radiation detectors, fail-safe light.
No safety device is to be bypassed or inactivated without written authorization. This includes:

- Interlocks
- Safety boxes
- Shutters
- Warning lights
- Monitoring equipment

B. X RAY SAFETY FOR MEDICAL PERSONNEL

Table 13 contains estimated patient doses obtained by being in the primary beam. The operator of medical systems should not be in the primary beam. Assuming that they are not and that the facility is properly designed, the operator should receive very little exposure, if any. These conditions may be different when handling animals in research environments.

TABLE 13
Active Marrow Dose Per Examination (mrem)

Skull	78
Chest	10
Thoracic spine	247
Lumbar/lumbosacral spine	400
Upper GI	535
Barium enema	875
Dental	9

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1. **Considerations for decreasing the dose from x rays to the patient and the operator:**
   a. There are three general technique factors which affect the dose:
   Time - Determines the total dose received
   Voltage - Determines the penetration of the x rays
   Current - Determines the dose rate
   b. Proper filtration removes the unwanted low-energy x rays from the primary beam. This is called hardening the beam.
   c. Proper collimation limits the beam to a useful area which should be as small an area as possible (of clinical interest). The intent is to keep the patient from being exposed to x rays which are not shown on the x ray film. It provides no useful benefit.

d. High speed image receptor provides the shortest time possible which will provide image quality desired for diagnosis. The film which responds faster, requires less radiation.
e. Patient screening will minimize exposures to specific audiences. Protection of the embryo/fetus is given special consideration.
f. Specialized shielding for sensitive organs like the lens of the eye, gonads and thyroid is used to minimize dose to these organs. The lens of the eye is of concern because the dose is accumulative. Gonads, bone marrow, and other organs with rapidly dividing cells are radiosensitive. These shields must be used properly to be effective.
g. Orientation of the beam should be directed to minimize exposure to everyone.
h. The maximum permissible x ray leakage is limited by federal standards.
I. Periodic checks are performed on the x ray system to ensure safety features are functional and provide the maximum protection to the patient and the operator.
j. Shielded enclosures are provided to minimize exposure to the operator.
k. Patients should be held only if available restraining devices are inadequate. If a patient is to be held, it is preferred that a relative hold the patient, not the operator. Law prohibits the x ray technician from holding the patient. The relative will only be performing this activity infrequently. An operator will be exposed to enough radiation (in surgery, fluoroscopy and while doing portable x rays) while performing routine duties. If an animal is the patient, consideration should be given to anesthesia.
l. A quality assurance program is implemented to ensure that the system (including the film development processor) is operating at its optimal performance. This will minimize retakes of the radiographs.
m. Technique factors are established for the procedure to be taken and adjusted for the x ray system.

2. Personnel monitoring and dose limits

Whole body monitors must be worn by everyone except the patient. The patient is receiving an intentional exposure. The monitors are worn outside of routine clothing between the collar and waist. The custom at most facilities is to wear them under any protective equipment such as lead aprons, although some facilities wear them over the equipment.

If procedures will involve high potential doses to the extremities, additional monitoring devices will be required, such as ring badges or eye monitors.

C. ANALYTICAL X RAY SYSTEMS

Two basic types of analytical x ray systems are recognized: Open beam and enclosed beam. In the enclosed beam system, as the name implies, the x ray beam path (both primary and diffracted beams) are completely enclosed and cannot be broken by any part of the body during normal operation.

Because it is much safer, an enclosed beam system should be selected over an open beam system whenever feasible. An open beam system is acceptable only if an enclosed beam system is impractical due to such operational requirements as:

- A need for frequent changes of attachments and configurations.
- A need for making adjustments with the x ray beam energized.
- Motion of specimen and detector over wide angular limits.
- Examination of large or bulky samples.

1. Common Features:

- A conspicuous fail-safe light must be installed near the x ray tube housing to indicate when x rays are on (or present).
- Every accessory to the equipment (e.g. powder diffraction camera) must include a beam stop.
- Shielding must be provided for tube housing leakage and scattered radiation.

2. Open Beam Only

- Each port of the x ray tube housing must be provided with a beam shutter.
- All shutters must be provided with a conspicuous "SHUTTER OPEN" indicator of fail-safe design.
- Whenever the accessory setup is not permanent (i.e. subject to change frequently or periodically as is the case with powder diffraction cameras), the beam shutter must be interlocked with every accessory apparatus coupling or collimator, such that the port will only be open when the collimator or coupling is in place.
- Shutters at unused ports should be secured to prevent casual opening.
- Exposure rates adjacent to the system must not exceed 2.5 mR/hr.

3. Enclosed Beam Only

- The sample chamber door must be interlocked with the x ray tube high-voltage supply or a shutter in the primary beam so that no x ray beam can enter the sample chamber while it is open.
- Radiation leakage measured at 5 cm from any outer surface must not exceed 0.5 mR/hr during normal operation.

D. BASIC X RAY SAFETY REQUIREMENTS

1. Shielding/Barriers

- X ray machines shall be designed with shielding or barriers (or both) so that personnel do not exceed regulatory dose limits.
- Dose equivalent rates around analytical x ray machines should not exceed 0.25 mrem/hr.

- All beams with exposure rates that exceed 0.1 R/hr shall be completely enclosed.
- All ports of an analytical x ray machine shall be covered with a radiation shield when not in use.

2. Interlocks

- Protective enclosures that are used to prevent access to x ray beams shall be interlocked during normal operations.
- X ray safety interlocks shall be of a fail-safe design.
- Enclosures for flash x ray machines shall be interlocked to prevent access or entry while the high-voltage system is charged or is being charged. This system shall be designed so that the high voltage system is grounded automatically if an interlock is opened.
- Rooms or facilities used as x ray enclosures shall have emergency shutdown ("run-safe") switches. These switches shall be labeled clearly, and their number and placement shall be reviewed by Radiation Safety personnel.

3. Warning Signs

- A CAUTION sign shall be posted at the room entrances or in the facility where x ray machines are operated to indicate that high levels of radiation can be produced by equipment in this area.
- A CAUTION sign shall be posted at the x ray machine enclosure or in the immediate area of the machine to indicate that high levels of radiation can be produced by the equipment in this enclosure.
- An approved operating procedure should be posted on or next to all x ray machines to indicate the maximum unshielded dose rate and maximum operating parameters at which the machine is approved to operate.

4. Key Control

Machines with key-controlled consoles shall have the key removed and secured when the machine is left unattended.

5. X Ray Surveys

- The appropriate x ray survey/monitoring instruments shall be available to survey the x ray machine.
- Before and after each use, x ray survey instruments should be checked to ensure that they operate properly. Check sources or field-test jugs should be used to check the instruments.
- The Radiation Safety personnel and/or the responsible individual (or a designated qualified operator) shall perform radiation surveys every six months. These surveys shall cover all accessible areas of the x ray machine, including the control panel and all used and unused ports. The responsible person shall document the survey results and maintain one copy on file in the log.

- A radiation survey shall be performed by Radiation Safety personnel and the responsible person (or a designated qualified operator) following modifications that may affect x ray production, shielding, or safety (e.g. higher tube current, new machine location, or different or nonstandard accessories).

6. **Interlock Checks**

- Interlocks shall be checked at least once every six months to ensure that they function properly. A qualified operator and Radiation Safety personnel or facility electronics personnel (or both) shall perform these checks in accordance with written interlock check procedures. The responsible individual shall keep two copies of the interlock checks and the check procedures, one on file and another in the log next to the x ray machine.
- Interlocks that malfunction shall be repaired and re-tested by a responsible individual before the machine can be operated.

7. **Personnel Monitoring**

- All personnel operating analytical x ray machines shall be on a monthly monitoring program
- Finger rings. Extremity dosimetry (e.g. finger rings) should be used for the following operations if they are performed while the x ray machine is energized:
    - Sample changing
    - Beam alignment
    - Target changing
    - Open beam operations
    - Interlock bypass operations

D. Module D - Practical Exercises

Module D contains eight (8) generic practical exercises that provides hands-on experiences for the worker. The module is designed to enhance the training contained in the entire Study Guide. Each section is designed to be an independent practical exercise. It will provide concepts and ideas to the instructor for additional practical exercises. The instructor is encouraged to select the section which will provide the most benefit for the worker.

Practical exercises focus primarily on the kinesthetic learning skills. The student is tasked to transfer the knowledge learned from the classroom to the job. This learning skill will strengthen the knowledge gained. The intent is to allow the student to develop the laboratory skills which will minimize risk in the laboratory and minimize regulatory impact. Know what the student should be able to perform. Compare the training to the objectives. If more objectives are needed, add them to the program.

Such exercises are innovative in nature. The exercises suggested are intended to give the instructor ideas and concepts which they can use to assist the students in learning. These exercises are intended to stimulate ideas within the training group. It is suggested that the instructor review the areas of concern or a standard which the student should be trained to, and incorporate these into the exercises.

Practical factors evaluation is used to demonstrate satisfactory completion of skills learned in the classroom and on the job. It is imperative that the instructor know what the student must be able to demonstrate as a minimum. The student should receive a pass or fail evaluation. A satisfactory score must be attained for each factor evaluated. The student will often have much experience which can aid in future exercises. This information should be retained to increase the quality of the training in the future.

1. SET UP A WORK STATION IN A LABORATORY

LEARNING OBJECTIVES:

LO1 IDENTIFY AND EXPLAIN if the facility is appropriate to use unsealed radioactive material (specific to the radionuclide of interest).

LO2 DEMONSTRATE how to set up a counter top, fume hood, or refrigerator to allow the use and/or storage of radioactive materials (sealed or unsealed).

LO3 ESTABLISH a work station which will minimize contamination from spreading.

INTRODUCTION

If the workstation is set up correctly, it will minimize exposures, contamination and cost, see figure D.1.1. The work station should not present an exposure potential to another individual within the laboratory or to the adjacent rooms and spaces, see figure D.1.2.

FIGURE D.1.1 - WORKPLACE SETUP

Your workstation should not present a
hazard to others!

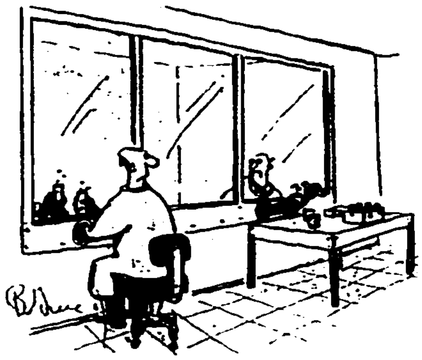

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FIGURE D.1.2 - CONFLICTING WORKSTATIONS

INSTRUCTOR PREPARATION

Identify a laboratory space to use for the exercise. The space should be vacant if possible but not necessarily empty. Collect the materials needed for the student to establish a work station correctly and according to facility guidelines or industry practice.

Examples:
absorbent paper
waste containers
shielding materials
survey forms
remote handling tools
disposable gloves and other PPE
radiation tape
secondary containers
pipettes
survey instrument
absorbents

Identify which radioisotopes the student must prepare for in their work. This should be the radioisotope should be the basis of the evaluation.

A. STUDENT EVALUATION - CRITERION ONE

The student should be able to identify a location within a laboratory where the use of radioactive material of interest is appropriate. The student should be able to explain why or why not the material may be used at a specific location. Each should be able to explain the advantages and disadvantages of a location.

B. STUDENT EVALUATION CRITERION TWO

Given the material resources, the student should be able to physically set up the area where the radioactive materials are handled. As an example, each should be able to place the absorbent paper (absorbent side up) at the preferred location using the radiation tape to identify the work station. The appropriate materials should be in place (ergonomically) such that the worker could respond to small emergencies.

C. STUDENT EVALUATION - CRITERION THREE

The student should be able to explain techniques to be used which will minimize the spread of contamination. An example may be to identify a small area in which contaminated equipment could be placed and how pipette tips may be placed in these locations. A planned location allows for improved control. The instructor should solicit input from the student realizing that the new radiation workers may need coaching.

Good housekeeping is always the first necessary step to contamination control. A cluttered work area which becomes contaminated will require extensive efforts to decontaminate. Regulators often survey cluttered areas for potential contamination when performing inspections.

If a refrigerator is used to store radioactive material, the appropriate label should be affixed to the door. The student should ensure that no food or drinks are contained inside. Consideration may be needed for explosion proof conditions, based upon the chemicals being used.

2. IDENTIFY THE APPROPRIATE POSTING OR LABELING

LEARNING OBJECTIVES:

LO1 CHOOSE which locations workers may or may not enter based upon laboratory posting and the level of training they have received.

LO2 LABEL various containers with the appropriate information based upon the information provided by the instructor.

LO3 DEMONSTRATE what happens when posting and labels are disregarded.

INTRODUCTION

Standard operating procedures are used to establish radiological control for areas where radiation sources are handled or stored. They serve to inform workers of each area's radiological conditions and entry requirements into the areas, special and general radioisotope handling instructions. They also provide a means to relate radiation doses received by workers due to specific work activities.

INSTRUCTOR PREPARATION

Prepare a location with several signs to identify the type of control imposed for the room. Also prepare several containers with (simulated) radioactive materials and some without. Identify the specific radioisotope(s) of interest to the student along with specific quantities.

A. STUDENT EVALUATION - CRITERION ONE

Workers are authorized entry into specific locations based upon their training. With various locations in a facility posted (differently), see figure D.2.1, allow students to choose which location they can or cannot enter. Have them actually enter the locations they have chosen. Upon entry, explain why they were correct or incorrect.

FIGURE D.2.1 - LABELING

B. STUDENT EVALUATION - CRITERION TWO

Have each student label various containers with the appropriate information which is required by facility guidelines or regulations. Not all the containers need to be labeled with radiation symbols. Have each student identify when a container should be labeled.

C. STUDENT EVALUATION - CRITERION THREE

Using a black light or some other method to identify a substance which has relocated by casual handling, have the student observe the spread of contamination. This is much more efficient when working with dry powders. Which are often used in general laboratories.

3. SELECT THE REQUIRED DOSIMETER(S), INSTRUMENTS, OR PROTECTIVE CLOTHING

LEARNING OBJECTIVES:

LO1 SELECT the appropriate dosimeters monitoring methods to be used for a specific radiation hazard.

LO2 SELECT the appropriate portable survey meters to be used for a specific radiation source.

LO3 SELECT the appropriate protective equipment for working with specific radiation sources.

INTRODUCTION

To assess a radiation worker's potential external and internal exposure to ionizing radiation, special types of monitoring are employed. The radiation worker should understand each method and device employed.

Using the appropriate survey instrument to monitor potential exposures or contamination is critical to a safe work environment. Often a worker is using an instrument which is not useful for what is being monitored. Each worker must have a basic understanding of the selection process.

INSTRUCTOR PREPARATION

Given a specific type of radiation hazard (i.e. sealed source, unsealed radionuclide, x ray generating device) which would be expected for a specific worker, students should know which device and/or monitoring system to use to monitor their exposure (i.e. whole body, extremity, internal).

Identify the specific type of radiation or radioactive material which the worker is expected to use. Place several types of survey instruments on display. Fixed monitoring systems (i.e. liquid scintillation counter) may also be used.

Prepare a display of several types of personal protective equipment. This would include clothing, lead aprons, respirators, disposable gloves, coveralls and laboratory coats, see figure D.3.1. Include as many of the critical items as necessary for the students work environment.

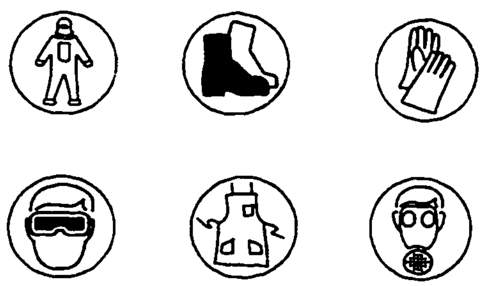

FIGURE D.3.1 - PERSONAL PROTECTIVE CLOTHING

A. STUDENT EVALUATION - CRITERION ONE

Have the student select the type of monitoring systems and/or devices from those displayed on a table top. The student should also show how to wear any devices. The monitoring system and/or devices should be what the worker would be expected to use based upon potential exposures.

B. STUDENT EVALUATION - CRITERION TWO

Have the students select the monitoring system which is needed for their each environment. They should also have some understanding of whether the monitoring system is for exposure or contamination monitoring, and what are the units of measure.

C. STUDENT EVALUATION - CRITERION THREE

From a large selection the student should be able to correctly select those personal protective equipment items needed for their work environment.

4. DEMONSTRATE THE USE OF SURVEY INSTRUMENTS

LEARNING OBJECTIVES:

LO1 DEMONSTRATE the various operational checks with a survey instrument and measure background.

LO2 DEMONSTRATE how to identify radiation sources from nonradiation sources.

LO3 DEMONSTRATE how to perform a personnel survey and an area survey.

INTRODUCTION

The worker should know how to determine if the instrument is operational and recognize if the instrument is calibrated. These are part of the operational checks. Once a survey instrument has be selected, the worker should demonstrate how to use the instrument to identify radiation sources. Finally the worker must be able to demonstrate the basic techniques of performing an area or personnel survey.

INSTRUCTOR PREPARATION

Prepare an area with several survey instruments. At least one instrument should have problems (i.e. no battery, out of calibration, the audio does not function). At another location set up another table with various items to be surveyed. A few of these should be radioactive such that the worker may identify them from the non radioactive items. Use commonly found items such as a plate (some Fiestaware contain radioactive material on the finish) or a rock. In a separate room, place specific radiation sources in key locations. Have the worker work from a sketch of the room to identify where the sources are located. The reading of each source should be noted on the sketch.

A. STUDENT EVALUATION - CRITERION ONE

The student should:

- Verify the calibration of the instrument (by reviewing the calibration sticker)
- Turn on the instrument
- Check if the battery is operational
- Turn on the audio (if any)
- Compare the instrument against a source check
- Measure the background

B. STUDENT EVALUATION - CRITERION TWO

The student should select which sources are radioactive from a group of sources on a countertop. If possible, each student should be able to differentiate between a gamma and beta source.

C. STUDENT EVALUATION - CRITERION THREE

The student should be able to:

- Perform a routine area survey
- Enter a laboratory with a sketch and locate several radiation sources with a portable survey meters
- Record the information normally required to be recorded for such surveys (i.e. background, date, location, reading)

5. DONN/DOFF PROTECTIVE CLOTHING AND DOSIMETER(S)

LEARNING OBJECTIVES:

LO1 DEMONSTRATE the donning of personal protective equipment.
LO2 DEMONSTRATE the doffing of personal protective equipment.
LO3 DEMONSTRATE how and where to wear specific dosimeters.

INTRODUCTION

The radiation worker should know how to select and use various personal protective equipment which may be required for each work location. For protective clothing, all workers should know how to put it on and remove it (don and doff) without damaging the clothing or contaminating themselves. Monitoring devices should also be worn appropriately.

INSTRUCTOR PREPARATION

Provide a display of personnel protective equipment which includes the equipment which workers would be required to use in their work location. Include several pieces of equipment which have problems such as tears or gloves too thick or thin. Also provide several monitoring devices. These can all be displayed on a counter top.

A. STUDENT EVALUATION - CRITERION ONE

With the knowledge of the specific hazards they must work in, students should be able to select the appropriate personal protective equipment (i.e. gloves, lead apron, respirator, laboratory coat, shields). Once they have selected the equipment, they should demonstrate how to put on the equipment correctly. An example would include putting on a laboratory coat and buttoning up the coat. They could also check for tears.

B. STUDENT EVALUATION - CRITERION TWO

Student should also be able to remove the personal protective equipment (assuming that they are contaminated) in a manner which would minimize the spread of contamination to themselves or others. Control of the contaminated equipment should be a part of the exercise. Each student should be able to explain what to do with contaminated equipment.

C. STUDENT EVALUATION - CRITERION THREE

Monitoring devices should be worn correctly by the student. If a whole body monitor is being worn, it should be worn on the outside of routine laboratory clothing between the collar and waist. Ring badges should be worn under gloves on the hand which is expected to receive the greatest exposure.

6. ENTER A SIMULATED AREA AND DEMONSTRATE ALARA TECHNIQUES

LEARNING OBJECTIVES:

LO1 DEMONSTRATE how to use specific radiation handling equipment.

LO2 DEMONSTRATE how to handle high specific activity sources.

LO3 CHOOSE the appropriate shielding for a specific radiation source.

INTRODUCTION

A radiation worker should know how to use equipment which has been designed for protection. Each should be able to enter an area and know how to use the basic means of protection (i.e. time, distance, shielding, contamination control). Each worker should also know how to use remote handling devices and when to use them. Each should also be able to select the appropriate shielding device for the radiation sources worked with.

INSTRUCTOR PREPARATION

Identify and select several types of equipment used for the laboratory operation which the worker must employ in a work environment. This should include remote handling devices (if any), secondary containers, and shielding equipment.

A. STUDENT EVALUATION - CRITERION ONE

The student should select the appropriate equipment from a large selection of equipment and demonstrate how to use it. The equipment used should be the same type of equipment which found within a work environment.

B. STUDENT EVALUATION - CRITERION TWO

The student should be able to enter a laboratory which has already been set up and perform a specific or general task (i.e., remove waste or move a source from one location to another). The sources used do not have to be radioactive. Students should be able to utilize the appropriate means of protection (i.e. time, distance, shielding, contamination control). Knowledge of what the sources are and the expected exposure rates for the exercise should also be demonstrated.

C. STUDENT EVALUATION - CRITERION THREE

The student should be able to select the appropriate shielding (from a selection of possible shields) for the radiation source being evaluated, and know where to place the shield to minimize exposures. An example would be to provide shielding on an island type counter where ^{32}P is to be used. The student must put the appropriate shielding in place to protect the individual on the other side of the counter. This is often missed.

7. MONITOR FOR CONTAMINATION AND RECORD THE APPROPRIATE INFORMATION

LEARNING OBJECTIVES:

LO1 DEMONSTRATE how to perform an area survey for contamination, and record the information.

LO2 DEMONSTRATE how to perform an area closet survey.

LO3 DEMONSTRATE how to perform routine monitoring in a laboratory.

INTRODUCTION

Contamination monitoring is one of the most important aspects of controlling contamination in the laboratory. Using the proper monitoring methods will help ensure a safe working environment. It is important for all radiation workers to identify sources of contamination as well as to use appropriate contamination prevention methods to minimize exposures to personnel and the environment.

INSTRUCTOR PREPARATION

Radiation workers should understand how to perform routine surveys which are used to support the laboratory. They should understand and demonstrate how to follow the facility guidelines or survey instructions. Provide each worker with a sample work sheet to record survey information and a sketch of a laboratory which is to be surveyed. Each person should be evaluated against one or more of monitoring requirements (i.e., routine monitoring for the type of laboratory, a close-out survey of a refrigerator or other equipment, a contamination survey of an individual).

A. STUDENT EVALUATION - CRITERION ONE

Select another individual and have the student survey the individual for contamination. The student should know the direction of the survey and how long a survey should take. The location of the individual being surveyed should be controlled to minimize the spread of contamination (i.e. control line). Appropriate information should also be recorded on a work sheet.

B. STUDENT EVALUATION - CRITERION TWO

Select a piece of equipment and have the student perform a close-out survey. A closet survey is more detailed oriented. Students should be able to identify if the equipment can be released to a nonradiation area. They should also record the appropriate information on a work sheet.

C. STUDENT EVALUATION - CRITERION THREE

The student should be able to perform a routine survey and record the appropriate information on the standard survey forms used by the facility.

8. RESPOND TO AN EMERGENCY SITUATION

LEARNING OBJECTIVES:

LO1 DEMONSTRATE what actions to take during a minor or major spill of radioactive material.

LO2 DEMONSTRATE what actions to take if required shielding fails.

LO3 DEMONSTRATE what to do if an individual is injured and contaminated in the laboratory.

INTRODUCTION

Various radiological monitoring systems are used to warn personnel if abnormal radiological conditions exist. It is important that radiation workers become familiar with these alarms to prevent unnecessary exposure to radiation and contamination. They should know what to do if an individual is injured and contaminated.

INSTRUCTOR PREPARATION

Set up an emergency situation most likely to occur in a laboratory (i.e. a minor spill). An additional condition which may be included would be to have an individual simulate an injured worker. The student should also demonstrate how to use the emergency notification system for the facility. Provide a shielding device which can be made to fail (i.e. fall down).

A. STUDENT EVALUATION - CRITERION ONE

The student should respond and begin working with the clean up of a minor spill. He/she should demonstrate how to clean up a wet spill (i.e. from the top to the bottom, from the outside to the inside). Have the student explain how to use specific absorbents. He/she should also know if the spill will present an exposure potential to others in the laboratory and what action to take.

B. STUDENT EVALUATION - CRITERION TWO

The student should demonstrate the appropriate action to take if a shielding fails. Have the student take the action to include notifying others in the laboratory and the emergency response systems (if appropriate for the situation).

C. STUDENT EVALUATION - CRITERION THREE

Students should demonstrate how to care for an individual who has been injured in the laboratory. They should be able to recognize if they should disregard any possible contamination concerns. This would imply that the students understand what others are doing in the laboratory and what the hazards are. They should also demonstrate how to respond to care for an injured worker who is also contaminated. Another condition would be for a worker to decontaminate another worker (i.e. assist in the washing of a hand which was contaminated and monitor for results).

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