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DOE-HDBK-1130-2008
Appendix B
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DOE HANDBOOK

RADIOLOGICAL WORKER TRAINING

RADIOLOGICAL CONTAMINATION CONTROL TRAINING FOR LABORATORY RESEARCH

U.S. Department of Energy **FSC 6910**
Washington, D.C. 20585

This document is available on the
Department of Energy
Technical Standards Program
Web Site at
http://www.hss.energy.gov/nuclearsafety/techstds/

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Radiological Worker Training Appendix B
Radiological Contamination Control for Laboratory Research
DOE-HDBK-1130-2008

Foreword

This Handbook describes a recommended implementation process for core training as outlined in the *DOE Radiological Control Standard (RCS)*. The Handbook is to assist those individuals, both within the Department of Energy (DOE) and Managing and Operating (M&O) contractors, identified as having responsibility for implementing the core training recommended by the *RCS*. This training may also be given to laboratory researchers to assist in meeting their job-specific training requirements of 10 CFR 835.

This Handbook contains recommended training materials consistent with other DOE standardized core radiological training material. The training material consists of the following documents:

> **Program Management Guide** - This document contains detailed information on how to use the Handbook material.
>
> **Instructor's Guide** - This document contains a lesson plan for instructor use, including notation of key points for inclusion of facility-specific information.
>
> **Student's Guide** - This document contains student handout material and also should be augmented by facility-specific information.

This Handbook was produced in Microsoft Word. Copies of this Handbook may be obtained from the DOE Radiation Safety Training Home Page Internet site (http://www.hss.energy.gov/HealthSafety/WSHP/radiation/RST/rstmater.htm) or the DOE Technical Standards Program Internet site (http://www.hss.energy.gov/NuclearSafety/techstds/standard/standard.html).

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(Part 1 of 3)

Radiological Worker Training
Radiological Contamination Control Training for Laboratory Research

Program Management Guide

Office of Health, Safety & Security
U.S. Department of Energy

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Table of Contents

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Program Management

Introduction

Purpose and Scope

This program management guide describes the proper implementation standard for core training as outlined in the *DOE Radiological Control (RadCon) Standard*. The guide is to assist those individuals, both within the Department of Energy (DOE) and Managing and Operating (M&O) contractors, identified as having responsibility for implementing the core training recommended by the RadCon Standard.

Management Guide Content

The management guide is divided into the following sections:

- Introduction
- Instructional Materials Development
- Training Program Standards and Policies
- Course-Specific Information

Core Training Goal

The goal of the core training program is to provide a standardized, baseline knowledge for those individuals completing the core training. Standardization of the knowledge provides personnel with the information necessary to perform their assigned duties at a predetermined level of expertise. Implementing a core training program ensures consistent and appropriate training of personnel.

Organizational Relationships and Reporting Structure

The DOE Office of Worker Safety and Health Policy (HS-11) is responsible for approving and maintaining the standardized core training materials associated with the core training program.

Continued on Next Page

Introduction (continued)

Organizational Relationships and Reporting Structure (continued)

The establishment of a comprehensive and effective contractor site radiological control training program is the responsibility of line management and their subordinates. The training function can be performed by a separate training organization, but the responsibility for quality and effectiveness rests with the line management.

Instructional Materials Development Next

Instructional Materials Development (continued)

Target Audience

Course instructional materials were developed for specific employees who are responsible for knowing or using the knowledge or skills for each course. With this in mind, the participant should never ask the question, "Why do I need to learn this?" However, this question is often asked when the participant cannot apply the content of the program. It is the responsibility of management to select and send workers to training who need the content of the program. When workers can benefit from the course, they can be motivated to learn the content and apply it on their jobs. Care should be taken to read the course descriptions along with the information about who should attend. Participants and DOE facilities alike will not benefit from workers attending training programs unsuitable for their needs.

Prerequisites

A background and foundation of knowledge facilitates the trainee in learning new knowledge or skills. It is much easier to learn new material if it can be connected or associated to what was previously learned or experienced. Curriculum developers who have been involved in preparing instructional materials for the core training know this and have established what is referred to as "prerequisites" for each course.

Certain competencies or experiences of participants were also identified as necessary prior to participants attending a course. Without these competencies or experiences, the participants would be at a great disadvantage and could be easily discouraged and possibly fail the course. It is not fair to the other participants, the unprepared participant, and the instructor to have this misunderstanding.

Continued on Next Page

Instructional Materials Development (continued)

Training Materials

Training materials for the core program consists of lesson plans, study guides, training aids, handouts, and in some cases, video. Overhead transparencies are sometimes provided in support of the core training content and may be substituted with updated, facility specific, or other information or material.

Supplemental material and training aids may be developed to address facility-specific radiological concerns and to suit individual training styles. References are cited in each lesson plan and may be used as a resource in preparing facility-specific information and training aids.

Each site is responsible for establishing a method to differentiate the facility-specific information from the standardized core lesson plan material. When additional or facility-specific information is added to the text of the core lesson plan material, a method should be used to differentiate site information from core material.

Training Delivery

Sites are encouraged to expand per provisions in the RadCon Standard and enhance the training materials through advanced training technologies. Computer-based training and multimedia are just a sample of such technologies.

Exemptions

Qualified personnel can be exempted from training if they have satisfactorily completed training programs (e.g., facility, college or university, military, or vendor programs) comparable in instructional objectives, content, and performance criteria, and have demonstrated this by the successful completion of an exam. The individual making the determination of comparability should be a subject matter expert in the course topic. Documentation of the applicable and exempted portions of training should be maintained.

Training Program Standards and Policies Next

Training Program Standards and Policies

Qualification of Instructors

The technical instructor plays a key role in the safe and efficient operation of DOE facilities. Workers must be well qualified and have a thorough understanding of the facility's operation, such as processing, handling, and storage of materials, and maintenance of equipment. Workers must know how to correctly perform their duties and why they are doing them. They must know how their actions influence other worker's responsibilities. Because workers' actions are so critical to their own safety and the safety of others, their trainers must be of the highest caliber. The technical instructor must understand thoroughly all aspects of the subjects being taught and the relationship of the subject content to the total facility. Additionally, the instructor must have the skills and knowledge to employ the instructional methods and techniques that will enhance learning and successful job performance. While the required technical and instructional qualifications are listed separately, it is the combination of these two factors that produces a qualified technical instructor.

The qualifications are based on the best industry practices that employ performance-based instruction and quality assurances. These qualifications are not intended to be restrictive, but to help ensure that workers receive the highest quality training possible. This is only possible when technical instructors possess the technical competence and instructional skills to perform assigned instructional duties in a manner that promotes safe and reliable DOE facility operations.

Technical Qualifications

Instructors must possess technical competence (theoretical and practical knowledge along with work experience) in the subject

Continued on Next Page

Technical Qualifications (continued)

areas in which they conduct training. The foundation for determining the instructor's technical qualifications are based on two factors:

- The trainees being instructed.
- The subject being presented.

The following is an example of a target audience, subject to be taught, and instructor technical qualifications.

TARGET AUDIENCE	SUBJECT BEING TAUGHT	TECHNICAL QUALIFICATION
Laboratory Researchers	Contamination Control	Demonstrated knowledge and skills in radiation protection, above the level to be achieved by the trainees, as evidenced by previous training/education and through job performance, AND Completion of all qualification requirements for the senior-level radiation protection technician position at the trainees’ facility or a similar facility

Methods for verifying the appropriate level of technical competence may include the review of prior training and education, observation, and evaluation of recent related job performance, and oral or written examination. Other factors that may be appropriate consideration include DOE, NRC, or other government license or certification, vendor or facility certification, and most importantly job experience.

Continued on Next Page

Training Program Standards and Policies (continued)

Technical Qualifications (continued)

To maintain technical competence, a technical instructor should continue to perform satisfactorily on the job and participate in continuing technical training.

Instructional Capability and Qualifications

Qualifications of instructional capability should be based on demonstrated performance of the instructional tasks for the specific course requirements and the instructor's position. Successful completion of instructor training and education programs, as well as an evaluation of on-the-job performance, is necessary for verification of instructional capability. Instructional capability qualification should be granted as the successful completion of an approved professional development program for training instructors. The program should contain theory and practice of instructional skills and techniques; adult learning; and planning, conducting, and evaluating classroom, simulator, laboratory, and on-the-job training activities.

Illustrated talks, demonstrations, discussions, role playing, case studies, coaching, and individual projects and presentations should be used as the principal instructional methods for presenting the instructional training program. Each instructional method should incorporate the applicable performance-based principles and practices. Every effort should be made to apply the content to actual on-the-job experience or to simulate the content in the classroom/laboratory. The appropriate methodology required to present the instructional content will indicate a required level of instructional qualification and skill.

Current instructors' training, education, and job performance should be reviewed to determine their training needs for particular courses.

Continued on Next Page

Instructional Capability and Qualifications (continued)

Based on this review, management may provide exemptions based on demonstrated proficiency in performing technical instructor's tasks

Through training or experience, technical instructors should be able to: *

- Review instructional materials and modify to fully meet the needs of the training group.
- Arrange the training facility (classroom/laboratory or other instructional setting) to meet the requirements for the training sessions.
- Effectively communicate, verbally and non-verbally, lessons to enhance learning.
- Invoke student interaction through questions and student activity.
- Respond to students' questions.
- Provide positive feedback to students.
- Use appropriate instructional materials and visual aids to meet the lesson objectives.
- Administer performance and written tests.
- Ensure evaluation materials and class rosters are maintained and forwarded to the appropriate administrative personnel.
- Evaluate training program effectiveness.
- Modify training materials based on evaluation of training program.

*Stein, F. *Instructor Competencies: The Standards.* International Board of Standards for Training, Performance and Instruction; 1992.

Continued on Next Page

Selection of Instructors

Selection of instructors should be based on the technical and instructional qualifications specified in the "Course-Specific Information" section of this guide. In addition to technical and instructional qualifications, oral and written communication skills, and interpersonal skills, should be included in the process of selecting and approving instructors.

Since selection of instructors is an important task, those who share in the responsibility for ensuring program effectiveness should:

- Interview possible instructors to ensure they understand the importance of the roles and responsibilities of technical instructors and are willing to accept and fulfill their responsibilities in a professional manner.
- Maintain records of previous training, education, and work experience.

Procedures for program evaluation will include documentation of providing qualified instructors for generic and facility-specific training programs.

Continued on Next Page

Test Administration A test bank of questions for each course that has an exam should be developed and content validated. As the test banks are used, statistical validation of the test bank should be performed to fully refine the questions and make the tests as effective as possible. The questions contained in the test bank are linked directly to the objectives for each course. In this way, trainee weaknesses can be readily identified and remedial procedures can be put into place. The test outcomes can also be used to document competence and the acquisition of knowledge.

The test banks should also be used by the instructors to identify possible weaknesses in the instruction. If numerous trainees fail to correctly answer a valid set of questions for an objective, the instruction for that objective needs to be reviewed for deficiencies.

Written examinations may be used to demonstrate satisfactory completion of theoretical classroom instruction. The following are some recommended minimal requirements for the test banks and tests:

- Tests are randomly generated from the test bank.
- Tests items represent all objectives in the course.
- All test bank items are content validated by a subject matter expert.
- Test banks are secured and are not released either before or after the test is administered.
- Trainees should receive feedback on their test performance.
- For the first administrations of tests, a minimum of 80% should be required for a passing score. As statistical analysis of test results is performed, a more accurate percentage for a passing score may be identified.

Continued on Next Page

Test Administration (continued)

Test administration is critical in accurately assessing the trainee's acquisition of knowledge being tested. The following rules should be adhered to:

- Tests should be announced at the beginning of the training sessions.
- Instructors should monitor trainees during completion of tests.
- All tests and answers should be collected at the conclusion of each test.
- No notes can be made by trainees concerning the test items.
- Effort should be made to eliminate all noise during the test
- No talking (aside from questions) should be allowed.
- Answers to questions during a test should be provided, but answers to test items should not be provided or alluded to.
- Where possible, multiple versions of each test should be produced from the test bank for each test administration.
- After test completion, trainees may turn in their materials and leave the room while other trainees complete their tests.
- Trainee scores on the tests should be held as confidential. No other person should have access to results other than the trainee and test administrator.

Continued on Next Page

Program Management

Training Program Standards and Policies (continued)

Program Records and Administration	Training records and documentation shall meet the requirements of 10 CFR 835.704.
Training Program Development/Change Requests	All requests for program changes and revisions should be submitted in accordance with the DOE Technical Standards Program.
Audits (Internal and External)	Internal verification of training effectiveness should be accomplished through senior instructor or supervisor observation of practical applications and discussions of course material. All results should be documented and maintained by the organization responsible for Radiological Control training. The core training program materials and processes should be evaluated on a periodic basis by DOE-HQ. The evaluation should include a comparison of program elements with applicable industry standards and requirements.
Evaluating Training Program Effectiveness	Verification of the effectiveness of Radiological Control training should be accomplished per DOE-HDBK-1130-2008, “Radiological Worker Training.”

Course-Specific Information Next

Program Management

Course-Specific Information

Purpose	This section of the program management guide is to assist those individuals assigned responsibility for implementing the *Radiological Contamination Control Training for Laboratory Research*. Standardized implementation of this training ensures consistent and appropriate training for all personnel.
Course Goal	Upon completion of this training, the participant will understand the basic radiological contamination control measures for working in a laboratory, such as a biomedical research laboratory.
Target Audience	Individuals who have assigned duties as laboratory researchers.
Course Description	This course illustrates and reinforces the skills and knowledge needed to assist personnel with radiological controls for laboratory research facilities.
Prerequisites	This training material is designed to augment the DOE Radiological Worker core training.
Length	2 - 8 hours (depending on facility-specific information and incorporation of practical exercises.)
Test Bank	Radiological Worker (DOE-HDBK-1130-2008).
Retraining	Requalification same as radiological worker.

Continued on Next Page

Instructor Qualifications

Instructors of this course have a major role in making it successful and meeting the specified objectives. Instructors must have related experience and be technically competent. In this course it is imperative that the instructor have the background and experience of working in biomedical research facilities. Instructors must be able to relate their own work experience to the workers in biomedical research facilities. Instructors must be able to answer specific questions and use a variety of instructional material to meet the objectives.

Education:
Minimum of B.S. degree in Health Physics or related discipline is preferred.

Certification:
Certification by American Board of Health Physics (ABHP) or National Registry of Radiation Protection Technologists (NRRPT) preferred.

Experience:
At least five years of applied radiological protection experience in an operating radiological facility including experience in radiological protection at biomedical research facility or equivalent is preferred. The area of experience should include:

- Radiological controls associated with biomedical research facilities.
- Conducting surveys and monitoring at biomedical research facilities.

Intimate knowledge of Federal regulations and guidance, and best nuclear industry practices, pertaining to radiological protection.

Continued on Next Page

Materials Checklist

The following checklist should be used to ensure all training materials are available. All materials are provided in Word format.

- Program Management Guide.
- Instructor's Guide.
- Student's Guide.

Equipment Checklist

The following checklist should be used before training is provided to ensure equipment is available and working.

- Overhead projector.
- Screen.
- Flip chart.
- Markers.
- Facility-specific monitoring equipment (as appropriate).

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Program Management

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(Part 2 of 3)

RADIOLOGICAL WORKER TRAINING
RADIOLOGICAL CONTAMINATION CONTROL TRAINING FOR LABORATORY RESEARCH

Instructor's Guide

Office of Health, Safety & Security
U.S. Department of Energy

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Table of Contents

Table of Contents
(Continued)

Page

DEPARTMENT OF ENERGY - COURSE/LESSON PLAN

Standardized Core Course Materials

Course Goal:	Upon completion of this training, the participant will have a basic understanding of radiological contamination control measures for laboratory research facilities.
Target Audience:	Individuals who have assigned duties as laboratory researchers.
Course Description:	This course illustrates and reinforces the skills and knowledge needed to assist personnel with radiological controls for laboratory research facilities.
Prerequisites:	None
Length:	2-8 hours (depending on facility-specific information and incorporation of practical exercises)

Course Objectives Next

Terminal Objective: At the end of this course, the participant will understand the basic radiological contamination control measures for working in a research laboratory.

Enabling Objectives:

EO1 DISTINGUISH between ionizing radiation and radioactive contamination.

EO2 DEFINE
- Fixed.
- Removable.
- Airborne contamination.

EO3 IDENTIFY the units used to measure radioactive contamination.

EO4 IDENTIFY causes of radioactive contamination.

EO5 IDENTIFY methods used to control radioactive contamination.

EO6 DEFINE Contamination Area, High Contamination Area, and Airborne Radioactivity Area.

EO7 IDENTIFY the requirements for entry, working in, and exiting Contamination Areas and Airborne Radioactivity Areas.

EO8 IDENTIFY the proper use of protective clothing.

EO9 STATE the appropriate response to a spill of radioactive material.

Continued on Next Page

Enabling Objectives: (continued)	E010 IDENTIFY methods for reducing radioactive waste. E011 IDENTIFY the purpose and use of personnel contamination monitors. E012 IDENTIFY the normal methods used for decontamination.
Student Materials:	Student's Guide Plus any handouts or other materials for facility-specific information or activities.

Bibliography Next

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Continued on Next Page

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Stein (1992), F., "Instructor Competencies: The Standards," International Board of Standards for Training, Performance and Instruction.

Lesson Summary Next

LESSON SUMMARY

Introduction

Welcome students to the course.
Introduce self to the participants and establish rapport.
Define logistics:

- Safety briefing - exits.
- Restrooms.
- Hours.
- Breaks.
- Sign-in sheets.
- Test - accountability.
- End-of-course evaluation.

Terminal Objective

At the end of this course, the participant should be able to understand the basic radiological contamination control measures for working in a research laboratory.

State Enabling Objectives.

ENABLING OBJECTIVES:

The participant will be able to:

E01 DISTINGUISH between ionizing radiation and radioactive contamination.

E02 DEFINE
- Fixed.
- Removable.
- Airborne contamination.

E03 IDENTIFY the units used to measure radioactive contamination.

E04 IDENTIFY causes of radioactive contamination.

E05 IDENTIFY methods used to control radioactive contamination.

E06 DEFINE Contamination Area, High Contamination Area, and Airborne Radioactivity Area.

E07 IDENTIFY the requirements for entry, working in, and exiting Contamination Areas and Airborne Radioactivity Areas.

E08 IDENTIFY the proper use of protective clothing.

E09 STATE the appropriate response to a spill of radioactive material.

E10 IDENTIFY methods for reducing radioactive waste.

E11 IDENTIFY the purpose and use of personnel contamination monitors.

E12 IDENTIFY the normal methods used for decontamination.

Course Content

Briefly review the content of the course, noting that there is a logical sequence ("flow") to the material covered. As you present the material, relate it to the circumstances they can expect to find in the facility workplace and procedures. (You will be inserting facility-specific laboratory researcher information.)

Lesson Plan and Instructor's Notes Next

I. RADIOLOGICAL CONTAMINATION

EO1 DISTINGUISH between ionizing radiation and radioactive contamination.

A. Comparison of Radiation and Radioactive Contamination

Radioactive contamination is radioactive materials where you do not want it.

Recall that radioactive material is material that contains unstable "radioactive" atoms. Even when this radioactive material is properly contained, it still emits radiation and may be an external dose hazard, but it will not be a contamination hazard. When radioactive material is inadvertently released from its container (e.g., a spill), it is then referred to as radioactive contamination.

Radiation is energy, contamination is a material. Exposure to radiation does NOT result in contamination.

B. Types of Contamination

EO2 DEFINE fixed, removable and airborne contamination.

Contamination can be grouped into 3 types:

- Fixed.
- Removable/transferable.
- Airborne.

1. Fixed contamination

Fixed contamination is contamination that cannot be readily removed from surfaces.

- It cannot be removed by casual contact, wiping, brushing, or washing.
- It may be released when the surface is disturbed (buffing, grinding, using volatile liquids for cleaning, construction, etc.).
- Over time it may "weep," leach, or otherwise become loose or transferable.

2. Removable/transferable contamination

   Removable/transferable contamination is contamination that can be readily removed or transferred from surfaces.

   - It may be removed or transferred by casual contact, wiping, brushing, or washing.

   - Air movement across this type of contamination could cause the contamination to become airborne.

3. Airborne contamination

   Airborne contamination is contamination suspended in air.

   This creates a particular hazard because of the possibility of intake by inhalation. Inhalation is the most common mode of uptake of radioactive material in the working environment. In addition to the hazard to the worker, radioactive materials may be carried into ventilation systems, the material may be deposited on surfaces over a large area, and there is the potential for releases outside of the facility.

C. Units of Radioactive Contamination

Because radioactive contamination is radioactive material, the units are the same, e.g., disintegrations per minute (dpm) for both.

EO3	*IDENTIFY the units used to measure radioactive contamination.*

When measuring the amount of radioactive contamination (material) on a surface, the units most commonly used are disintegrations per minute per 100 centimeters squared (dpm/100 cm^2).

1. Direct reading

   Contamination monitors measure radiation emitted by the radioactive material. The units are normally seen by the monitor as counts per minute (cpm).

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

(*Explain counter efficiency*.)

There is a direct relationship between the counts recorded and the actual activity (disintegrations) present. The counter efficiency (expressed as the ratio of cpm/dpm) is divided into the measured cpm to obtain the activity.

D. Causes of Radioactive Contamination

EO4 IDENTIFY causes of radioactive contamination.

Radioactive material can be spread to unwanted locations. The following are some causes of radioactive contamination:

(*Optional method may include listing trainees' response on board or flip chart.*)

1. Sloppy work practices, such as cross-contamination of tools, equipment, or workers.
2. Not wearing gloves, or removing them prematurely.
3. Poor housekeeping in contaminated areas.
4. Opening radioactive materials/systems without proper controls.
5. Leaking containers or tears in radiological containers such as barrels, plastic bags, boxes, or protective gear.
6. Spills, glass breakage, and animal fluids.
7. Airborne contamination depositing on surfaces.
8. Not adhering to standard laboratory procedures (such as not checking gloves after handling radioactive materials or working in a potentially contaminated area).
9. Emergencies including:
   - Fire.
   - Earthquake, etc.

E. Indicators of Possible Area Contamination

The following are some indicators of possible area contamination:

1. Visual indicators, such as:
   - Leaks, spills, standing liquids.
   - Damaged radiological containers.
2. Detection of contamination or elevated radiation levels including:

- Spurious or unexplained personnel contamination.
- Radioactivity observed in bioassay samples collected.
-

(*Presence of higher than background levels of radioactivity in bioassay samples indicates radiological control measures are not being effectively implemented*.)

- Higher than normal background on personnel contamination survey devices.
- Higher than normal background radiation levels on area monitors and air samples.
- Routine radiation and contamination surveys conducted by Radiological Control Organization.

F. Primary Reasons for Contamination Control

1. Protection of the worker

   Measures to control radioactive contamination are implemented to protect workers by:

   - 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 (e.g., sharp instrument punctures).
   - Absorption (skin, mucous membranes, eyes).
   - Ingestion (biting nails, applying cosmetics, eating, drinking or smoking in the lab or outside without monitoring or washing hands).

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.

Also, note that resources applied to cleanup reduce the resources available for other program goals. Additionally, serious contamination events may detract from maintaining good public relations.

G. Radiological Contamination Control Measures

Contamination control measures should address:

1. Characteristics of radionuclides used:

   Type of radiation emitted
   Energy of radiation emitted
   Half-life

2. Preparation of areas and materials - including:

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

3. Good work practices - including:
   - Special precautions for handling liquids.
   - Special precautions for handling sharps.
   - Clean up the work area at the end of the job or end of the day, whichever is first.

4. Radioactive waste management.

5. Radiation monitoring (including interpretation of meter readings) during and at completion of work. If a problem is detected or suspected, notify the Radiological Control Organization.

6. Decontamination.

7. Regulatory requirements.

8. Training requirements.

II. CHARACTERISTICS OF COMMONLY USED RADIONUCLIDES

Because radioactive contamination is radioactive material, the units are expressed in activity; e.g. disintegrations per minute (dpm).

(*Select those radionuclides from Appendix A that are applicable to your facility and add applicable radionuclide information*.)

Insert facility-specific radionuclides (see Appendix A).

III. PREPARATION OF WORK AREA AND MATERIALS

EO5	*IDENTIFY methods used to control radioactive contamination.*

A. Appropriate Selection of Work Area

(*Material in this Section may be deleted if it is covered in other training*.)

The work station should not present an exposure potential to another individual within the laboratory or to the adjacent laboratory. The work station should not conflict with other work within the laboratory (i.e., strong gamma emitters near low background counting equipment, etc.).

B. Preparation of Work Areas

1. Minimize area

   Confine operations involving radioactive materials to as small a space as practical.

2. Clear area

   Clear area of extraneous items and material.

3. Work surface

   Cover area as appropriate. Diaper paper should be placed absorbent side up.

4. Containment

   Use trays when appropriate.

5. Waste

   Receptacles for radioactive waste should be located by the work station so you may conveniently dispose of waste without further contamination of the work area.

C. Preparation of Equipment/Materials

(*State that later in the course the selection and use of the proper instruments will be covered (Section VI*).)

1. Assemble survey meters

   The survey meter should be turned on and located in close proximity to the work station. A pre-operational check is necessary before use to ensure the meter is working properly. Position the detector so it is directed toward your work area.

This will enable you to conveniently monitor your hands as you work and also can indicate when materials are removed from shielded containers. Always work with the audio turned on. Your safety and the safety of others must take priority over the concept that the sound may be disturbing to others. Know the location of nearby phones. Post the Radiological Control Organization phone number nearby.

2. Equipment preparation

   Use dedicated equipment/tools when appropriate. Cover/tape tools or equipment used during the job to minimize radioactive contamination.

3. Assemble materials and supplies

   Those supplies that would minimize small spills of radioactive materials should be within arm's reach while handling unsealed radioactive materials.

4. Marking and labeling

(*Show appropriate labels, tape, etc. Discuss consequences if radiation label is found in municipal waste stream*.)

- The area/material is marked and labeled as appropriate (typically by Radiological Control personnel).
- Do **NOT** discard intact radioactive labels/markings in normal trash!
- Remove or deface labels before discarding boxes, etc.

D. Shielding

1. Placement

   Placement of shielding materials is critical to both your safety and that of your colleagues. Work stations that require the use of shielding should be located where there would be no worker on the opposite side of the workbench, such as in corners and against walls.

2. Penetration through walls

   Be certain to consider what (or who) is on the other side of the wall. However, if this can not be accommodated, shielding should be considered for the work station on the opposite side of the workbench or wall where your colleague may be working.

3. Beta and Gamma Emitters

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

4. Considerations

   Some considerations for use of shielding were addressed above. Because issues involving shielding can be complex, always consult the Radiological Control Organization before using shielding.

E. Ventilation Control

1. Airflow

   Airflow should be from the areas of least contamination to areas of most contamination (e.g., clean to contaminated to highly contaminated areas) such as fume hoods, gloveboxes, etc.

2. Pressure differential

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

3. High Efficiency Particulate Air (HEPA) filtration.

   HEPA filters, which remove radioactive particles from the air, may be used. This is commonly required for higher levels of airborne radioactivity such as concentrations exceeding 10 percent of the Derived Air Concentration (DAC) for a particular radionuclide. Charcoal filters are required for specific radionuclides such as iodine. Ventilation system requirements should be determined in consultation with the Radiological Control Organization.

   A DAC is the radionuclide airborne concentration. Breathing an air concentration of 1 DAC for 1 working year (2,000 hours) will result in committed dose equal to an annual limit, i.e., 5 rem whole-body or 50 rem to any organ or tissue.

4. Flow rate

   Always check the flow rate or pressure in ventilated enclosures before starting operations. Air flow is easily measured with an inexpensive velometer. Refer to facility-specific flow rate measurement requirements.

(*Insert facility-specific requirements*.)

F. Posting of Radiological Areas

(*Materials in this Section need not be repeated if it is covered in other training*.)

10 CFR 835.602 requires that each access point to a controlled area be appropriately posted. Further, 835.603 requires that each access point to a radiological area be appropriately posted.

(*Reference 10 CFR 835 and exemptions from posting. Reference Glossary for definition of radioactive material, controlled area, and radiological area*.)

Posting of radiological areas is typically a Radiological Control Organization function. Workers should become aware of the posting requirements. DOE has designated the following areas as requiring posting:

(*Discuss that entry requirements may be included on radiological postings, (e.g., TLD required, monitor upon exiting and/or protective clothing required). Insert facility-specific posting requirements and examples here*.)

1. Radioactive Material Area

   An area or structure where radioactive material, exceeding the values provided in 10 CFR 835 Appendix E, is used, handled, or stored. The posting/sign will indicate:

   "CAUTION, RADIOACTIVE MATERIAL" or
   "DANGER, RADIOACTIVE MATERIAL"

   Additional posting is not required if the Radioactive Material Area is inside a Contamination, High Contamination, or Airborne Radioactivity Area.

2. Contamination Area

   Any area where removable contamination levels are greater than the values specified in Appendix D of 10 CFR 835, but less than or equal to 100 times those levels.

   The posting/signs will indicate:

   "CAUTION, CONTAMINATION AREA"

Abbreviated Table of Contamination Values (See 10 CFR 835 Appendix D for Complete Listing)		
NUCLIDE	REMOVABLE	TOTAL
I-125	20	500
I-131, I-133	200	1,000
Beta/gamma	1,000	5,000
Tritium	10,000	N/A

3. High Contamination Area

(*Reference: 10 CFR 835.2(a))*

Any area where removable contamination levels are greater than 100 times the values listed in Appendix D of 10 CFR 835.

The posting/sign will indicate:

"DANGER, HIGH CONTAMINATION AREA" or

"CAUTION, HIGH CONTAMINATION AREA

4. Airborne Radioactivity Area

(*Reference: 10 CFR 835.2(a) and 835.603(d))*

Any area where the measured concentration of airborne radioactivity, above natural background, exceeds or is likely to exceed the derived air concentration (DAC) values listed in Appendix A or Appendix C of 10 CFR 835 or where an individual in the area without respiratory protection could receive an intake exceeding 12 DAC-hours in a week.

The posting/sign will indicate:

"CAUTION, AIRBORNE RADIOACTIVITY AREA" or

"DANGER, AIRBORNE RADIOACTIVITY AREA"

A DAC is the radionuclide airborne concentration. Breathing an air concentration of 1 DAC for 1 working **year** (2,000 hours) will result in committed equivalent dose equal to an annual limit, i.e., 5 rem whole-body or 50 rem to any organ or tissue.

G. Labeling of Radioactive Materials and Other Postings

(*Reference: 10 CFR 835*)

1. **"CAUTION, RADIOACTIVE MATERIAL"**

   Equipment, components, and other items that are radioactive, potentially radioactive, or have been in contact with radioactive contamination or activation sources.

2. **"CAUTION, INTERNAL CONTAMINATION" or**

(*Reference: RCS, Ch. 1, Article 412*)

"CAUTION, POTENTIAL INTERNAL CONTAMINATION"

Equipment, components, and other items with actual or potential internal contamination.

3. **"CAUTION, FIXED CONTAMINATION"**

(*Reference: RCS, Ch. 1, Article 412*)

Components, equipment, or other items with fixed contamination.

4. **Facility-Specific Postings/Labeling**

   These may include Radiological Buffer Areas.

(*Add facility-specific postings/labeling. Discuss differences between posting and labeling. Areas that can be physically entered are posted. Equipment, components, and radioactive sources are labeled. Reference: RCS Article 233*)

IV. CONDUCT OF WORK - GOOD PRACTICES

A. Personal Preparation

Ensure that you are ready to work and that you have the following:

- Training to meet entry requirements.
- Work permits, procedures, etc.
- Dosimetry.
- Personal protective equipment.

B. Requirements of Posted Contamination Areas

EO7 IDENTIFY the requirements for entry, working in and exiting Contamination Areas and Airborne Radioactivity Areas.

1. Requirements for entry into posted contamination areas.

(*Reference: RCS, Rev 1, Article 335*)

The RadCon Standard recommends individuals allowed unescorted entry into Contamination Areas be provided the following:

- Radiological Worker II training.
- Worker's signature on the Radiological Work Permit, as applicable.
- Protective clothing/equipment as required by the Radiological Work Permit.
- Personnel dosimetry, as appropriate.
- Pre-job briefing for High Contamination and Airborne Radioactivity Areas.

2. Requirements for working in posted contamination areas.

   The RadCon Standard recommends that individuals allowed unescorted entry into
   Contamination Areas:

   - 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. This could result in skin contamination.

   Smoking, eating, chewing, drinking, and putting on makeup could result in ingesting radioactive material; for this reason, the activities are not allowed in Contamination Areas.

3. Requirements for exiting posted contamination areas.

(*Reference: RCS, Rev 1, Article 335*)

RadCon Standard recommends that individuals allowed unescorted entry into Contamination Areas:

a. Exit only at 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. Correct use of step-off pads is included in the practical factors exercise.
   - If more than one step-off pad is used, the final step-off pad is "clean," outside the exit point, and 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 potential inhalation if contamination becomes airborne.

c. Perform a personal survey. If contamination is indicated:

(*In some cases, Radiological Control personnel may perform the survey. Tritium cannot be detected with standard survey meters*.)

- Stay in the area.
- Notify Radiological Control personnel.
- Take action to minimize cross-contamination (e.g., put a glove on a contaminated hand or tape over contamination on clothing too).

d. Tools or equipment being removed from a posted area must be monitored prior to release.

(*Reference: 10 CFR 835.1101 requirements*.)

e. After exiting and monitoring yourself, it is a good practice to wash your hands.

(*Insert facility-specific procedures*.)

C. Dosimetry

(*Insert facility-specific dosimetry requirements*.)

Always have proper personnel monitoring that might include:

1. Whole body

   Whole-body dosimeter such as a thermoluminescent dosimeter (TLD) or film badge.

2. Extremity monitoring

   Finger rings, if handling high contact dose rate materials such as P-32.

D. Personnel Protective Clothing (Anti-C)

The degree of clothing required is dependent on the work area, radiological conditions, and the nature of the job. The use of personnel protective clothing and equipment is the least desired option. Use of engineering controls such as gloveboxes or fumehoods is preferred. Standard clothing requirements for research laboratory work include:

EO8 IDENTIFY the proper use of protective clothing.

- Lab coats with long sleeves that are buttoned or otherwise closed.

- Surgeon's gloves; the gloves may need to protect against radioactive contaminants as well as other lab hazards applicable, such as acids and caustics.

(*DISCUSS the use of gloves.*
DEMONSTRATE how to change gloves without contaminating fingers or wrists.
DISCUSS how and why contamination can reach the skin and clothing.)

- Closed-toed shoes.

- Safety glasses or equivalent for eye protection from eye hazards including radiological hazards such as from P-32.

1. Proper use of protective clothing

   - Inspect all protective clothing for rips, tears, holes, or wear prior to use.

   - Personal effects such as watches, rings, jewelry, etc. should not be worn.

   - After donning protective clothing, such as anti-contamination clothing, proceed directly from the dress-out area to the work area. In general, a lab coat is sufficient to protect the individual at most research laboratories.

   - Avoid getting lab coats wet. Wet lab coats provide a means for contamination to reach the skin/clothing.

   - Contact Radiological Control personnel if clothing becomes ripped, torn, etc. during operations.

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. This training course does not qualify a worker to wear respiratory equipment. Ventilation design should eliminate the need to use respiratory equipment except in extreme cases.

E. Storage and Containment of Radioactive Material

Containment generally means using vessels, trays, diaper paper, bench tops, etc. to contain contamination.

EO5	*IDENTIFY methods used to control radioactive contamination.*

1. Storage areas
   a. Store large bottles and containers close to the floor.

   b. Shelves should:
      - Be secured (bolted) to a wall.
      - Have lips or restraining cords to prevent bottles from falling.

   c. Storage area should be well lit, properly ventilated, and have an even temperature.

2. Radioactive materials should be properly stored:

   - In unbreakable containers; if not possible, secondary containment (the secondary containment should be able to contain the entire volume of the primary container).

   - In stable containers with secure means of closing.

   - Away from sinks and drains or other possible pathways that do not collect in retention tanks.

   - Protected from adverse environmental factors.

   - Away from combustibles and other fire sources.

   - Protected from "unauthorized relocation," this may include locked refrigerators and storage cabinets.

   - With the outside of the container clearly labeled with contents.

   - With provided instructions to open containers.

3. Posting and labeling of storage areas

   Room access and cabinets, refrigerators, freezers, etc., that house the container should be posted or labeled "Caution Radioactive Material" or "Danger, Radioactive Material."

4. Chemical considerations for storage

(*Storage of chemicals may be addressed here if not covered in other training*.)

Segregate incompatibles and store by hazard class. Appendices B and C address chemical storage in more detail.

F. Good Housekeeping

EO5	*IDENTIFY methods used to control radioactive contamination.*

"Good housekeeping" is the prime factor in an effective contamination control program and 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. RadCon Required Actions and Good Practices

1. BELIEVE! labels and posted areas.

(*It is important to remove labels and postings as soon as the radioactive materials are no longer present so that employees will believe that the labels are correct at all times.)*

2. Avoid Contamination and Airborne Radioactivity Areas. These areas should be isolated from routine operations.

3. Treat Contamination Areas as if everything was contaminated.

4. Minimize the number of items carried or placed into potentially contaminated areas.

5. Use proper and functional radiation detection instrumentation.

(*Remind attendees that there are release requirements*.)

6. Do not eat, drink, apply makeup, etc.

7. 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, e.g., under equipment.

1. Handling liquids

(*Note: If the liquids could generate airborne radioactivity, additional posting and monitoring may be required*.)

Standard good practices for handling liquids include:

- Use appropriate gloves for liquids being handled.
- Protect personal clothing.
- Work in a tray with absorbent paper.
- Use mechanical pipettes and dilutors (**NEVER** pipette by mouth).
- Work in a properly vented area.
- Report any spills or suspected spills.

(*Discuss facility-specific reporting requirements*.)

2. Preventing 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 closure.
- Avoiding unstable (top heavy) containers or arrangements.
- Using secondary containment for liquids.
- Leaking containers
- Report all suspected leaks immediately to the Radiological Control Organization.
- 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

EO9	*IDENTIFY the appropriate response to a spill of radioactive material.*

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

(*Discuss and demonstrate facility/room-specific response to a spill*.)

- **S**top the spill.
- **W**arn others.
- **I**solate the area.
- **M**inimize exposure.
- **S**ecure the ventilation system (as necessary, and if qualified). If the spill involves volatile chemical or volatile or gaseous radionuclides, the ventilation may need to be left on.
- As previously discussed, report the spill to the Radiological Control Organization.

V. RADIOACTIVE WASTE MANAGEMENT

E05	*IDENTIFY methods for reducing radioactive waste.*

A. Segregation

Segregate waste by waste stream category and half-life to facilitate storage, minimization, and disposal.

B. Waste Storage

(*Waste Stream Segregation includes maintaining separation between hazardous and radioactive wastes*.)

Each laboratory should have a designated location for storing 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, recognizable, and properly labeled and shielded.

Liquid waste materials should be kept in secondary containers and segregated by hazard class. Secondary containers may be lab trays or any device that will contain 110 percent of the largest container.

C. Sharps

Contaminated syringes, glass pipettes, and other sharp items must be placed in a specifically designed, rigid container.

D. Methods for Minimizing Waste

(*Ask attendees for reasons and methods*.)

1. Minimize waste generation

   a. <u>Confine operations:</u> Confine operations with radioactive materials to as small an area as possible.

   b. <u>Minimize materials:</u> Minimize materials introduced into radioactive material handling areas.

   c. <u>Segregate:</u> Segregate clean materials from radioactive materials. Do not dispose of clean materials in radioactive waste containers.

   d. <u>Good housekeeping:</u> Contamination control measures such as covering benches, etc. generate waste. On the other hand, decontamination generates a great deal of waste. Good housekeeping, following procedures, minimizing bench areas, and secondary containment can reduce the amount of coverings required.

2. Storage for Decay

(*Reference: Lorenzen (1994*))

a. Storage: Some radionuclides have a short half-life and can be stored, with appropriate DOE approval, for decay. Normal storage times are 10 half-lives. The waste must be surveyed prior to disposal to ensure it is below disposal criteria.

b. Substitution: Substitute shorter-lived for longer-lived radionuclides, if possible.

3. Disposal via Sanitary Sewer

(*Reference: DOE (1993)DOE allows discharge via sanitary sewer per Order5400.5, Ch. 2, Chapter II, 3.d. Include facility-specific procedures. NRC licensees and most agreement States allow for limited quantities of radionuclides to be disposed via the sanitary sewer per 10 CFR 20.2003 or the agreement State equivalent regulation. Reference: NRC (1991)*).

Disposal of small quantities via sanitary sewer is available to some facilities. Add facility-specific information.

4. Disposal of specific waste per 10 CFR 20.2005

In accordance with Part 20.2005, NRC licensees may dispose of the following as if it were not radioactive:

a. Liquid scintillation counting media: Liquid scintillation counting media containing 0.05 microcuries or less per gram of medium of H-3 or C-14.

(Discuss *concerns of LSC sewer disposal (clog drains, exposure to LSC fluid*). Need to follow facility-specific procedures. Encourage use of non-tolulene-based LSC.)

b. Animal carcasses: Animal carcasses containing 0.05 microcuries or less per gram of animal tissue (averaged over the weight of the entire animal) of H-3 or C-14.

(*Animal carcasses can't be used for human food or animal feed*.)

5. Volume reduction

a. Compaction: May produce reduction factors of up to 5 to 1.

(*Reference: Woehr (1994*))

b. Shredding: May produce reduction factors of up to 12 to 1.

c. Incineration: Difficult under present regulations and political climate; allowed under 10 CFR 20.2004. Currently, scintillation fluids are incinerated by commercially licensed vendors.

E. Mixed Waste

(*Reference: Stevens (1994)*)

Mixed waste is exceedingly difficult, if not impossible, to dispose of at this time. Currently, DOE has a self-imposed moratorium on the off-site shipment of RCRA/TSCA waste suspected of having radioactivity. This moratorium was instituted by the DOE Office of Waste Management (EM-30).

1. The EM-30 Performance Objective (PO) for Certification of Non-radioactive Hazardous Wastes was developed in 1991 and is currently under revision. This PO was developed to guide DOE sites in addressing the issue of hazardous waste that contains added radioactivity.

2. Ways to avoid generating mixed waste:

   - Use non-hazardous cleaning materials for decontamination whenever possible.

   - Segregate "radioactive only" from "hazardous only" at the source.

   - Explore the use of other materials that are non-hazardous for use in radiological areas to prevent the generation of mixed waste.

   - Discontinue use of non-biodegradable (organic solvent based) liquid scintillation media. Biodegradable liquid scintillation media are available.

   - Some States are more restrictive than the U.S. Environmental Protection Agency (EPA) in their listing of those scintillation cocktails that are biodegradable.

   - Organic solvents with a flash point below 60$_o$C (140$_o$F) may be classified as "ignitable," thus creating a mixed waste where disposal may not be possible. If the flash point is above 140$_o$F, the organic solvent may not be considered as ignitable; however, these materials must be handled and disposed of with extreme caution.

3. Other methods for facilitating disposal:

   - Do not combine solvents with metals; disposal is very difficult. Examples are lead or mercury combined with solvents.

   - Generally, it is a good idea to separate organics and inorganics whenever possible to facilitate disposal.

VI. MONITORING FOR CONTAMINATION

While handling unsealed radioactive materials, you should monitor your hands frequently as you work. Monitor your hands, feet, sleeves, and lab coat when leaving the work station or laboratory. It is common to find contamination on the lab coat where you may be leaning against your work station.

A. Contamination Monitoring Equipment

Always use radiation survey meters. Tritium and certain other isotopes, such as C-14, cannot be detected with a thin-window G-M survey instrument. For these isotopes, wipe tests, which are counted in a liquid scintillation counter, are required.

E011 IDENTIFY the purpose and use of personnel contamination monitors.

1. Purpose

   Contamination-monitoring equipment is used to detect radioactive contamination of personnel and work areas.

2. Selection of proper survey instrument

(*INTRODUCE facility specific instruments and procedures*.)

   Correction factors for the specific radionuclide being monitored should be known when surveying. Often the survey instrument will over or under respond when monitoring for beta or alpha radiation.

3. Pre-operational Checks

(*DEMONSTRATE preoperational checks*.)

   Perform pre-operational checks before work:

   - Confirm calibration is current.
   - Verify that battery is OK.
   - Perform an audio check (audio response is immediate, while needle response takes time to stabilize.
   - Ensure instrument responds to source.
   - Verify that background count rate is normal.

(*Explain that there is a statistical variation in count rates and demonstrate this range daily*.)

- Variation of daily counting results.

B. Conducting Surveys - General

(*Demonstrate general surveys*.)

1. Survey hands before picking the probe up.
2. Hold the probe approximately ½ inch from surface being surveyed.
3. Move probe slowly over surface to be surveyed, approximately 2 inches per second.

C. Area Surveys

(*Explain facility policy. Clarify who is responsible to perform these surveys*.)

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

(*Explain wipe survey*.)

D. Personnel Surveys

(*Demonstrate personnel surveys*.)

1. Proceed to survey in the following typical order:
    - Head (pause at mouth and nose for approximately 5 seconds).
    - Neck and shoulders.
    - Arms (pause at each elbow), hands, 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).

2. The whole-body survey should take approximately 3 minutes. A full whole-body survey or 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 lab coat and repeated on personal clothing if contamination is found. If contamination is detected, take proper steps as addressed below in Section E.

3. 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.

4. Carefully return the probe to holder.

5. Keep the instrument close to the work area to facilitate frequent checking of hands and fingers.

E. Detection of Contamination

If contamination is indicated:

1. Remain in the immediate area.
2. Notify Radiological Control personnel.
3. Minimize cross-contamination (such as putting a glove on a contaminated hand until decontamination can be attempted).

F. Release of Materials

(Insert facility-specific information as appropriate (if laboratory personnel do not conduct release surveys, it may be appropriate to just cover their responsibilities).
Reference: DOE/CH-9401 (1993)
Reference: 10 CFR 835.1101(b))

1. Release to Controlled Areas.

   Release from potentially contaminated areas to Controlled Areas is covered by 10 CFR 835. Equipment and materials released from a potentially contaminated area must be surveyed and released under a formal program. If surveys indicate the presence of removable contamination at levels greater than 10 CFR 835

Appendix D, the materials may be moved to another posted area. Appropriate controls must be established. Appropriate controls should include:

- Surveys of materials before movement.
- Containment of materials during transit.
- Establishment of approved transit routes.
- Survey of transit route after movement (if materials exhibited removable contamination).

If surveys indicate presence of fixed contamination only (removable contamination less than 10 CFR 835 Appendix D values), the items may be released to the controlled area if:

- Routine surveys are performed to ensure contamination remains fixed to surface.
- The item must be clearly labeled or tagged to warn others of the contamination.
- Written procedures must be established to control such items.

(*Reference: 10 CFR 835.1101(c)*)

2. Unrestricted Release

   Unrestricted release is addressed in DOE Order 5400.5. See Appendix F for more information. A November 17, 1995, memorandum from EH-412 to the field provides supporting guidance (reference DOE 1995).

3. Techniques

   Monitoring techniques for release of materials is covered in Appendix D.

VII. DECONTAMINATION

(*DISCUSS who makes the decision when to decontaminate*.)

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.

A. Decontamination or Not

If the presence of loose contamination is discovered, decontamination is a valuable means of control.

1. Economical conditions

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

2. Radiological conditions

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

B. Preventive Methods

1. Identifying and repairing leaks before they become a serious problem.

2. Changing out gloves or protective gear as necessary to prevent cross-contamination of equipment.

C. Skin Contamination

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

E012 IDENTIFY the normal methods used for decontamination.

1. Concerns of skin contamination are:

   - Cross-contamination by touching.
   - Absorption through the skin.
   - Threat of uptake by ingestion, touching face, etc.

2. Skin decontamination

(*Discuss the need to involve RadCon personnel as appropriate. Refer to facility specific requirement.*)

Intact skin is an excellent barrier, so use gentle methods to decontaminate.

Normally, mild soap and lukewarm water are used to decontaminate personnel. Good practices include:

- Do not abrade skin.
- Do not chap skin by cold water or harsh chemicals.
- Avoid hot water because it will open pores.

3. If skin contamination remains, a common procedure is to wear surgeon's gloves overnight to induce sweat that will lift contamination from the skin. The decision to wear gloves to induce sweat must be made by the responsible Health Physicist. This practice requires detailed documentation and procedural guidance.

D. Material Decontamination

E012 IDENTIFY the normal methods used for decontamination.

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

1. Establish controls to prevent spread of contamination.
2. A high priority is to prevent airborne radioactivity.
3. Decontaminate from areas of low to high contamination (exception is when potential for airborne is high).
4. Decontaminate from top to bottom so that contamination will not run down on the clean surface.
5. Only make one pass, then discard or turn wipe to a clean surface (don't recontaminate area).
6. The Radiological Control Organization will make the final determination if the material has been adequately decontaminated.

VIII. FACILITY-SPECIFIC REQUIREMENTS

Insert facility-specific information.

IX. CONTAMINATION CONTROL LESSONS LEARNED

Insert facility-specific information.

X. SUMMARY - Review of Objectives

EO1 DISTINGUISH between ionizing radiation and radioactive contamination.

EO2 DEFINE
- Fixed.
- Removable.
- Airborne contamination.

EO3 IDENTIFY the units used to measure radioactive contamination.

EO4 IDENTIFY causes of radioactive contamination.

EO5 IDENTIFY methods used to control radioactive contamination.

EO6 DEFINE Contamination Area, High Contamination Area, and Airborne Radioactivity Area.

EO7 IDENTIFY the requirements for entry, working in, and exiting Contamination Areas and Airborne Radioactivity Areas.

EO8 IDENTIFY the proper use of protective clothing.

EO9 STATE the appropriate response to a spill of radioactive material.

EO10 IDENTIFY methods for reducing radioactive waste.

EO11 IDENTIFY the purpose and use of personnel contamination monitors.

EO12 IDENTIFY the normal methods used for decontamination.

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GLOSSARY

Terms used consistent with regulatory definitions.

Becquerel (Bq): The SI unit for activity equivalent to 1 nuclear disintegration per second.

Beta Decay: Radioactive decay in which a beta particle is emitted. This transformation changes only the atomic number of the nucleus, raising or lowering the atomic number (Z) by one for emission of a negative or positive beta particle, respectively.

Beta Particle: Charged particle emitted from the nucleus during radioactive decay, having a mass and charge equal to that of an electron.

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

Biological Half-Life: See Half-Life Biological.

Characteristic X-ray: X-rays that are characteristic of the element in which they are produced. Their emission results from the rearrangement of electrons in the shells of excited atoms.

Contamination: Undesired (e.g., radioactive or hazardous) material that is deposited on the surface of, or internally ingrained into, structures or equipment, or that is mixed with another material.

> Radioactive Contamination: A radioactive substance dispersed in materials or places where it is undesirable.
>
> Fixed Contamination: Radioactivity remaining on a surface after repeated decontamination attempts fail to significantly reduce the contamination level.
>
> Removable Contamination: That fraction of the radioactive contamination present on a surface that can be transferred to a swipe tab by rubbing with moderate pressure.
>
> Surface Contamination: The deposition and attachment of radioactive materials to a surface, also the resulting deposit.

Continuous Air Monitor (CAM): Instrument that continuously samples and measures the levels of airborne radioactive materials on a "real time" basis and has alarm capabilities at preset levels.

Curie: The unit of activity equal to a rate of 3.7×10^{10} nuclear disintegrations per second.

Decontamination: The reduction or removal of contaminating radioactive material from a structure, area, object, or person. Decontamination may be accomplished by treating the surface to remove or decrease the contamination, or by letting the material stand so that the radioactivity is decreased as a result of natural decay.

Disintegration, Nuclear: A spontaneous nuclear transformation (radioactivity) characterized by the emission of energy and/or mass from the nucleus. When numbers of nuclei are involved, the process is characterized by a definite half-life.

Dosimeter: A portable instrument for measuring and registering the total accumulated dose to ionizing radiation.

Dosimetry: The theory and application of the principles and techniques involved in the measurement and recording of radiation doses. Its practical aspect is concerned with the use of various types of radiation instruments with which measurements are made.

Dose Rate: The radiation dose delivered per unit of time. Measured, for example, in rad per hour.

Effective Half-Life: See Half-Life, Effective.

External Radiation: Exposure to ionizing radiation when the radiation source is located outside the body.

Flash Point: The minimum temperature at which a substance gives off flammable vapor that will ignite if in contact with spark or flame.

Fume Hood: Ventilated containment space, enclosed on five sides, with the sixth side covered by a movable glass or plastic window to allow access and to maintain sufficient inflow of air and splash control to protect the worker from the hazardous materials handled inside.

Gamma Ray: Very penetrating electromagnetic radiation of nuclear origin. Except for its origin, it is identical to an X-ray.

Geiger-Mueller Counter: A radiation detection and measuring instrument. It consists of a gas-filled tube containing electrodes, between which there is an electrical voltage but no current flowing. When ionizing radiation passes through the tube, a short, intense pulse of current passes from the negative electrode to the positive electrode and is measured or counted. The number of pulses per second measures the intensity of radiation. It is sometimes called simply a Geiger counter, or a G-M counter.

Gray (Gy): The SI unit for absorbed dose. One gray is equivalent to one Joule per kilogram or 100 rad.

Half-Life Biological (T_{bio}): The time required for the body to eliminate one-half of an administered dose of any substance by regular processes of elimination. This time is usually the same for both stable and radioactive isotopes of a particular element. The biological half-life of tritium is 10 days, whereas the physical half-life is 12.3 years.

Half-Life, Effective (T_{eff}): The time required for the amount of a radioactive nuclide deposited in a living organism to be diminished 50 percent as a result of the combined action of radioactive decay $T_{½}$ and biological elimination T_{bio}.

$$T_{eff} = T_{bio} \times T_{½} / T_{bio} + T_{½}$$

Half-Life, Physical ($T_{½}$): The time in which half the atoms of a particular radioactive substance disintegrate to another nuclear form. Measured half-lives vary from millionths of a second to billions of years.

Half-Value Layer (HVL): Thickness of a specified substance which, when introduced into the path of a given beam of radiation, reduces the exposure rate by one half.

Health Physicist: A person trained to advise on operating procedures for minimizing radiation exposures, perform radiation surveys, oversee radiation monitoring, and estimate the degree of radiation hazard.

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

Health, Radiological: The art and science of protecting human beings from injury by radiation, as well as promoting better health through beneficial applications of radiation.

High Efficiency Particulate Air (HEPA): An air filter generally rated as being capable of removing at least 99.97 percent of the particulate material in an air stream.

Indirect Bioassay: The assessment of radioactive material deposited in the body by detection of radioactivity in material excreted or removed from the body.

Intake: The quantity of material (activity or mass) initially taken into the body. (For example, in the case of inhalation, the intake includes the quantity of material immediately exhaled.)

Internal Emitter: A term used for a radionuclide deposited in the body.

In-vitro Methods: Detection of radiations emitted by radioactive materials excreted or removed from the body, using radiochemical and/or radioanalytical techniques.

In-vivo Methods: Detection of radiations emitted by radioactive materials deposited in the body, usually by whole body (or critical organ) counting techniques.

Ionization (Ion) Chamber: An instrument that detects and measures ionizing radiation by measuring the electrical current that flows when radiation ionizes gas in a chamber, making the gas a conductor of the electricity.

Ionizing Radiation: Any electromagnetic or particulate radiation capable of producing ions (either directly or indirectly) in its passage through matter.

Irradiation: Exposure to radiation.

Isotope: One of two or more atoms with the same number of protons, but different numbers of neutrons in their nuclei. Isotopes have very nearly the same chemical properties.

keV: The symbol for one thousand-electron-volts (1,000 eV).

Kilo: Symbol k. A prefix indication base unit is to be multiplied by 1,000.

Kilovolt (kV): A unit of electrical potential equal to 1,000 volts.

Lead Equivalent: The thickness of lead affording the same attenuation, under specified conditions, as the material in question.

License: Written authorization issued to the licensee by the NRC or agreement State to perform specific activities related to the possession and use of byproduct, source, or special nuclear material.

MeV: A unit of energy. The energy acquired by an electron accelerated through a potential difference of one million volts.

Micro-: A prefix that divides a basic unit into one million parts. Often used with activity such as microcurie.

Milli-: A prefix that divides a basic unit by 1,000. Often used with dose and activity such as millirem or millicurie.

Million Electron Volts (MeV): Energy equal to that acquired by a particle with one electronic charge in passing through a potential difference of one million volts.

Minimum Detectable Activity (MDA): The lowest amount of any specific radiation that can be detected with a particular level of statistical significance above background levels.

Nano-: A prefix that divides a basic unit by one billion. Often used in measurements of activity such as nanocurie.

Nuclide: A species of atom having a specified number of neutrons and protons in its nucleus.

Personnel Monitoring: Monitoring any part of individuals, their breaths, or excretions, or any part of their clothing to determine the amount of radioactivity present in or on an individual.

Pico-: A prefix that divides a basic unit by one trillion. Often used in measurements of activity such as picocurie.

Proportional Counter: An instrument in which an electronic detection system receives pulses that are proportional to the number of ions formed in a gas-filled tube by ionizing radiation.

Prospective Monitoring: Routine workplace and personnel monitoring for possible intakes of radioactive materials. Prospective monitoring will typically include air monitoring, surface contamination surveys, and bioassay. Any prospective monitoring results above Investigation Levels will trigger retrospective monitoring.

Rad: A unit of absorbed dose. The word comes from the acronym Radiation Absorbed Dose and is equivalent to 100 ergs per gram. It does not take into account the biological effect resulting from the absorbed dose.

Radioactive Material: Radioactive material includes any material, equipment, or system component determined to be contaminated or suspected of being contaminated. Radioactive material also includes activated material, sealed and unsealed sources, and material that emits radiation.

Radioactivity: The process whereby certain nuclides undergo spontaneous disintegration in which energy is liberated, generally resulting in the formation of new nuclides. The process is accompanied by the emission of one or more types of radiation, such as alpha particles and gamma photons.

Radiochemical: A molecule or a chemical compound or substance containing one or more radioactive atoms.

Radiological Buffer Area (RBA): An intermediate area established to prevent the spread of radioactive contamination and to protect personnel from radiation exposure.

Radiological Work Permit (RWP): Permit that identifies radiological conditions, establishes worker protection and monitoring requirements, and contains specific approvals for radiological work activities. The Radiological Work Permit serves as an administrative process for planning and controlling radiological work and informing the worker of the radiological conditions.

Radionuclide: A radioactive (unstable) nuclide.

Radioisotope: An unstable isotope of an element that decays or disintegrates spontaneously, emitting radiation. Approximately 5,000 natural and artificial radioisotopes have been identified.

Reference Man: A hypothetical individual whose characteristics are often used to estimate radiation dose. Reference Man is to be 20-30 years of age, 170 cm (5 ft 10 in) in height, weighing 70 kg (160 lb); and living in a climate with an average temperature of from 10° to 20° C. Reference Man is a Caucasian and is Western European or North American in habitat and custom.

Rem: The unit of equivalent dose. The word comes from the acronym Roentgen Equivalent Man and takes into account the biological effect from an absorbed dose of radiation.

Retrospective Monitoring: Retrospective monitoring is a series of measurements made after an intake is suspected to confirm the intake and assess any doses that may result from the intake.

Roentgen: The unit for exposure. It is that amount of gamma or X-rays required to produce ions carrying 1 electrostatic unit of electrical charge in 1 cubic centimeter (2.58×10^{-4} coulomb/kg) of dry air under standard conditions.

Scintillation Detector: The combination of phosphor, photomultiplier tube, and associated electronic circuits for counting light emissions produced in the phosphor by ionizing radiation.

Shielding: Any material or obstruction that absorbs radiation and thus tends to protect personnel or materials from the effects of ionizing radiation.

SI: The International System of Units ("Le Systeme International d'Unites") as defined by the General Conference of Weights and Measures in 1960. These units are generally based on the meter/kilogram/second units, with special quantities for radiation including the becquerel, gray, and sievert.

Sievert (Sv): The SI unit of equivalent dose. It is equivalent to 100 rem.

Specific Activity: The total activity of a given nuclide per gram of material. Specific activity is a function of half-life and is therefore also unique to each radionuclide. There are approximately 10,000 curies in a gram of tritium and 1 curie in a gram of radium-226.

Survey Meter: An instrument used to monitor the presence of radioactivity by detecting the radiation emitted during the radioactive decay.

Tenth Value Layer (TVL): Amount of shielding material required to reduce radiation exposure by a factor of 10. One TVL is equal to 3.3 HVL.

Tissue Equivalent Material: Material made up of the same elements in the same proportions as they occur in a particular biological tissue.

Thermoluminescent Dosimeters (TLD): Dosimeters made of certain crystalline materials that are capable of both storing a fraction of absorbed ionizing radiation and releasing this energy in the form of visible photons when heated. The amount of light released can be used as a measure of radiation exposure to these crystals.

Tritium: The hydrogen isotope with one proton and two neutrons in the nucleus. Tritium is radioactive and has a half-life of 12.3 years.

Uptake: Quantity of a radionuclide taken up by the systemic circulation, e.g., by injection into the blood, by absorption from compartments in the respiratory or gastrointestinal tracts, or by absorption through the skin or through wounds in the skin.

Whole-Body Counter: A device used to identify and measure the radiation in the body (body burden) of human beings and animals; it uses heavy shielding to keep out background radiation and ultrasensitive scintillation detectors and electronic equipment.

Whole-Body Counting: A technique to determine the internally deposited radionuclides within the body by measuring with an external radiation detector the photons emitted. Results are generally expressed in the form of percent of the ALI for the nuclides in question. This technique can identify and measure accurately normal body radiations as well as those that are taken into the body due to such things as injection, ingestion, and inhalation from atmospheric releases, medical diagnostic and therapeutic techniques, etc.

Whole Body Equivalent Dose: The equivalent dose that results when the whole body is irradiated and taken, when the irradiation is uniform, as equivalent to the effective dose.

X-rays: Penetrating electromagnetic radiation having wavelengths shorter than those of visible light, usually produced by bombardment of a metallic target with fast electrons in a high vacuum.

In nuclear reactions, it is customary to refer to photons originating in the nucleus as gamma rays, and those originating in the extra nuclear part of the atom as X-rays.

APPENDIX A
CHARACTERISTICS OF COMMONLY USED RADIONUCLIDES

TRITIUM (H-3)

(*Select those radionuclides that are applicable to your facility and add applicable radionuclide information. Effective half-life values are from LA-4400 (see reference LA-4400 1970) Individuals who handle large quantities of tritium may benefit from the Article 663 course Radiological Training for Tritium Facilities*.)

Tritium is a low-energy beta emitter and cannot be monitored directly with a thin-window G-M probe. 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 or about 1/3 the maximum energy).
2. Maximum range in air: 1/4 inch (6 mm).
3. Maximum range in water: 6×10^{-3} mm.
4. International Atomic Energy Agency (IAEA) toxicity classification: Low.
5. Physical half-life ($T_{1/2}$): 12.35 years.
6. Effective half-life (T_{eff}): 10 days (the time it takes for ½ of the material to be eliminated from the body by both biological processes and radioactive decay).
7. Critical organ: Whole body (the part of the body where the most limiting dose is delivered).
8. Personnel monitoring: Bioassay - urinanalysis, NOT detected with a dosimeter (thermoluminescent dosimeter or film).
9. Annual Limit of Intake (ALI):
   - Tritiated water: 80 mCi (3×10^9 Bq) by inhalation or ingestion.

   (*Elemental tritium is not taken into the body and is assigned an ALI based on a TED resulting from lung exposure. However, in many environments elemental tritium converts rapidly to tritiated water vapor.)*
10. Shielding: None (the low-energy beta is not very penetrating).

11. Special Considerations:
    - Cannot be measured directly with a thin-window G-M probe (standard survey meter).
    - Can be absorbed through the skin.
    - Many compounds readily penetrate gloves and skin. Handle these compounds remotely, wear two pairs of gloves, and change the outer layer at least every 20 minutes.
    - Tritiated DNA precursors are considered more toxic than tritiated water. However, they are generally less volatile and do not present a significantly greater hazard.

CARBON-14 (C-14)

Carbon-14 is a low-energy beta emitter (about 10 times more energetic than tritium). C-14 is not easily detected with a hand-held survey instrument such as a thin-window G-M (the efficiency is ~ 10%). Monitoring is normally performed by taking a swipe of the area and counting the swipe in a liquid scintillation counter.

1. Maximum energy: 0.156 MeV (the average energy is 0.052 MeV).
2. Maximum range in air: 9 inches (24 cm).
3. IAEA toxicity classification: Medium-low.
4. Physical half-life: 5,730 years.
5. Effective half-life (T_{eff}): 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 (thermoluminescent dosimeter or film).
8. ALI:
   - 2 mCi (8×10^7 Bq) -labeled organic compounds by inhalation or ingestion.
   - 1.6 Ci (6×10^{10} Bq) CO by inhalation.
   - 200 mCi (7×10^9 Bq) CO_2 by inhalation.
9. Shielding: 3mm of plexiglass (if needed) - thicker plexiglass may be used for rigidity.
10. Special Considerations:
    - Detection of C-14 by radiation survey instruments requires special care due to the low efficiency of detection.
    -
    - Some C-14-labeled compounds may penetrate gloves and skin. Handle these compounds remotely, wear two pairs of gloves, and change the outer layer frequently.
    - 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-window G-M probe, sodium-iodide scintillation counter, or liquid scintillation detector.

1. Energy:
   - Maximum beta energy: 0.546 MeV, average energy 0.182 MeV.
   - Gamma energy: 1.275 MeV.
   - Annihilation photon: 0.511 MeV.
2. Maximum beta range in air: 4.7 feet (1.4 m).
3. Unshielded dose rate from 1mCi point source at 1/2 inch (1cm): 11.8 rad/hr.
4. IAEA toxicity classification: High-medium.
5. Physical half-life: 950 days.
6. Effective half-life (T_{eff}): 10.9 days.
7. Critical organ:
   - Whole body for intake of transportable compounds.
   - Lungs for inhalation.
   - Lower large intestine for ingestion.
8. Personnel monitoring: dosimeter and finger rings, uptakes may be 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:
    - Half-value layer (the thickness required to attenuate the dose rate by 1/2) is 0.26 inches (6.5mm) of lead.

- 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:
    - Near an unshielded Na-22 source, dose rates due to beta radiation can be much higher than dose rates due to gamma radiation.
    - Avoid direct eye exposure by interposing transparent shielding or indirect viewing.
    - Avoid skin dose by indirect handling.

PHOSPHORUS-32 (P-32)

Phosphorus-32 is a high-energy beta emitter that may create a whole body, skin, and an 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 toxicity classification: Medium-low.

5. Physical half-life: 14.29 days.

6. Effective half-life (T_{eff}): 10-14 days.

7. Critical organ:

   - Bone for transportable compounds.
   - Lung and lower large intestine are critical organs for inhalation and ingestion, respectively.

8. Personnel monitoring: Dosimeter and finger rings, uptakes may be determined by urinalysis.

9. ALI:

   - 1mCi (4×10^7 Bq) by inhalation, clearance in days.
   - 0.4 mCi (1×10^7 Bq) by inhalation, clearance in weeks.
   - 0.5 mCi (2×10^7 Bq) by ingestion.

10. Shielding: 1/2 inch (1.2 cm) of plexiglass (that will shield the beta particles and minimize the production of bremsstrahlung).

    P-32 betas will travel
    - 19 feet in air.
    - 0.8 cm in tissue.
    - 0.7 cm in plexiglass.
    - 0.3 cm in aluminum.

11. Special considerations:
    - A high local dose can be received if the radioactive material is touched and allowed to remain in contact with the skin.

- Do not work over an open container, the eyes can receive a substantial beta dose.
- Safety glasses can provide eye protection.
- Contamination is easily detected with G-M thin-window probe.
- Bremsstrahlung radiation will be a consideration for millicurie quantities.
- Radwaste containers may need to be shielded with plexiglass.

Typical dose rates from 0.1 mCi (4×10^6 Bq):

- 3 mrad/hr at 1 cm.
- 0.03 mrad/hr at 10 cm.
- 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: 1.5 feet (0.5 m).

3. Maximum range in tissue: 1 mm.

4. IAEA toxicity classification: Medium-low.

5. Physical half-life: 24.4 days.

6. Effective half-life (T_{eff}): 10-24 days.

7. Critical organ:
   - Bone for transportable compounds.
   - Lung and lower large intestine are critical organs for inhalation and ingestion, respectively.

8. Personnel monitoring: NOT detected with a dosimeter (thermoluminescent dosimeter or film) dosimeter and finger rings, uptakes may be determined by urinalysis.

9. ALI:
   - 9 mCi (3×10^8 Bq) by inhalation, clearance in days.
   - 1 mCi (3×10^7 Bq) by inhalation, clearance in weeks.
   - 1 mCi (3×10^7 Bq) by ingestion.

10. Shielding: 3mm of plexiglass (if needed).

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 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: 0.32mm.
4. IAEA toxicity classification: Medium-low.
5. Physical half-life: 87.4 days.
6. Effective half-life (T_{eff}): 77 days.
7. Critical organ: Whole body and testis.
8. Personnel monitoring: Bioassay - urinanalysis, NOT detected with a dosimeter (thermoluminescent dosimeter or film).
9. ALI:
   - 11 mCi (4×10^8 Bq) inorganic compounds (vapor inhalation).
   - 1 mCi (6×10^7 Bq) organic compounds.
   - 1 mCi (4×10^7 Bq) by inhalation, clearance in weeks.
   - 7 mCi (2×10^8 Bq) by ingestion.
10. Shielding: 3mm of plexiglass (if needed).
11. Special Considerations:
    - Detection of S-35 by radiation survey instruments requires special care due to the low efficiency of detection.
    - Sulfur-35 compounds, including methionin, generate volatile fractions particularly during lyophilization or incubation.

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: 0.710 MeV (the average energy is 0.233 MeV).

2. Maximum range in air: 7 feet (2 m).

3. Maximum range in tissue: 0.1 inch (2.6 mm).

4. IAEA toxicity classification: High-medium.

5. Physical half-life: 3×10^5 years.

6. Effective half-life (T_{eff}): 10-29 days.

7. Critical organ:
   - Whole body for transportable compounds.
   - Lung for inhalation.
   - Lower large intestine for ingestion.

8. Personnel monitoring: Urinanalysis, finger rings.

9. ALI:
   - 2 mCi (9×10^7 Bq) by inhalation.
   - 1 mCi (5×10^7 Bq) by ingestion.

10. Shielding: 0.25 inches (6mm) of plexiglass.

11. Special Considerations:
    - Cl-36 beta particles have sufficient energy to penetrate gloves and skin.
    - When handling millicurie quantities, do not work over an open container.
    - Avoid glove and skin contamination or ensure that it is promptly detected and removed.

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 beta energies: 0.257 MeV (the average energy is 0.086 MeV).

2. Maximum range in air: 20 inches (52 cm).

3. Maximum range in tissue: 0.62mm.

4. IAEA toxicity classification: High.

5. Physical half-life: 163 days.

6. Effective half-life (T_{eff}): 163 days.

7. Critical organ: Bone.

8. Personnel monitoring: Bioassay, initially by urine, later by feces. NOT detected with a dosimeter (thermoluminescent dosimeter or film).

9. ALI:

   - 0.5 mCi (2 x 10^7 Bq) by inhalation.

   - 1.7 mCi (6 x 10^7 Bq) by ingestion.

10. Shielding: 3mm of plexiglass.

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 an X-ray emitter. Cr-51 is readily detected with a thin-window G-M probe. Liquid scintillation counting is also used.

1. Maximum energy: 0.32 MeV gamma ray (9.8%), a very low energy (0.005 MeV) X-ray (22 %), and 0.004 MeV (66.9%) auger electron.

2. IAEA toxicity classification: Medium-low.

3. Physical half-life: 27.7 days.

4. Effective biological half-life: 27 days.

5. Critical organ: Lower large intestine and lungs.

6. Personnel monitoring: Dosimeter, internal uptakes may be determined by urine or fecal sampling.

7. ALI:

   - 37 mCi (1 x 10^9 Bq) by inhalation, yearly clearance.

   - 35 mCi (1 x 10^9 Bq) by ingestion.

8. Shielding: - 3.2 mm of lead is the first half value layer (thickness of lead that will reduce the dose rate by one-half).

9. Special Considerations:

   Use thin-end window G-M or solid scintillation detectors or liquid scintillation counting.

IRON-55 (Fe-55)

Iron-55 decays by electron capture and is an X-ray emitter. Fe-55 contamination may be detected by a thin-window G-M probe looking at the very low-energy characteristic Mn-55 X-rays. Manganese is formed when the iron nucleus captures an electron. The manganese emits X-rays characteristic to its electron shell structure. Liquid scintillation counting may also be used.

1. Average X-ray energy: Electron capture with an average low energy of 0.006 MeV.
2. IAEA toxicity classification: Medium-low.
3. Physical half-life: 2.6 years.
4. Effective half-life (T_{eff}): 370 days.
5. Critical organ:
   - Liver and spleen for inhalation.
   - Lower large intestine for ingestion.
6. Personnel monitoring: Uptakes evaluated by analysis of blood.
7. ALI:
   - 1 mCi (5 x 10^7 Bq) by inhalation, daily clearance.
   - 4 mCi (1 x 10^8 Bq) by ingestion.

COBALT-57
(Co-57)

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

1. Maximum energy: X-ray radiation from 0.014 to 0.692 MeV (0.122 MeV emitted 85.5% of the time).
2. IAEA toxicity classification: Medium-low.
3. Physical half-life: 270.9 days.
4. Effective half-life (T_{eff}): 9 days.
5. Critical organ: Lower large intestine.
6. Personnel monitoring: Dosimeter, uptakes may be evaluated by whole body counting.
7. ALI:
   - 2 mCi (8×10^7 Bq) by inhalation, yearly clearance.
   - 7 mCi (2×10^8 Bq) by ingestion.
8. Shielding: 3.2 mm of lead is the first half value layer.

IRON-59 (Fe-59)

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

1. Maximum beta energies:
   - 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.

2. Gamma energies:
   - 1.292 MeV.
   - 1.099 MeV.
   - 0.192 MeV.
   - 0.143 MeV.

3. Maximum range in air of beta: 45 inches (115 cm).

4. Unshielded dose rate from 1 mCi point source at 1/2 inch (1 cm): 6.18 rad/hr.

5. IAEA toxicity classification: Medium-high.

6. Physical half-life: 44.6 days.

7. Effective half-life (T_{eff}): 42 days.

8. Critical organ:
   - Liver and spleen for inhalation.
   - Lower large intestine for ingestion.

9. Personnel monitoring: Dosimeter, finger rings - fecal analysis may be used to determine uptake for weeks or months after handling. Urinalysis is recommended from 4-24 hours after handling.

10. ALI:
    - 0.4 mCi (1×10^7 Bq) by inhalation.
    - 0.7 mCi (2×10^7 Bq) by ingestion.

11. Shielding: 0.38 inch (9.7 mm) of lead is the first half-value layer.

12. Special considerations:
    - Near an unshielded Fe-59 source, dose rates from beta radiation can be much higher than dose rates due to gamma radiation.

- Avoid direct eye exposure.
- Avoid skin exposure.

IODINE-125 (I-125)

Iodine-125 is a gamma and X-ray emitter. I-125 contamination may be detected by a thin-window G-M probe or with liquid scintillation counting.

1. Maximum energy: 0.035 MeV gamma (6.5%), 0.027 MeV x-ray (112.5%) and 0.031 MeV X-ray (25.4%).

2. IAEA toxicity classification: Medium-high.

3. Physical half-life: 60 days.

4. Effective half-life (T_{eff}): 42 days.

5. Critical organ: Thyroid gland.

6. Personnel monitoring: Internal uptakes evaluated by thyroid scan.

7. ALI:

   - 0.05 mCi (1.8 x 10^6 Bq) by inhalation, vapor.
   - 0.04 mCi (1 x 10^6 Bq) by ingestion.

8. Shielding: 0.25 mm of lead is the first half-value layer.

9. Other considerations for iodine compounds:

   - Volatilization of iodine (NaI) is the most significant hazard.
   - Simply opening a vial of sodium iodide at high-radioactive concentrations can cause minute droplets to become airborne.
   - Solutions containing iodide ions should not be made acidic nor stored frozen; both lead to formation of volatile elemental iodine.
   - Some iodide compounds can penetrate surgical rubber gloves - wear two pairs or polyethylene gloves over rubber.
   - Can be easily absorbed through the skin.

IODINE-131 (I-131)

Iodine-131 is a gamma, X-ray and beta emitter. I-131 contamination may be detected by a thin-window G-M probe or with liquid scintillation counting.

1. Maximum beta energies: 0.248 - 0.606 MeV.

2. Primary gamma energies: 0.364 MeV, 0.637 MeV and 0.284 MeV.

   (*Note: gammas are by decreasing percentages*.)

3. IAEA toxicity classification: Medium-high.

4. Physical half-life: 8 days.

5. Effective half-life (T_{eff}): 7.6 days.

6. Critical organ: Thyroid gland.

7. Personnel monitoring: Dosimeter, thyroid scan for uptakes.

8. ALI:

   - 0.03 mCi (1 x 10^6 Bq) by inhalation, vapor.

   - 0.03 mCi (1 x 10^6 Bq) by ingestion.

9. Shielding: 2.3 mm of lead is the first half-value layer.

10. Other considerations for iodine compounds:

    Volatilization of iodine is the most significant hazard.

    - Simply opening a vial of sodium iodide (NaI) at high-radioactive concentrations can cause minute droplets to become airborne.

    - Solutions containing iodide ions should not be made acidic nor stored frozen; both lead to formation of volatile elemental iodine.

- Some iodide compounds can penetrate surgical rubber gloves - wear two pairs or polyethylene gloves over rubber.

- Can be easily absorbed through the skin.

APPENDIX B
STORAGE OF RADIOACTIVE/HAZARDOUS MATERIALS

1.0 Containment of Material

Containment generally means using vessels, trays, diaper paper, bench tops, etc. to contain contamination.

2.0 Segregation and Storage

Segregate incompatibles and store by hazard class. Recommended general hazard classes for storage are:

1. Caustics (bases).
2. Acids (mineral).
3. Flammables (including organic acids).
4. Poisons (toxics).
5. Oxidizers.
6. Water reactives.

3.0 General Guidelines

1. Keep flammables by themselves in Underwriters Laboratory (UL) or Factory Mutual (FM) approved safety cans or cabinets.
2. Keep acids away from bases.
3. Separate organics from inorganics.
4. Store oxidizers away from flammables.
5. Provide as much physical separation as possible between classes.
6. Biohazards should be properly labeled and may be stored as one group.

7. Class B and C carcinogens should be properly labeled and stored with their chemical family.

8. Store Class A carcinogens in the glovebox or another regulated area.

   Note: EPA carcinogen designations are as follows:
   EPA-A Human Carcinogen: sufficient evidence from epidemiologic studies to support a casual association between exposure and cancer.

   EPA-B Probable Human Carcinogen: weight of evidence of human carcinogenicity based on epidemiologic studies is limited; agents for which weight of evidence of carcinogenicity based on animal studies is sufficient. Two subgroups: B1: Limited evidence of carcinogenicity from epidemiologic studies; B2: Sufficient evidence from animal studies; inadequate evidence or no data from epidemiologic studies.

   EPA-C: Possible Human Carcinogen: Limited evidence of carcinogenicity in animals in the absence of human data.

4.0 Formation of Organic Peroxides

Organic peroxides are a class of compounds that have unusual stability problems that make 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.
- Divinylidene chloride.
- Cumene.
- Sodium amide.
- Methyl acetylene.
- Methylcyclopentene.

APPENDIX C
STORAGE GUIDELINES BY HAZARD CLASS

1.0 Caustics

Caustics are materials with pH > 10. Examples include ammonium hydroxide, calcium hydroxide, and sodium hydroxide.

1.1 Separate from acids.

1.2 Store solutions of inorganic hydroxides in polyethylene containers.

1.3 Store large containers below eye level.

2.0 Acids

Acids are materials with pH < 5. Examples include acetic, chromic, and hydrofluoric.

2.1 Separate from bases and materials that could evolve toxic vapors on contact (i.e., sodium cyanide).

2.2 Store large bottles low to the ground -- at least below eye level.

2.3 Separate inorganic acids from organic acids (i.e., acetic, oxalic, etc.).

2.4 Separate from active metals (i.e., sodium, potassium).

2.5 Store perchloric and nitric acid as oxidizers.

3.0 Flammables/Combustibles

Flammables/combustibles vapors ignite easily at room temperature. Examples include alcohols, esters, ketones, ethers, and pyrophorics.

3.1 Keep flammables by themselves in Underwriters Laboratory (UL) or Factory Mutual (FM approved safety cans or cabinets.

3.2 Keep away from heat, sun, flame, and spark sources.

3.3 Separate from oxidizers.

3.4 Use only (UL) or FM approved “explosion safe” or “spark-proof” refrigerators for cold storage of flammables.

4.0 Poisons (Toxics)

Poisons are dangerous if inhaled, swallowed, or absorbed through the skin. Examples include phenol and hydrazine.

4.1 Store according to label directions.

4.2 Separate from other hazard classes.

4.3 Keep tightly sealed.

5.0 Oxidizers

Oxidizers are materials that yield oxygen: react with water, fire, flammables, and combustibles. Examples include inorganic nitrates, permanganates, inorganic peroxides, persulfates, and perchlorates.

Oxidizers must be stored in accordance with NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals* and NFPA *430, Code for the Storage of Liquid and Solid Oxidizers.*

5.1 Keep separate from flammables and other organic materials.

5.2 Keep separate from reducing agents (i.e., zinc, alkaline metals, formic acid).

5.3 Do not store directly on wooden surfaces.

5.4 Peroxide formers should be labeled with date received and opened, and should be discarded as hazardous waste within three to six months of opening. Depending on the chemical, unopened peroxide performers should be discarded within 12 months of receipt.

6.0 Organic Peroxides

Organic peroxides are a class of compounds that have unusual stability problems.

Oxidizers must be stored in accordance with NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals* and NFPA *432, Code for the Storage of Organic Peroxides*.

APPENDIX D

I. RELEASE OF MATERIALS

A. Monitoring Techniques General

Monitoring techniques for release of materials are addressed in DOE/CH-9401 (1993). The following techniques apply for G-M detectors (H-3 cannot be measured).

1. Surveys should be conducted in a low background area (background levels are not to exceed 300 cpm; lower levels are preferable and in most cases achievable).

2. Direct measurement should be made prior to smear surveys.

3. 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.

   If potential for internal contamination cannot be adequately assessed, material may not be released.

4. An audible response should be utilized as the principal indicator for initial detection of surface radioactivity.

5. The assigned instrument/detector efficiencies should reflect a prior evaluation of facility wastes.

   Typical efficiencies for a thin-window G-M probe.
   - C-14, S-35 - 10%.
   - P-32 - 50%.

B. Beta/Gamma Direct Monitoring

(*Results: If surveys indicate presence of contamination (refer to 10 CFR 835 Appendix D for release from controlled areas or DOE 5400.5, Ch.2, for unrestricted release), the material should not be released. Prior to release, contamination levels must be less than appropriate values and should be reduced as low as reasonably achievable*.)

1. Window: Use a thin-window probe, detector window thickness (mylar) should not be more than 2.0 mg/cm^2.

2. Scanning: Scan the surface; in most cases, scanning will cover nearly 100 percent 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. Scan speed should be no more than 2"/sec.

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

C. Smear Surveys for Releasing Material

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

2. These large-area wipes may be evaluated by holding the probe up to the swipe (~5 sec.)

3. If initial screening evaluation indicates presence of contamination, take representative disc smears (100 cm^2 area) of up to 100 percent of accessible surface areas.

D. Documentation

All surveys for release shall be documented in writing. Documentation of release from controlled areas should include information required by RCM Article 421.5.

APPENDIX E
IDENTIFICATION OF MIXED LOW-LEVEL RADIOACTIVE WASTE (LLW)

1.0 40 CFR PART 261

RCRA, in 40 CFR Part 261 Subpart C, defines general characteristics that, if exhibited by a waste material, require the classification of that material as hazardous. These characteristics are:

1.1 Ignitability.

1.2 Corrosivity.

1.3 Reactivity.

1.4 Toxicity.

2.0 Specific Waste Streams

In addition to defining the characteristics of hazardous wastes, 40 CFR Part 261 lists specific waste streams that are considered hazardous. These lists are compiled in tables in Subpart D according to:

2.1 Hazardous waste from nonspecific.

2.2 Hazardous waste from specific sources.

2.3 Discarded commercial chemical products, off-specification species, and container and spill residues.

APPENDIX F
RELEASE OF POTENTIALLY CONTAMINATED MATERIAL - DOE ORDER 5400.5, Ch.2

1.0 Surface Contamination Levels

Prior to being released, property should be surveyed to determine whether both removable and total surface contamination (including contamination present on and under any coating) is greater than the levels given in the DOE Order 5400.5, Ch.2.

2.0 Potential For Contamination

Property should be considered to be potentially contaminated if it has been used or stored in radiological 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.

3.0 Inaccessible Areas

Where potentially contaminated surfaces are not accessible for measurement, such property may be released after case-by-case evaluation and documentation based on both the history of its use and available measurements demonstrate that the unsurveyable surfaces are likely to be within the release criteria.

4.0 Volume Contamination

EH-412 has provided guidance for release of material that has been contaminated with tritium (reference DOE 1995). Other materials may be released if criteria and survey techniques are approved by DOE.

5.0 Items With Fixed Contamination

Under exceptional conditions, materials and equipment with fixed contamination that exceeds the release criteria may be released for use in Controlled Areas outside of Radiological Areas. As a condition of such release, the removable contamination levels must be below the level specified in Appendix D of 10 CFR 835. The materials shall be routinely monitored, clearly labeled and/or tagged to alert personnel of the contaminated status, and have appropriate administrative procedures established and exercised to maintain control of these items.

6.0 Covering of Contaminated Surfaces

Radioactivity on equipment should not be covered by paint, plating, or other covering material unless contamination levels, as determined by a survey and documented, are below the "Removable" Criteria of Table 1 of DOE Order 5400.5, Ch. 2 (see below). A reasonable effort must be made to minimize the contamination prior to use of any covering.

If it is likely that contamination exists under a painted surface, it may be necessary to remove some of the painted surface to measure contamination levels below. Use a paint remover to collect paint samples from areas of approximately 200 cm^2. Measure alpha and/or beta-gamma levels beneath paint. Check with Radiological Control personnel prior to using any paint remover to eliminate the generation of mixed waste.

Where potentially contaminated surfaces are not accessible for measurement, the equipment may be released after case-by-case evaluation and documentation based on both the history of its use and available measurements demonstrate that the unsurveyable surfaces are likely to be within the release criteria.

Radionuclides 2/	Average 3/, 4/	Maximum 4/, 5/	Removable 4/, 6/
Transuranics, I-125, I-129, Ra-226,	500	1500	20
Ac-227, Ra-228, Th-228, Th-230, Pa-231. Th-Natural, Sr-90, I-126, I-131,	1,000	3,000	200
I-133, Ra-223, Ra-224, U-232, Th-232 U-Natural, U-235, U-238, and associated decay product, alpha emitters.	5,000	15,000	1,000
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above. 7/	5,000	15,000	1,000

Figure IV-1 Surface Contamination Guidelines

1/ As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

2/ Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.

3/ Measurements of average contamination should not be averaged over an area of more than 1 m^2. For objects of less surface area, the average should be derived for each such object.

4/ The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm.

5/ The maximum contamination level applies to an area of not more than 100 cm^2.

6/ The amount of removable material per 100 cm^2 of surface area should be determined by wiping an area of that size with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wiping 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. It is not necessary to use wiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.

7/ This category of radionuclides includes mixed fission products, including the Sr-90 which is present in them. It does not apply to Sr-90 which has been separated from the other fission products or mixtures where the Sr-90 has been enriched.

APPENDIX G
ANIMAL FACILITIES

1.0 Objective

Describe the exposure potentials when handling animals that contain radionuclides during experiments.

2.0 Outline

- Exposure potentials.
- Methods of minimizing external exposures.
- Methods of minimizing internal exposures.
- Methods of minimizing cross contamination.
- Room contamination problems.

3.0 Dose Potentials

Animals that have had radionuclides administered to them can present a hazard both to the individuals working with them and to the success of the experiment as well. When using radionuclides in animals, one must be sure that the cages are well labeled, away from much foot traffic, and properly maintained to minimize the hazards arising from radionuclide use. Hazards that are likely to be encountered when using radionuclides in animals are listed below:

3.1 External personnel exposure resulting from gamma-emitting radionuclides that have been used in an animal.

3.2 Internal radiation exposure resulting from accidental ingestion of radionuclides.

3.3 Cross contamination of radionuclides from one radiological experiment to another.

3.4 Room contamination that can result in the spread of radionuclides to a non-radioactive use area.

4.0 Methods of Minimizing External Dose

4.1 <u>Distance</u>
Maintain the greatest distance possible between the worker and the gamma-emitting animal to make full use of the inverse square law. This law, simply stated, implies that if the distance from a radioactive source is doubled, the dose is reduced by a factor of four.

4.2 <u>Time</u>
When the distance cannot be minimized, the amount of time spent in the proximity of the radioactive animal should be kept at a minimum.

4.3 <u>Shielding</u>
When the above is not possible for any reason or when the dose rate is determined to be very high, lead shielding of the proper thickness should be placed between the

worker and animal. This is a clumsy technique and should only be attempted following consultation with a health physicist.

4.4 Source Reduction
Following the experiment and/or the death the animal, proper waste disposal proceedings should be initiated.

5.0 Methods of Minimizing Internal Dose

When handling radioactive animals or applying radionuclides to animals, it is required that the handler wear gloves that can be thrown away when contaminated. This will prevent the transfer of radionuclides from hand to mouth and is equally important when handling excreta or animal parts that may be radioactive.

Procedures for handling of the animal should be implemented to reduce the possibility of animal bites. This would include such activities as sedation of the animal in some procedures and special handling techniques for specific animals in other procedures. Both the researcher and the animal handler should be trained in these procedures.

6.0 Methods of Minimizing Cross Contamination

Cross contamination may cause the radioactive materials used in one experiment to turn up unexpectedly in the results of another. Since some experiments utilize only minute amounts of radionuclides while others use large amounts, it is easy to visualize the confusion when large amounts of unknown radionuclides appear suddenly in a low-level experiment.

Cross contamination can result from mishandling; contaminated protective clothing; contaminated cages, food, and water supplies; and airborne materials being transferred from cage to cage.

Contaminated cages should be allowed to decay where possible, and then be thoroughly washed. Following washing, they must be surveyed before re-use.

7.0 Room Contamination Problems

These problems can best be avoided by maintaining radioactive animals in a separate room and maintaining high standards of housekeeping in the room. Feces, cage linings, and urine should be stored in the appropriate containers. These items should not be allowed to accumulate.

In case any of the above-mentioned items are spilled, they should be cleaned up immediately, utilizing absorbent, disposable materials. All materials used in cleaning up a spill should be placed in the appropriate containers to preclude the possibility of further contamination spread. It is essential that spills be cleaned up without delay.

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(Part 3 of 3)

RADIOLOGICAL WORKER TRAINING
RADIOLOGICAL CONTAMINATION CONTROL TRAINING FOR LABORATORY RESEARCH

Student's Guide

Office of Health, Safety & Security
U.S. Department of Energy

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Table of Contents

Table of Contents
(Continued)

Page

Student's Guide

TERMINAL OBJECTIVE:

At the end of this course, the participant should be able to understand the basic radiological contamination control measures for working in a research laboratory.

ENABLING OBJECTIVES:

The participant will be able to:

E01 DISTINGUISH between ionizing radiation and radioactive contamination.

E02 DEFINE
- Fixed.
- Removable.
- Airborne contamination.

E03 IDENTIFY the units used to measure radioactive contamination.

E04 IDENTIFY causes of radioactive contamination.

E05 IDENTIFY methods used to control radioactive contamination.

E06 DEFINE Contamination Area, High Contamination Area, and Airborne Radioactivity Area.

E07 IDENTIFY the requirements for entry, working in, and exiting Contamination Areas and Airborne Radioactivity Areas.

E08 IDENTIFY the proper use of protective clothing.

E09 STATE the appropriate response to a spill of radioactive material.

E10 IDENTIFY methods for reducing radioactive waste.

E11 IDENTIFY the purpose and use of personnel contamination monitors.

E12 IDENTIFY the normal methods used for decontamination.

I. RADIOLOGICAL CONTAMINATION

EO1 DISTINGUISH between ionizing radiation and radioactive contamination.

A. Comparison of Radiation and Radioactive Contamination

Radioactive contamination is radioactive materials where you do not want it.

Recall that radioactive material is material that contains unstable "radioactive" atoms. Even when this radioactive material is properly contained, it still emits radiation and may be an external dose hazard, but it will not be a contamination hazard. When radioactive material is inadvertently released from its container (e.g., a spill), it is then referred to as radioactive contamination.

Radiation is energy, contamination is a material. Exposure to radiation does NOT result in contamination.

B. Types of Contamination

EO2 DEFINE fixed, removable and airborne contamination.

Contamination can be grouped into 3 types:

- Fixed.
- Removable/transferable.
- Airborne.

4. Fixed contamination

   Fixed contamination is contamination that cannot be readily removed from surfaces.

   - It cannot be removed by casual contact, wiping, brushing, or washing.
   - It may be released when the surface is disturbed (buffing, grinding, using volatile liquids for cleaning, construction, etc.).
   - Over time it may "weep," leach, or otherwise become loose or transferable.

5. Removable/transferable contamination

   Removable/transferable contamination is contamination that can be readily removed or transferred from surfaces.

   - It may be removed or transferred by casual contact, wiping, brushing, or washing.

- Air movement across this type of contamination could cause the contamination to become airborne.

6. Airborne contamination

Airborne contamination is contamination suspended in air.

This creates a particular hazard because of the possibility of intake by inhalation. Inhalation is the most common mode of uptake of radioactive material in the working environment. In addition to the hazard to the worker, radioactive materials may be carried into ventilation systems, the material may be deposited on surfaces over a large area, and there is the potential for releases outside of the facility.

C. Units of Radioactive Contamination

Because radioactive contamination is radioactive material, the units are the same, e.g., disintegrations per minute (dpm) for both.

EO3	*IDENTIFY the units used to measure radioactive contamination.*

When measuring the amount of radioactive contamination (material) on a surface, the units most commonly used are disintegrations per minute per 100 centimeters squared (dpm/100 cm^2).

1. Direct reading

Contamination monitors measure radiation emitted by the radioactive material. The units are normally seen by the monitor 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. The counter efficiency (expressed as the ratio of cpm/dpm) is divided into the measured cpm to obtain the activity.

D. Causes of Radioactive Contamination

EO4	*IDENTIFY causes of radioactive contamination.*

Radioactive material can be spread to unwanted locations. The following are some causes of radioactive contamination:

1. Sloppy work practices, such as cross-contamination of tools, equipment, or workers.

2. Not wearing gloves, or removing them prematurely.

3. Poor housekeeping in contaminated areas.

4. Opening radioactive materials/systems without proper controls.

5. Leaking containers or tears in radiological containers such as barrels, plastic bags, boxes, or protective gear.

6. Spills, glass breakage, and animal fluids.

7. Airborne contamination depositing on surfaces.

8. Not adhering to standard laboratory procedures (such as not checking gloves after handling radioactive materials or working in a potentially contaminated area).

9. Emergencies including:

    - Fire.
    - Earthquake, etc.

E. Indicators of Possible Area Contamination

The following are some indicators of possible area contamination:

1. Visual indicators, such as:

    - Leaks, spills, standing liquids.
    - Damaged radiological containers.

2. Detection of contamination or elevated radiation levels including:

    - Spurious or unexplained personnel contamination.
    - Radioactivity observed in bioassay samples collected.
    - Higher than normal background on personnel contamination survey devices.
    - Higher than normal background radiation levels on area monitors and air samples.
    - Routine radiation and contamination surveys conducted by Radiological Control Organization.

F. Primary Reasons for Contamination Control

1. Protection of the worker

Measures to control radioactive contamination are implemented to protect workers by:

- 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 (e.g., sharp instrument punctures).
   - Absorption (skin, mucous membranes, eyes).
   - Ingestion (biting nails, applying cosmetics, eating, drinking or smoking in the lab or outside without monitoring or washing hands).

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.

Also, note that resources applied to cleanup reduce the resources available for other program goals. Additionally, serious contamination events may detract from maintaining good public relations.

G. Radiological Contamination Control Measures

Contamination control measures should address:

1. Characteristics of radionuclides used:

   Type of radiation emitted
   Energy of radiation emitted
   Half-life

2. Preparation of areas and materials - including:

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

3. Good work practices - including:

   - Special precautions for handling liquids.
   - Special precautions for handling sharps.
   - Clean up the work area at the end of the job or end of the day, whichever is first.

4. Radioactive waste management.

5. Radiation monitoring (including interpretation of meter readings) during and at completion of work. If a problem is detected or suspected, notify the Radiological Control Organization.

6. Decontamination.

7. Regulatory requirements.

8. Training requirements.

II. CHARACTERISTICS OF COMMONLY USED RADIONUCLIDES

Because radioactive contamination is radioactive material, the units are expressed in activity; e.g. disintegrations per minute (dpm).

Insert facility-specific radionuclides (see Appendix A).

V. PREPARATION OF WORK AREA AND MATERIALS

EO5 IDENTIFY methods used to control radioactive contamination.

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 laboratory. The work station should not conflict with other work within the laboratory (i.e., strong gamma emitters near low background counting equipment, etc.).

B. Preparation of Work Areas

1. Minimize area

   Confine operations involving radioactive materials to as small a space as practical.

2. Clear area

   Clear area of extraneous items and material.

3. Work surface

   Cover area as appropriate. Diaper paper should be placed absorbent side up.

4. Containment

   Use trays when appropriate.

5. Waste

   Receptacles for radioactive waste should be located by the work station so you may conveniently dispose of waste without further contamination of the work area.

C. Preparation of Equipment/Materials

1. Assemble survey meters

   The survey meter should be turned on and located in close proximity to the work station. A pre-operational check is necessary before use to ensure the meter is working properly. Position the detector so it is directed toward your work area. This will enable you to conveniently monitor your hands as you work and also can indicate when materials are removed from shielded containers. Always work with the audio turned on. Your safety and the safety of others must take priority over the concept that the sound may be disturbing to others. Know the location of nearby phones. Post the Radiological Control Organization phone number nearby.

2. Equipment preparation

   Use dedicated equipment/tools when appropriate. Cover/tape tools or equipment used during the job to minimize radioactive contamination.

3. Assemble materials and supplies

   Those supplies that would minimize small spills of radioactive materials should be within arm's reach while handling unsealed radioactive materials.

4. Marking and labeling

   - The area/material is marked and labeled as appropriate (typically by Radiological Control personnel).
   - Do **NOT** discard intact radioactive labels/markings in normal trash!
   - Remove or deface labels before discarding boxes, etc.

D. Shielding

1. Placement

   Placement of shielding materials is critical to both your safety and that of your colleagues. Work stations that require the use of shielding should be located where there would be no worker on the opposite side of the workbench, such as in corners and against walls.

2. Penetration through walls

   Be certain to consider what (or who) is on the other side of the wall. However, if this can not be accommodated, shielding should be considered for the work station on the opposite side of the workbench or wall where your colleague may be working.

3. Beta and Gamma Emitters

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

4. Considerations

Some considerations for use of shielding were addressed above. Because issues involving shielding can be complex, always consult the Radiological Control Organization before using shielding.

E. Ventilation Control

1. Airflow

   Airflow should be from the areas of least contamination to areas of most contamination (e.g., clean to contaminated to highly contaminated areas) such as fume hoods, gloveboxes, etc.

2. Pressure differential

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

3. High Efficiency Particulate Air (HEPA) filtration.

   HEPA filters, which remove radioactive particles from the air, may be used. This is commonly required for higher levels of airborne radioactivity such as concentrations exceeding 10 percent of the Derived Air Concentration (DAC) for a particular radionuclide. Charcoal filters are required for specific radionuclides such as iodine. Ventilation system requirements should be determined in consultation with the Radiological Control Organization.

   A DAC is the radionuclide airborne concentration. Breathing an air concentration of 1 DAC for 1 working year (2,000 hours) will result in committed dose equal to an annual limit, i.e., 5 rem whole-body or 50 rem to any organ or tissue.

4. Flow rate

   Always check the flow rate or pressure in ventilated enclosures before starting operations. Air flow is easily measured with an inexpensive velometer. Refer to facility-specific flow rate measurement requirements.

F. Posting of Radiological Areas

10 CFR 835.602 requires that each access point to a controlled area be appropriately posted. Further, 835.603 requires that each access point to a radiological area be appropriately posted.

Posting of radiological areas is typically a Radiological Control Organization function. Workers should become aware of the posting requirements. DOE has designated the following areas as requiring posting:

1. Radioactive Material Area

An area or structure where radioactive material, exceeding the values provided in 10 CFR 835 Appendix E, is used, handled, or stored. The posting/sign will indicate:

"CAUTION, RADIOACTIVE MATERIAL" or
"DANGER, RADIOACTIVE MATERIAL"

Additional posting is not required if the Radioactive Material Area is inside a Contamination, High Contamination, or Airborne Radioactivity Area.

2. Contamination Area

   Any area where removable contamination levels are greater than the values specified in Appendix D of 10 CFR 835, but less than or equal to 100 times those levels.

   The posting/signs will indicate:

   "CAUTION, CONTAMINATION AREA"

Abbreviated Table of Contamination Values (See 10 CFR 835 Appendix D for Complete Listing)		
NUCLIDE	REMOVABLE	TOTAL
I-125	21	500
I-131, I-133	200	1,000
Beta/gamma	1,000	5,000
Tritium	10,000	N/A

3. High Contamination Area

   Any area where removable contamination levels are greater than 100 times the values listed in Appendix D of 10 CFR 835.

   The posting/sign will indicate:

   "DANGER, HIGH CONTAMINATION AREA" or

   "CAUTION, HIGH CONTAMINATION AREA"

4. Airborne Radioactivity Area

Any area where the measured concentration of airborne radioactivity, above natural background, exceeds or is likely to exceed the derived air concentration (DAC) values listed in Appendix A or Appendix C of 10 CFR 835 or where an individual in the area without respiratory protection could receive an intake exceeding 12 DAC-hours in a week.

The posting/sign will indicate:

"CAUTION, AIRBORNE RADIOACTIVITY AREA" or

"DANGER, AIRBORNE RADIOACTIVITY AREA"

A DAC is the radionuclide airborne concentration. Breathing an air concentration of 1 DAC for 1 working **year** (2,000 hours) will result in committed equivalent dose equal to an annual limit, i.e., 5 rem whole-body or 50 rem to any organ or tissue.

G. Labeling of Radioactive Materials and Other Postings

1. **"CAUTION, RADIOACTIVE MATERIAL"**

   Equipment, components, and other items that are radioactive, potentially radioactive, or have been in contact with radioactive contamination or activation sources.

2. **"CAUTION, INTERNAL CONTAMINATION" or**

   "CAUTION, POTENTIAL **INTERNAL CONTAMINATION"**

   Equipment, components, and other items with actual or potential internal contamination.

3. **"CAUTION, FIXED CONTAMINATION"**

   Components, equipment, or other items with fixed contamination.

4. **Facility-Specific Postings/Labeling**

   These may include Radiological Buffer Areas.

VI. CONDUCT OF WORK - GOOD PRACTICES

A. Personal Preparation

Ensure that you are ready to work and that you have the following:

- Training to meet entry requirements.
- Work permits, procedures, etc.
- Dosimetry.
- Personal protective equipment.

B. Requirements of Posted Contamination Areas

EO7 IDENTIFY the requirements for entry, working in and exiting Contamination Areas and Airborne Radioactivity Areas.

1. Requirements for entry into posted contamination areas.

   The RadCon Standard recommends individuals allowed unescorted entry into Contamination Areas be provided the following:

   - Radiological Worker II training.
   - Worker's signature on the Radiological Work Permit, as applicable.
   - Protective clothing/equipment as required by the Radiological Work Permit.
   - Personnel dosimetry, as appropriate.
   - Pre-job briefing for High Contamination and Airborne Radioactivity Areas.

2. Requirements for working in posted contamination areas.

   The RadCon Standard recommends that individuals allowed unescorted entry into Contamination Areas:

   - 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. This could result in skin contamination.

Smoking, eating, chewing, drinking, and putting on makeup could result in ingesting radioactive material; for this reason, the activities are not allowed in Contamination Areas.

3. Requirements for exiting posted contamination areas.

   RadCon Standard recommends that individuals allowed unescorted entry into Contamination Areas:

   a. Exit only at 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. Correct use of step-off pads is included in the practical factors exercise.

      - If more than one step-off pad is used, the final step-off pad is "clean," outside the exit point, and 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 potential inhalation if contamination becomes airborne.

   c. Perform a personal survey. If contamination is indicated:

      - Stay in the area.

      - Notify Radiological Control personnel.

      - Take action to minimize cross-contamination (e.g., put a glove on a contaminated hand or tape over contamination on clothing too).

   d. Tools or equipment being removed from a posted area must be monitored prior to release.

   e. After exiting and monitoring yourself, it is a good practice to wash your hands.

C. Dosimetry

Always have proper personnel monitoring that might include:

1. Whole body

   Whole-body dosimeter such as a thermoluminescent dosimeter (TLD) or film badge.

2. Extremity monitoring

   Finger rings, if handling high contact dose rate materials such as P-32.

D. Personnel Protective Clothing (Anti-C)

The degree of clothing required is dependent on the work area, radiological conditions, and the nature of the job. The use of personnel protective clothing and equipment is the least desired option. Use of engineering controls such as gloveboxes or fumehoods is preferred. Standard clothing requirements for research laboratory work include:

EO8	*IDENTIFY the proper use of protective clothing.*

- Lab coats with long sleeves that are buttoned or otherwise closed.
- Surgeon's gloves; the gloves may need to protect against radioactive contaminants as well as other lab hazards applicable, such as acids and caustics.
- Closed-toed shoes.
- Safety glasses or equivalent for eye protection from eye hazards including radiological hazards such as from P-32.

1. Proper use of protective clothing

   - Inspect all protective clothing for rips, tears, holes, or wear prior to use.
   - Personal effects such as watches, rings, jewelry, etc. should not be worn.
   - After donning protective clothing, such as anti-contamination clothing, proceed directly from the dress-out area to the work area. In general, a lab coat is sufficient to protect the individual at most research laboratories.
   - Avoid getting lab coats wet. Wet lab coats provide a means for contamination to reach the skin/clothing.
   - Contact Radiological Control personnel if clothing becomes ripped, torn, etc. during operations.

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. This training course does not qualify a worker to wear respiratory equipment. Ventilation design should eliminate the need to use respiratory equipment except in extreme cases.

E. Storage and Containment of Radioactive Material

Containment generally means using vessels, trays, diaper paper, bench tops, etc. to contain contamination.

EO5	*IDENTIFY methods used to control radioactive contamination.*

1. Storage areas

   a. Store large bottles and containers close to the floor.

   b. Shelves should:
      - Be secured (bolted) to a wall.
      - Have lips or restraining cords to prevent bottles from falling.

   c. Storage area should be well lit, properly ventilated, and have an even temperature.

2. Radioactive materials should be properly stored:

   - In unbreakable containers; if not possible, secondary containment (the secondary containment should be able to contain the entire volume of the primary container).

   - In stable containers with secure means of closing.

   - Away from sinks and drains or other possible pathways that do not collect in retention tanks.

   - Protected from adverse environmental factors.

   - Away from combustibles and other fire sources.

   - Protected from "unauthorized relocation," this may include locked refrigerators and storage cabinets.

   - With the outside of the container clearly labeled with contents.

- With provided instructions to open containers.

3. Posting and labeling of storage areas

   Room access and cabinets, refrigerators, freezers, etc., that house the container should be posted or labeled "Caution Radioactive Material" or "Danger, Radioactive Material."

4. Chemical considerations for storage

   Segregate incompatibles and store by hazard class. Appendices B and C address chemical storage in more detail.

F. Good Housekeeping

EO5	*IDENTIFY methods used to control radioactive contamination.*

"Good housekeeping" is the prime factor in an effective contamination control program and 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. RadCon Required Actions and Good Practices

1. BELIEVE! labels and posted areas.
2. Avoid Contamination and Airborne Radioactivity Areas. These areas should be isolated from routine operations.
3. Treat Contamination Areas as if everything was contaminated.
4. Minimize the number of items carried or placed into potentially contaminated areas.
5. Use proper and functional radiation detection instrumentation.
6. Do not eat, drink, apply makeup, etc.
7. 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, e.g., under equipment.

1. Handling liquids

   Standard good practices for handling liquids include:

   - Use appropriate gloves for liquids being handled.
   - Protect personal clothing.
   - Work in a tray with absorbent paper.
   - Use mechanical pipettes and dilutors (**NEVER** pipette by mouth).
   - Work in a properly vented area.
   - Report any spills or suspected spills.

2. Preventing 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 closure.
   - Avoiding unstable (top heavy) containers or arrangements.
   - Using secondary containment for liquids.
   - Leaking containers
   - Report all suspected leaks immediately to the Radiological Control Organization.
   - 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

EO9	*IDENTIFY the appropriate response to a spill of radioactive material.*

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

- **S**top the spill.
- **W**arn others.
- **I**solate the area.
- **M**inimize exposure.
- **S**ecure the ventilation system (as necessary and if qualified). If the spill involves volatile chemical or volatile or gaseous radionuclides, the ventilation may need to be left on.
- As previously discussed, report the spill to the Radiological Control Organization.

V. RADIOACTIVE WASTE MANAGEMENT

E05	*IDENTIFY methods for reducing radioactive waste.*

A. Segregation

Segregate waste by waste stream category and half-life to facilitate storage, minimization, and disposal.

B. Waste Storage

Each laboratory should have a designated location for storing 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, recognizable, and properly labeled and shielded.

Liquid waste materials should be kept in secondary containers and segregated by hazard class. Secondary containers may be lab trays or any device that will contain 110 percent of the largest container.

C. Sharps

Contaminated syringes, glass pipettes, and other sharp items must be placed in a specifically designed, rigid container.

D. Methods for Minimizing Waste

1. Minimize waste generation
   a. Confine operations: Confine operations with radioactive materials to as small an area as possible.

   b. Minimize materials: Minimize materials introduced into radioactive material handling areas.

   c. Segregate: Segregate clean materials from radioactive materials. Do not dispose of clean materials in radioactive waste containers.

   d. Good housekeeping: Contamination control measures such as covering benches, etc. generate waste. On the other hand, decontamination generates a great deal of waste. Good housekeeping, following procedures, minimizing bench areas, and secondary containment can reduce the amount of coverings required.

2. Storage for Decay

   a. Storage: Some radionuclides have a short half-life and can be stored, with appropriate DOE approval, for decay. Normal storage times are 10 half-lives. The waste must be surveyed prior to disposal to ensure it is below disposal criteria.

b. Substitution: Substitute shorter-lived for longer-lived radionuclides, if possible.

3. Disposal via Sanitary Sewer

Disposal of small quantities via sanitary sewer is available to some facilities. Add facility-specific information.

4. Disposal of specific waste per 10 CFR 20.2005

In accordance with Part 20.2005, NRC licensees may dispose of the following as if it were not radioactive:

a. Liquid scintillation counting media: Liquid scintillation counting media containing 0.05 microcuries or less per gram of medium of H-3 or C-14.

b. Animal carcasses: Animal carcasses containing 0.05 microcuries or less per gram of animal tissue (averaged over the weight of the entire animal) of H-3 or C-14.

5. Volume reduction

a. Compaction: May produce reduction factors of up to 5 to 1.

b. Shredding: May produce reduction factors of up to 12 to 1.

c. Incineration: Difficult under present regulations and political climate; allowed under 10 CFR 20.2004. Currently, scintillation fluids are incinerated by commercially licensed vendors.

E. Mixed Waste

Mixed waste is exceedingly difficult, if not impossible, to dispose of at this time. Currently, DOE has a self-imposed moratorium on the off-site shipment of RCRA/TSCA waste suspected of having radioactivity. This moratorium was instituted by the DOE Office of Waste Management (EM-30).

1. The EM-30 Performance Objective (PO) for Certification of Non-radioactive Hazardous Wastes was developed in 1991 and is currently under revision. This PO was developed to guide DOE sites in addressing the issue of hazardous waste that contains added radioactivity.

2. Ways to avoid generating mixed waste:
   - Use non-hazardous cleaning materials for decontamination whenever possible.

- Segregate "radioactive only" from "hazardous only" at the source.

- Explore the use of other materials that are non-hazardous for use in radiological areas to prevent the generation of mixed waste.

- Discontinue use of non-biodegradable (organic solvent based) liquid scintillation media. Biodegradable liquid scintillation media are available.

- Some States are more restrictive than the U.S. Environmental Protection Agency (EPA) in their listing of those scintillation cocktails that are biodegradable.

- Organic solvents with a flash point below 60$_o$C (140$_o$F) may be classified as "ignitable," thus creating a mixed waste where disposal may not be possible. If the flash point is above 140$_o$F, the organic solvent may not be considered as ignitable; however, these materials must be handled and disposed of with extreme caution.

3. Other methods for facilitating disposal:

    - Do not combine solvents with metals; disposal is very difficult. Examples are lead or mercury combined with solvents.

    - Generally, it is a good idea to separate organics and inorganics whenever possible to facilitate disposal.

VI. MONITORING FOR CONTAMINATION

While handling unsealed radioactive materials, you should monitor your hands frequently as you work. Monitor your hands, feet, sleeves, and lab coat when leaving the work station or laboratory. It is common to find contamination on the lab coat where you may be leaning against your work station.

A. Contamination Monitoring Equipment

Always use radiation survey meters. Tritium and certain other isotopes, such as C-14, cannot be detected with a thin-window G-M survey instrument. For these isotopes, wipe tests, which are counted in a liquid scintillation counter, are required.

E011 IDENTIFY the purpose and use of personnel contamination monitors.

1. Purpose

   Contamination-monitoring equipment is used to detect radioactive contamination of personnel and work areas.

2. Selection of proper survey instrument

   Correction factors for the specific radionuclide being monitored should be known when surveying. Often the survey instrument will over or under respond when monitoring for beta or alpha radiation.

3. Pre-operational Checks

   Perform pre-operational checks before work:

   - Confirm calibration is current.
   - Verify that battery is OK.
   - Perform an audio check (audio response is immediate, while needle response takes time to stabilize.
   - Ensure instrument responds to source.
   - Verify that background count rate is normal.
   - Variation of daily counting results.

B. Conducting Surveys - General

1. Survey hands before picking the probe up.

2. Hold the probe approximately ½ inch from surface being surveyed.

3. Move probe slowly over surface to be surveyed, approximately 2 inches per second.

C. Area Surveys

1. Frequently monitor work areas.

2. Monitor upon completion of work (or prior to taking a break and leaving the work area).

3. Monitor at least every 2 hours for work in progress.

4. Wipe surveys should be performed on equipment and areas where survey instruments are not adequate to monitor contamination.

D. Personnel Surveys

1. Proceed to survey in the following typical order:
   - Head (pause at mouth and nose for approximately 5 seconds).
   - Neck and shoulders.
   - Arms (pause at each elbow), hands, 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).

2. The whole-body survey should take approximately 3 minutes. A full whole-body survey or 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 lab coat and repeated on personal clothing if contamination is found. If contamination is detected, take proper steps as addressed below in Section E.

3. 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.

4. Carefully return the probe to holder.

5. Keep the instrument close to the work area to facilitate frequent checking of hands and fingers.

E. Detection of Contamination

If contamination is indicated:

1. Remain in the immediate area.
2. Notify Radiological Control personnel.
3. Minimize cross-contamination (such as putting a glove on a contaminated hand until decontamination can be attempted).

F. Release of Materials

1. Release to Controlled Areas.

   Release from potentially contaminated areas to Controlled Areas is covered by 10 CFR 835. Equipment and materials released from a potentially contaminated area must be surveyed and released under a formal program. If surveys indicate the presence of removable contamination at levels greater than 10 CFR 835 Appendix D, the materials may be moved to another posted area. Appropriate controls must be established. Appropriate controls should include:

   - Surveys of materials before movement.
   - Containment of materials during transit.
   - Establishment of approved transit routes.
   - Survey of transit route after movement (if materials exhibited removable contamination).

   Reference: 10 CFR 835.1101(b)

   If surveys indicate presence of fixed contamination only (removable contamination less than 10 CFR 835 Appendix D values), the items may be released to the controlled area if:

   - Routine surveys are performed to ensure contamination remains fixed to surface.
   - The item must be clearly labeled or tagged to warn others of the contamination.
   - Written procedures must be established to control such items.

Reference: 10 CFR 835.1101(c)

2. Unrestricted Release

   Unrestricted release is addressed in DOE Order 5400.5. See Appendix F for more information. A November 17, 1995, memorandum from EH-412 to the field provides supporting guidance (reference DOE 1995).

3. Techniques

   Monitoring techniques for release of materials is covered in Appendix D.

VII. 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.

A. Decontamination or Not

If the presence of loose contamination is discovered, decontamination is a valuable means of control.

1. Economical conditions

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

2. Radiological conditions

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

B. Preventive Methods

1. Identifying and repairing leaks before they become a serious problem.

2. Changing out gloves or protective gear as necessary to prevent cross-contamination of equipment.

C. Skin Contamination

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

E012 IDENTIFY the normal methods used for decontamination.

1. Concerns of skin contamination are:
   - Cross-contamination by touching.
   - Absorption through the skin.
   - Threat of uptake by ingestion, touching face, etc.

2. Skin decontamination

   Intact skin is an excellent barrier, so use gentle methods to decontaminate.

   Normally, mild soap and lukewarm water are used to decontaminate personnel. Good practices include:

- Do not abrade skin.
- Do not chap skin by cold water or harsh chemicals.
- Avoid hot water because it will open pores.

3. If skin contamination remains, a common procedure is to wear surgeon's gloves overnight to induce sweat that will lift contamination from the skin. The decision to wear gloves to induce sweat must be made by the responsible Health Physicist. This practice requires detailed documentation and procedural guidance.

D. Material Decontamination

E012	*IDENTIFY the normal methods used for decontamination.*

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

1. Establish controls to prevent spread of contamination.
2. A high priority is to prevent airborne radioactivity.
3. Decontaminate from areas of low to high contamination (exception is when potential for airborne is high).
4. Decontaminate from top to bottom so that contamination will not run down on the clean surface.
5. Only make one pass, then discard or turn wipe to a clean surface (don't recontaminate area).
6. The Radiological Control Organization will make the final determination if the material has been adequately decontaminated.

VIII. FACILITY-SPECIFIC REQUIREMENTS

Insert facility-specific information.

IX. CONTAMINATION CONTROL LESSONS LEARNED

Insert facility-specific information.

X. SUMMARY - Review of Objectives

EO1 DISTINGUISH between ionizing radiation and radioactive contamination.

EO2 DEFINE

- Fixed.
- Removable.
- Airborne contamination.

EO3 IDENTIFY the units used to measure radioactive contamination.

EO4 IDENTIFY causes of radioactive contamination.

EO5 IDENTIFY methods used to control radioactive contamination.

EO6 DEFINE Contamination Area, High Contamination Area, and Airborne Radioactivity Area.

EO7 IDENTIFY the requirements for entry, working in, and exiting Contamination Areas and Airborne Radioactivity Areas.

EO8 IDENTIFY the proper use of protective clothing.

EO9 STATE the appropriate response to a spill of radioactive material.

EO10 IDENTIFY methods for reducing radioactive waste.

EO11 IDENTIFY the purpose and use of personnel contamination monitors.

EO12 IDENTIFY the normal methods used for decontamination.

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GLOSSARY

Terms used consistent with regulatory definitions.

Becquerel (Bq): The SI unit for activity equivalent to 1 nuclear disintegration per second.

Beta Decay: Radioactive decay in which a beta particle is emitted. This transformation changes only the atomic number of the nucleus, raising or lowering the atomic number (Z) by one for emission of a negative or positive beta particle, respectively.

Beta Particle: Charged particle emitted from the nucleus during radioactive decay, having a mass and charge equal to that of an electron.

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

Biological Half-Life: See Half-Life Biological.

Characteristic X-ray: X-rays that are characteristic of the element in which they are produced. Their emission results from the rearrangement of electrons in the shells of excited atoms.

Contamination: Undesired (e.g., radioactive or hazardous) material that is deposited on the surface of, or internally ingrained into, structures or equipment, or that is mixed with another material.

> Radioactive Contamination: A radioactive substance dispersed in materials or places where it is undesirable.
>
> Fixed Contamination: Radioactivity remaining on a surface after repeated decontamination attempts fail to significantly reduce the contamination level.
>
> Removable Contamination: That fraction of the radioactive contamination present on a surface that can be transferred to a swipe tab by rubbing with moderate pressure.
>
> Surface Contamination: The deposition and attachment of radioactive materials to a surface, also the resulting deposit.

Continuous Air Monitor (CAM): Instrument that continuously samples and measures the levels of airborne radioactive materials on a "real time" basis and has alarm capabilities at preset levels.

Curie: The unit of activity equal to a rate of 3.7×10^{10} nuclear disintegrations per second.

Decontamination: The reduction or removal of contaminating radioactive material from a structure, area, object, or person. Decontamination may be accomplished by treating the surface to remove or decrease the contamination, or by letting the material stand so that the radioactivity is decreased as a result of natural decay.

Disintegration, Nuclear: A spontaneous nuclear transformation (radioactivity) characterized by the emission of energy and/or mass from the nucleus. When numbers of nuclei are involved, the process is characterized by a definite half-life.

Dosimeter: A portable instrument for measuring and registering the total accumulated dose to ionizing radiation.

Dosimetry: The theory and application of the principles and techniques involved in the measurement and recording of radiation doses. Its practical aspect is concerned with the use of various types of radiation instruments with which measurements are made.

Dose Rate: The radiation dose delivered per unit of time. Measured, for example, in rad per hour.

Effective Half-Life: See Half-Life, Effective.

External Radiation: Exposure to ionizing radiation when the radiation source is located outside the body.

Flash Point: The minimum temperature at which a substance gives off flammable vapor that will ignite if in contact with spark or flame.

Fume Hood: Ventilated containment space, enclosed on five sides, with the sixth side covered by a movable glass or plastic window to allow access and to maintain sufficient inflow of air and splash control to protect the worker from the hazardous materials handled inside.

Gamma Ray: Very penetrating electromagnetic radiation of nuclear origin. Except for its origin, it is identical to an X-ray.

Geiger-Mueller Counter: A radiation detection and measuring instrument. It consists of a gas-filled tube containing electrodes, between which there is an electrical voltage but no current flowing. When ionizing radiation passes through the tube, a short, intense pulse of current passes from the negative electrode to the positive electrode and is measured or counted. The number of pulses per second measures the intensity of radiation. It is sometimes called simply a Geiger counter, or a G-M counter.

Gray (Gy): The SI unit for absorbed dose. One gray is equivalent to one Joule per kilogram or 100 rad.

Half-Life Biological (T_{bio}): The time required for the body to eliminate one-half of an administered dose of any substance by regular processes of elimination. This time is usually the same for both stable and radioactive isotopes of a particular element. The biological half-life of tritium is 10 days, whereas the physical half-life is 12.3 years.

Half-Life, Effective (T_{eff}): The time required for the amount of a radioactive nuclide deposited in a living organism to be diminished 50 percent as a result of the combined action of radioactive decay $T_{½}$ and biological elimination T_{bio}.

$$T_{eff} = T_{bio} \times T_{½} / T_{bio} + T_{½}$$

Half-Life, Physical ($T_{½}$): The time in which half the atoms of a particular radioactive substance disintegrate to another nuclear form. Measured half-lives vary from millionths of a second to billions of years.

Half-Value Layer (HVL): Thickness of a specified substance which, when introduced into the path of a given beam of radiation, reduces the exposure rate by one half.

Health Physicist: A person trained to advise on operating procedures for minimizing radiation exposures, perform radiation surveys, oversee radiation monitoring, and estimate the degree of radiation hazard.

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

Health, Radiological: The art and science of protecting human beings from injury by radiation, as well as promoting better health through beneficial applications of radiation.

High Efficiency Particulate Air (HEPA): An air filter generally rated as being capable of removing at least 99.97 percent of the particulate material in an air stream.

Indirect Bioassay: The assessment of radioactive material deposited in the body by detection of radioactivity in material excreted or removed from the body.

Intake: The quantity of material (activity or mass) initially taken into the body. (For example, in the case of inhalation, the intake includes the quantity of material immediately exhaled.)

Internal Emitter: A term used for a radionuclide deposited in the body.

In-vitro Methods: Detection of radiations emitted by radioactive materials excreted or removed from the body, using radiochemical and/or radioanalytical techniques.

In-vivo Methods: Detection of radiations emitted by radioactive materials deposited in the body, usually by whole body (or critical organ) counting techniques.

Ionization (Ion) Chamber: An instrument that detects and measures ionizing radiation by measuring the electrical current that flows when radiation ionizes gas in a chamber, making the gas a conductor of the electricity.

Ionizing Radiation: Any electromagnetic or particulate radiation capable of producing ions (either directly or indirectly) in its passage through matter.

Irradiation: Exposure to radiation.

Isotope: One of two or more atoms with the same number of protons, but different numbers of neutrons in their nuclei. Isotopes have very nearly the same chemical properties.

keV: The symbol for one thousand-electron-volts (1,000 eV).

Kilo: Symbol k. A prefix indication base unit is to be multiplied by 1,000.

Kilovolt (kV): A unit of electrical potential equal to 1,000 volts.

Lead Equivalent: The thickness of lead affording the same attenuation, under specified conditions, as the material in question.

License: Written authorization issued to the licensee by the NRC or agreement State to perform specific activities related to the possession and use of byproduct, source, or special nuclear material.

MeV: A unit of energy. The energy acquired by an electron accelerated through a potential difference of one million volts.

Micro-: A prefix that divides a basic unit into one million parts. Often used with activity such as microcurie.

Milli-: A prefix that divides a basic unit by 1,000. Often used with dose and activity such as millirem or millicurie.

Million Electron Volts (MeV): Energy equal to that acquired by a particle with one electronic charge in passing through a potential difference of one million volts.

Minimum Detectable Activity (MDA): The lowest amount of any specific radiation that can be detected with a particular level of statistical significance above background levels.

Nano-: A prefix that divides a basic unit by one billion. Often used in measurements of activity such as nanocurie.

Nuclide: A species of atom having a specified number of neutrons and protons in its nucleus.

Personnel Monitoring: Monitoring any part of individuals, their breaths, or excretions, or any part of their clothing to determine the amount of radioactivity present in or on an individual.

Pico-: A prefix that divides a basic unit by one trillion. Often used in measurements of activity such as picocurie.

Proportional Counter: An instrument in which an electronic detection system receives pulses that are proportional to the number of ions formed in a gas-filled tube by ionizing radiation.

Prospective Monitoring: Routine workplace and personnel monitoring for possible intakes of radioactive materials. Prospective monitoring will typically include air monitoring, surface contamination surveys, and bioassay. Any prospective monitoring results above Investigation Levels will trigger retrospective monitoring.

Rad: A unit of absorbed dose. The word comes from the acronym Radiation Absorbed Dose and is equivalent to 100 ergs per gram. It does not take into account the biological effect resulting from the absorbed dose.

Radioactive Material: Radioactive material includes any material, equipment, or system component determined to be contaminated or suspected of being contaminated. Radioactive material also includes activated material, sealed and unsealed sources, and material that emits radiation.

Radioactivity: The process whereby certain nuclides undergo spontaneous disintegration in which energy is liberated, generally resulting in the formation of new nuclides. The process is accompanied by the emission of one or more types of radiation, such as alpha particles and gamma photons.

Radiochemical: A molecule or a chemical compound or substance containing one or more radioactive atoms.

Radiological Buffer Area (RBA): An intermediate area established to prevent the spread of radioactive contamination and to protect personnel from radiation exposure.

Radiological Work Permit (RWP): Permit that identifies radiological conditions, establishes worker protection and monitoring requirements, and contains specific approvals for radiological work activities. The Radiological Work Permit serves as an administrative process for planning and controlling radiological work and informing the worker of the radiological conditions.

Radionuclide: A radioactive (unstable) nuclide.

Radioisotope: An unstable isotope of an element that decays or disintegrates spontaneously, emitting radiation. Approximately 5,000 natural and artificial radioisotopes have been identified.

Reference Man: A hypothetical individual whose characteristics are often used to estimate radiation dose. Reference Man is to be 20-30 years of age, 170 cm (5 ft 10 in) in height, weighing 70 kg (160 lb); and living in a climate with an average temperature of from 10° to 20° C. Reference Man is a Caucasian and is Western European or North American in habitat and custom.

Rem: The unit of equivalent dose. The word comes from the acronym Roentgen Equivalent Man and takes into account the biological effect from an absorbed dose of radiation.

Retrospective Monitoring: Retrospective monitoring is a series of measurements made after an intake is suspected to confirm the intake and assess any doses that may result from the intake.

Roentgen: The unit for exposure. It is that amount of gamma or X-rays required to produce ions carrying 1 electrostatic unit of electrical charge in 1 cubic centimeter (2.58×10^{-4}coulomb/kg) of dry air under standard conditions.

Scintillation Detector: The combination of phosphor, photomultiplier tube, and associated electronic circuits for counting light emissions produced in the phosphor by ionizing radiation.

Shielding: Any material or obstruction that absorbs radiation and thus tends to protect personnel or materials from the effects of ionizing radiation.

SI: The International System of Units ("Le Systeme International d'Unites") as defined by the General Conference of Weights and Measures in 1960. These units are generally based on the meter/kilogram/second units, with special quantities for radiation including the becquerel, gray, and sievert.

Sievert (Sv): The SI unit of equivalent dose. It is equivalent to 100 rem.

Specific Activity: The total activity of a given nuclide per gram of material. Specific activity is a function of half-life and is therefore also unique to each radionuclide. There are approximately 10,000 curies in a gram of tritium and 1 curie in a gram of radium-226.

Survey Meter: An instrument used to monitor the presence of radioactivity by detecting the radiation emitted during the radioactive decay.

Tenth Value Layer (TVL): Amount of shielding material required to reduce radiation exposure by a factor of 10. One TVL is equal to 3.3 HVL.

Tissue Equivalent Material: Material made up of the same elements in the same proportions as they occur in a particular biological tissue.

Thermoluminescent Dosimeters (TLD): Dosimeters made of certain crystalline materials that are capable of both storing a fraction of absorbed ionizing radiation and releasing this energy in the form of visible photons when heated. The amount of light released can be used as a measure of radiation exposure to these crystals.

Tritium: The hydrogen isotope with one proton and two neutrons in the nucleus. Tritium is radioactive and has a half-life of 12.3 years.

Uptake: Quantity of a radionuclide taken up by the systemic circulation, e.g., by injection into the blood, by absorption from compartments in the respiratory or gastrointestinal tracts, or by absorption through the skin or through wounds in the skin.

Whole-Body Counter: A device used to identify and measure the radiation in the body (body burden) of human beings and animals; it uses heavy shielding to keep out background radiation and ultrasensitive scintillation detectors and electronic equipment.

Whole-Body Counting: A technique to determine the internally deposited radionuclides within the body by measuring with an external radiation detector the photons emitted. Results are generally expressed in the form of percent of the ALI for the nuclides in question. This technique can identify and measure accurately normal body radiations as well as those that are taken into the body due to such things as injection, ingestion, and inhalation from atmospheric releases, medical diagnostic and therapeutic techniques, etc.

Whole Body Equivalent Dose: The equivalent dose that results when the whole body is irradiated and taken, when the irradiation is uniform, as equivalent to the effective dose.

X-rays: Penetrating electromagnetic radiation having wavelengths shorter than those of visible light, usually produced by bombardment of a metallic target with fast electrons in a high vacuum.

In nuclear reactions, it is customary to refer to photons originating in the nucleus as gamma rays, and those originating in the extra nuclear part of the atom as X-rays.

APPENDIX A
CHARACTERISTICS OF COMMONLY USED RADIONUCLIDES

TRITIUM (H-3)

Tritium is a low-energy beta emitter and cannot be monitored directly with a thin-window G-M probe. 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 or about 1/3 the maximum energy).

2. Maximum range in air: 1/4 inch (6 mm).

3. Maximum range in water: 6×10^{-3} mm.

4. International Atomic Energy Agency (IAEA) toxicity classification: Low.

5. Physical half-life ($T_{1/2}$): 12.35 years.

6. Effective half-life (T_{eff}): 10 days (the time it takes for ½ of the material to be eliminated from the body by both biological processes and radioactive decay).

7. Critical organ: Whole body (the part of the body where the most limiting dose is delivered).

8. Personnel monitoring: Bioassay - urinanalysis, NOT detected with a dosimeter (thermoluminescent dosimeter or film).

9. Annual Limit of Intake (ALI):

    - Tritiated water: 80 mCi (3×10^9 Bq) by inhalation or ingestion.

10. Shielding: None (the low-energy beta is not very penetrating).

11. <u>Special Considerations</u>:
    - Cannot be measured directly with a thin-window G-M probe (standard survey meter).
    - Can be absorbed through the skin.
    - Many compounds readily penetrate gloves and skin. Handle these compounds remotely, wear two pairs of gloves, and change the outer layer at least every 20 minutes.
    - Tritiated DNA precursors are considered more toxic than tritiated water. However, they are generally less volatile and do not present a significantly greater hazard.

CARBON-14 (C-14)

Carbon-14 is a low-energy beta emitter (about 10 times more energetic than tritium). C-14 is not easily detected with a hand-held survey instrument such as a thin-window G-M (the efficiency is ~ 10%). Monitoring is normally performed by taking a swipe of the area and counting the swipe in a liquid scintillation counter.

1. Maximum energy: 0.156 MeV (the average energy is 0.052 MeV).
2. Maximum range in air: 9 inches (24 cm).
3. IAEA toxicity classification: Medium-low.
4. Physical half-life: 5,730 years.
5. Effective half-life (T_{eff}): 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 (thermoluminescent dosimeter or film).
8. ALI:
    - 2 mCi (8×10^7 Bq) -labeled organic compounds by inhalation or ingestion.
    - 1.6 Ci (6×10^{10} Bq) CO by inhalation.
    - 200 mCi (7×10^9 Bq) CO_2 by inhalation.
9. Shielding: 3mm of plexiglass (if needed) - thicker plexiglass may be used for rigidity.
10. Special Considerations:
    - Detection of C-14 by radiation survey instruments requires special care due to the low efficiency of detection.
    - Some C-14-labeled compounds may penetrate gloves and skin. Handle these compounds remotely, wear two pairs of gloves, and change the outer layer frequently.
    - 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-window G-M probe, sodium-iodide scintillation counter, or liquid scintillation detector.

1. Energy:
   - Maximum beta energy: 0.546 MeV, average energy 0.182 MeV.
   - Gamma energy: 1.275 MeV.
   - Annihilation photon: 0.511 MeV.
2. Maximum beta range in air: 4.7 feet (1.4 m).
3. Unshielded dose rate from 1mCi point source at 1/2 inch (1cm): 11.8 rad/hr.
4. IAEA toxicity classification: High-medium.
5. Physical half-life: 950 days.
6. Effective half-life (T_{eff}): 10.9 days.
7. Critical organ:
   - Whole body for intake of transportable compounds.
   - Lungs for inhalation.
   - Lower large intestine for ingestion.
8. Personnel monitoring: dosimeter and finger rings, uptakes may be determined by urinalysis.
9. ALI:
   - 0.6 mCi (2×10^7 Bq) by inhalation, clearance in weeks.
   - 0.4 mCi (1×10^7 Bq) by ingestion.
10. Shielding:
    - Half-value layer (the thickness required to attenuate the dose rate by 1/2) is 0.26 inches (6.5mm) of lead.

- 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. <u>Special considerations</u>:

- Near an unshielded Na-22 source, dose rates due to beta radiation can be much higher than dose rates due to gamma radiation.

- Avoid direct eye exposure by interposing transparent shielding or indirect viewing.

- Avoid skin dose by indirect handling.

PHOSPHORUS-32 (P-32)

Phosphorus-32 is a high-energy beta emitter that may create a whole body, skin, and an 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 toxicity classification: Medium-low.

5. Physical half-life: 14.29 days.

6. Effective half-life (T_{eff}): 10-14 days.

7. Critical organ:

   - Bone for transportable compounds.

   - Lung and lower large intestine are critical organs for inhalation and ingestion, respectively.

8. Personnel monitoring: Dosimeter and finger rings, uptakes may be determined by urinalysis.

9. ALI:

   - 1mCi (4×10^7 Bq) by inhalation, clearance in days.

   - 0.4 mCi (1×10^7 Bq) by inhalation, clearance in weeks.

   - 0.5 mCi (2×10^7 Bq) by ingestion.

10. Shielding: 1/2 inch (1.2 cm) of plexiglass (that will shield the beta particles and minimize the production of bremsstrahlung).

    P-32 betas will travel
    - 19 feet in air.
    - 0.8 cm in tissue.
    - 0.7 cm in plexiglass.
    - 0.3 cm in aluminum.

11. Special considerations:
    - A high local dose can be received if the radioactive material is touched and allowed to remain in contact with the skin.

- Do not work over an open container, the eyes can receive a substantial beta dose.
- Safety glasses can provide eye protection.
- Contamination is easily detected with G-M thin-window probe.
- Bremsstrahlung radiation will be a consideration for millicurie quantities.
- Radwaste containers may need to be shielded with plexiglass.

Typical dose rates from 0.1 mCi (4×10^6 Bq):

- 3 mrad/hr at 1 cm.
- 0.03 mrad/hr at 10 cm.
- 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: 1.5 feet (0.5 m).

3. Maximum range in tissue: 1 mm.

4. IAEA toxicity classification: Medium-low.

5. Physical half-life: 24.4 days.

6. Effective half-life (T_{eff}): 10-24 days.

7. Critical organ:
   - Bone for transportable compounds.
   - Lung and lower large intestine are critical organs for inhalation and ingestion, respectively.

8. Personnel monitoring: NOT detected with a dosimeter (thermoluminescent dosimeter or film) dosimeter and finger rings, uptakes may be determined by urinalysis.

9. ALI:
   - 9 mCi (3 x 10^8 Bq) by inhalation, clearance in days.
   - 1 mCi (3 x 10^7 Bq) by inhalation, clearance in weeks.
   - 1 mCi (3 x 10^7 Bq) by ingestion.

10. Shielding: 3mm of plexiglass (if needed).

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 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: 0.32mm.
4. IAEA toxicity classification: Medium-low.
5. Physical half-life: 87.4 days.
6. Effective half-life (T_{eff}): 77 days.
7. Critical organ: Whole body and testis.
8. Personnel monitoring: Bioassay - urinanalysis, NOT detected with a dosimeter (thermoluminescent dosimeter or film).
9. ALI:
   - 11 mCi (4 x 10^8 Bq) inorganic compounds (vapor inhalation).
   - 1 mCi (6 x 10^7 Bq) organic compounds.
   - 1 mCi (4 x 10^7 Bq) by inhalation, clearance in weeks.
   - 7 mCi (2 x 10^8 Bq) by ingestion.
10. Shielding: 3mm of plexiglass (if needed).
11. Special Considerations:
    - Detection of S-35 by radiation survey instruments requires special care due to the low efficiency of detection.
    - Sulfur-35 compounds, including methionin, generate volatile fractions particularly during lyophilization or incubation.

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: 0.710 MeV (the average energy is 0.233 MeV).

2. Maximum range in air: 7 feet (2 m).

3. Maximum range in tissue: 0.1 inch (2.6 mm).

4. IAEA toxicity classification: High-medium.

5. Physical half-life: 3×10^5 years.

6. Effective half-life (T_{eff}): 10-29 days.

7. Critical organ:
   - Whole body for transportable compounds.
   - Lung for inhalation.
   - Lower large intestine for ingestion.

8. Personnel monitoring: Urinanalysis, finger rings.

9. ALI:
   - 2 mCi (9×10^7 Bq) by inhalation.
   - 1 mCi (5×10^7 Bq) by ingestion.

10. Shielding: 0.25 inches (6mm) of plexiglass.

11. Special Considerations:
    - Cl-36 beta particles have sufficient energy to penetrate gloves and skin.
    - When handling millicurie quantities, do not work over an open container.
    - Avoid glove and skin contamination or ensure that it is promptly detected and removed.

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 beta energies: 0.257 MeV (the average energy is 0.086 MeV).

2. Maximum range in air: 20 inches (52 cm).

3. Maximum range in tissue: 0.62mm.

4. IAEA toxicity classification: High.

5. Physical half-life: 163 days.

6. Effective half-life (T_{eff}): 163 days.

7. Critical organ: Bone.

8. Personnel monitoring: Bioassay, initially by urine, later by feces. NOT detected with a dosimeter (thermoluminescent dosimeter or film).

9. ALI:

   - 0.5 mCi (2×10^7 Bq) by inhalation.

   - 1.7 mCi (6×10^7 Bq) by ingestion.

10. Shielding: 3mm of plexiglass.

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 an X-ray emitter. Cr-51 is readily detected with a thin-window G-M probe. Liquid scintillation counting is also used.

1. Maximum energy: 0.32 MeV gamma ray (9.8%), a very low energy (0.005 MeV) X-ray (22 %), and 0.004 MeV (66.9%) auger electron.

2. IAEA toxicity classification: Medium-low.

3. Physical half-life: 27.7 days.

4. Effective biological half-life: 27 days.

5. Critical organ: Lower large intestine and lungs.

6. Personnel monitoring: Dosimeter, internal uptakes may be determined by urine or fecal sampling.

7. ALI:

   - 37 mCi (1 x 10^9 Bq) by inhalation, yearly clearance.

   - 35 mCi (1 x 10^9 Bq) by ingestion.

8. Shielding: - 3.2 mm of lead is the first half value layer (thickness of lead that will reduce the dose rate by one-half).

9. Special Considerations:

   Use thin-end window G-M or solid scintillation detectors or liquid scintillation counting.

IRON-55 (Fe-55)

Iron-55 decays by electron capture and is an X-ray emitter. Fe-55 contamination may be detected by a thin-window G-M probe looking at the very low-energy characteristic Mn-55 X-rays. Manganese is formed when the iron nucleus captures an electron. The manganese emits X-rays characteristic to its electron shell structure. Liquid scintillation counting may also be used.

1. Average X-ray energy: Electron capture with an average low energy of 0.006 MeV.
2. IAEA toxicity classification: Medium-low.
3. Physical half-life: 2.6 years.
4. Effective half-life (T_{eff}): 370 days.
5. Critical organ:
   - Liver and spleen for inhalation.
   - Lower large intestine for ingestion.
6. Personnel monitoring: Uptakes evaluated by analysis of blood.
7. ALI:
   - 1 mCi (5 x 10^7 Bq) by inhalation, daily clearance.
   - 4 mCi (1 x 10^8 Bq) by ingestion.

COBALT-57
(Co-57)

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

1. Maximum energy: X-ray radiation from 0.014 to 0.692 MeV (0.122 MeV emitted 85.5% of the time).

2. IAEA toxicity classification: Medium-low.

3. Physical half-life: 270.9 days.

4. Effective half-life (T_{eff}): 9 days.

5. Critical organ: Lower large intestine.

6. Personnel monitoring: Dosimeter, uptakes may be evaluated by whole body counting.

7. ALI:

   - 2 mCi (8×10^7 Bq) by inhalation, yearly clearance.

   - 7 mCi (2×10^8 Bq) by ingestion.

8. Shielding: 3.2 mm of lead is the first half value layer.

IRON-59 (Fe-59)

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

1. Maximum beta energies:
   - 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.

2. Gamma energies:
   - 1.292 MeV.
   - 1.099 MeV.
   - 0.192 MeV.
   - 0.143 MeV.

3. Maximum range in air of beta: 45 inches (115 cm).

4. Unshielded dose rate from 1 mCi point source at 1/2 inch (1 cm): 6.18 rad/hr.

5. IAEA toxicity classification: Medium-high.

6. Physical half-life: 44.6 days.

7. Effective half-life (T_{eff}): 42 days.

8. Critical organ:

   - Liver and spleen for inhalation.
   - Lower large intestine for ingestion.

9. Personnel monitoring: Dosimeter, finger rings - fecal analysis may be used to determine uptake for weeks or months after handling. Urinalysis is recommended from 4-24 hours after handling.

10. ALI:

    - 0.4 mCi (1 x 10^7 Bq) by inhalation.

    - 0.7 mCi (2 x 10^7 Bq) by ingestion.

11. Shielding: 0.38 inch (9.7 mm) of lead is the first half-value layer.

12. Special considerations:

    - Near an unshielded Fe-59 source, dose rates from beta radiation can be much higher than dose rates due to gamma radiation.

- Avoid direct eye exposure.
- Avoid skin exposure.

IODINE-125 (I-125)

Iodine-125 is a gamma and X-ray emitter. I-125 contamination may be detected by a thin-window G-M probe or with liquid scintillation counting.

1. Maximum energy: 0.035 MeV gamma (6.5%), 0.027 MeV x-ray (112.5%) and 0.031 MeV X-ray (25.4%).

2. IAEA toxicity classification: Medium-high.

3. Physical half-life: 60 days.

4. Effective half-life (T_{eff}): 42 days.

5. Critical organ: Thyroid gland.

6. Personnel monitoring: Internal uptakes evaluated by thyroid scan.

7. ALI:

   - 0.05 mCi (1.8 x 10^6 Bq) by inhalation, vapor.
   - 0.04 mCi (1 x 10^6 Bq) by ingestion.

8. Shielding: 0.25 mm of lead is the first half-value layer.

9. Other considerations for iodine compounds:
   - Volatilization of iodine (NaI) is the most significant hazard.
   - Simply opening a vial of sodium iodide at high-radioactive concentrations can cause minute droplets to become airborne.
   - Solutions containing iodide ions should not be made acidic nor stored frozen; both lead to formation of volatile elemental iodine.
   - Some iodide compounds can penetrate surgical rubber gloves - wear two pairs or polyethylene gloves over rubber.
   - Can be easily absorbed through the skin.

IODINE-131 (I-131)

Iodine-131 is a gamma, X-ray and beta emitter. I-131 contamination may be detected by a thin-window G-M probe or with liquid scintillation counting.

1. Maximum beta energies: 0.248 - 0.606 MeV.

2. Primary gamma energies: 0.364 MeV, 0.637 MeV and 0.284 MeV.

3. IAEA toxicity classification: Medium-high.

4. Physical half-life: 8 days.

5. Effective half-life (T_{eff}): 7.6 days.

6. Critical organ: Thyroid gland.

7. Personnel monitoring: Dosimeter, thyroid scan for uptakes.

8. ALI:

   - 0.03 mCi (1 x 10^6 Bq) by inhalation, vapor.

   - 0.03 mCi (1 x 10^6 Bq) by ingestion.

9. Shielding: 2.3 mm of lead is the first half-value layer.

10. Other considerations for iodine compounds:

    Volatilization of iodine is the most significant hazard.

    - Simply opening a vial of sodium iodide (NaI) at high-radioactive concentrations can cause minute droplets to become airborne.

    - Solutions containing iodide ions should not be made acidic nor stored frozen; both lead to formation of volatile elemental iodine.

- Some iodide compounds can penetrate surgical rubber gloves - wear two pairs or polyethylene gloves over rubber.
- Can be easily absorbed through the skin.

APPENDIX B
STORAGE OF RADIOACTIVE/HAZARDOUS MATERIALS

1.0 Containment of Material

Containment generally means using vessels, trays, diaper paper, bench tops, etc. to contain contamination.

2.0 Segregation and Storage

Segregate incompatibles and store by hazard class. Recommended general hazard classes for storage are:

1. Caustics (bases).
2. Acids (mineral).
3. Flammables (including organic acids).
4. Poisons (toxics).
5. Oxidizers.
6. Water reactives.

3.0 General Guidelines

1. Keep flammables by themselves in Underwriters Laboratory (UL) or Factory Mutual (FM) approved safety cans or cabinets.

2. Keep acids away from bases.

3. Separate organics from inorganics.

4. Store oxidizers away from flammables.

5. Provide as much physical separation as possible between classes.

6. Biohazards should be properly labeled and may be stored as one group.

7. Class B and C carcinogens should be properly labeled and stored with their chemical family.

8. Store Class A carcinogens in the glovebox or another regulated area.

   Note: EPA carcinogen designations are as follows:
   EPA-A Human Carcinogen: sufficient evidence from epidemiologic studies to support a casual association between exposure and cancer.

   EPA-B Probable Human Carcinogen: weight of evidence of human carcinogenicity based on epidemiologic studies is limited; agents for which weight of evidence of carcinogenicity based on animal studies is sufficient. Two subgroups: B1: Limited evidence of carcinogenicity from epidemiologic studies; B2: Sufficient evidence from animal studies; inadequate evidence or no data from epidemiologic studies.

EPA-C: Possible Human Carcinogen: Limited evidence of carcinogenicity in animals in the absence of human data.

4.0 Formation of Organic Peroxides

Organic peroxides are a class of compounds that have unusual stability problems that make 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.
- Divinylidene chloride.
- Cumene.
- Sodium amide.
- Methyl acetylene.
- Methylcyclopentene.

APPENDIX C

STORAGE GUIDELINES BY HAZARD CLASS

1.0 Caustics

Caustics are materials with pH > 10. Examples include ammonium hydroxide, calcium hydroxide, and sodium hydroxide.

1.1 Separate from acids.

1.2 Store solutions of inorganic hydroxides in polyethylene containers.

1.3 Store large containers below eye level.

2.0 Acids

Acids are materials with pH < 5. Examples include acetic, chromic, and hydrofluoric.

2.1 Separate from bases and materials that could evolve toxic vapors on contact (i.e., sodium cyanide).

2.2 Store large bottles low to the ground -- at least below eye level.

2.3 Separate inorganic acids from organic acids (i.e., acetic, oxalic, etc.).

2.4 Separate from active metals (i.e., sodium, potassium).

2.5 Store perchloric and nitric acid as oxidizers.

3.0 Flammables/Combustibles

Flammables/combustibles vapors ignite easily at room temperature. Examples include alcohols, esters, ketones, ethers, and pyrophorics.

3.1 Keep flammables by themselves in Underwriters Laboratory (UL) or Factory Mutual (FM approved safety cans or cabinets.

3.2 Keep away from heat, sun, flame, and spark sources.

3.3 Separate from oxidizers.

3.4 Use only (UL) or FM approved "explosion safe" or "spark-proof" refrigerators for cold storage of flammables.

4.0 Poisons (Toxics)

Poisons are dangerous if inhaled, swallowed, or absorbed through the skin. Examples include phenol and hydrazine.

4.1 Store according to label directions.

4.2 Separate from other hazard classes.

4.3 Keep tightly sealed.

5.0 Oxidizers

Oxidizers are materials that yield oxygen: react with water, fire, flammables, and combustibles. Examples include inorganic nitrates, permanganates, inorganic peroxides, persulfates, and perchlorates.

Oxidizers must be stored in accordance with NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals* and NFPA *430, Code for the Storage of Liquid and Solid Oxidizers.*

5.1 Keep separate from flammables and other organic materials.

5.2 Keep separate from reducing agents (i.e., zinc, alkaline metals, formic acid).

5.3 Do not store directly on wooden surfaces.

5.4 Peroxide formers should be labeled with date received and opened, and should be discarded as hazardous waste within three to six months of opening. Depending on the chemical, unopened peroxide performers should be discarded within 12 months of receipt.

6.0 Organic Peroxides

Organic peroxides are a class of compounds that have unusual stability problems.

Oxidizers must be stored in accordance with NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals* and NFPA *432, Code for the Storage of Organic Peroxides*.

APPENDIX D

I. RELEASE OF MATERIALS

A. Monitoring Techniques General

Monitoring techniques for release of materials are addressed in DOE/CH-9401 (1993). The following techniques apply for G-M detectors (H-3 cannot be measured).

1. Surveys should be conducted in a low background area (background levels are not to exceed 300 cpm; lower levels are preferable and in most cases achievable).

2. Direct measurement should be made prior to smear surveys.

3. 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.

   If potential for internal contamination cannot be adequately assessed, material may not be released.

4. An audible response should be utilized as the principal indicator for initial detection of surface radioactivity.

5. The assigned instrument/detector efficiencies should reflect a prior evaluation of facility wastes.

   Typical efficiencies for a thin-window G-M probe.
   - C-14, S-35 - 10%.
   - P-32 - 50%.

B. Beta/Gamma Direct Monitoring

1. <u>Window</u>: Use a thin-window probe, detector window thickness (mylar) should not be more than 2.0 mg/cm^2.

2. <u>Scanning</u>: Scan the surface; in most cases, scanning will cover nearly 100 percent of accessible surfaces.

3. <u>Distance</u>: Maintain detector window no more than 1/2 inch from surface.

4. <u>Speed</u>: The number of counts produced in the detector is inversely proportional to the scanning speed. Scan speed should be no more than 2"/sec.

5. <u>Audio</u>: If at any point a perceivable audible or visual response is detected, perform a stationary evaluation of count rate.

C. Smear Surveys for Releasing Material

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

2. These large-area wipes may be evaluated by holding the probe up to the swipe (~5 sec.)

3. If initial screening evaluation indicates presence of contamination, take representative disc smears (100 cm^2 area) of up to 100 percent of accessible surface areas.

D. Documentation

All surveys for release shall be documented in writing. Documentation of release from controlled areas should include information required by RCM Article 421.5.

APPENDIX E

IDENTIFICATION OF MIXED LOW-LEVEL RADIOACTIVE WASTE (LLW)

1.0 40 CFR PART 261

RCRA, in 40 CFR Part 261 Subpart C, defines general characteristics that, if exhibited by a waste material, require the classification of that material as hazardous. These characteristics are:

1.1 Ignitability.

1.2 Corrosivity.

1.3 Reactivity.

1.4 Toxicity.

2.0 Specific Waste Streams

In addition to defining the characteristics of hazardous wastes, 40 CFR Part 261 lists specific waste streams that are considered hazardous. These lists are compiled in tables in Subpart D according to:

2.1 Hazardous waste from nonspecific.

2.2 Hazardous waste from specific sources.

2.3 Discarded commercial chemical products, off-specification species, and container and spill residues.

APPENDIX F

RELEASE OF POTENTIALLY CONTAMINATED MATERIAL - DOE ORDER 5400.5, Ch.2

1.0 Surface Contamination Levels

Prior to being released, property should be surveyed to determine whether both removable and total surface contamination (including contamination present on and under any coating) is greater than the levels given in the DOE Order 5400.5, Ch.2.

2.0 Potential For Contamination

Property should be considered to be potentially contaminated if it has been used or stored in radiological 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.

3.0 Inaccessible Areas

Where potentially contaminated surfaces are not accessible for measurement, such property may be released after case-by-case evaluation and documentation based on both the history of its use and available measurements demonstrate that the unsurveyable surfaces are likely to be within the release criteria.

4.0 Volume Contamination

EH-412 has provided guidance for release of material that has been contaminated with tritium (reference DOE 1995). Other materials may be released if criteria and survey techniques are approved by DOE.

5.0 Items With Fixed Contamination

Under exceptional conditions, materials and equipment with fixed contamination that exceeds the release criteria may be released for use in Controlled Areas outside of Radiological Areas. As a condition of such release, the removable contamination levels must be below the level specified in Appendix D of 10 CFR 835. The materials shall be routinely monitored, clearly labeled and/or tagged to alert personnel of the contaminated status, and have appropriate administrative procedures established and exercised to maintain control of these items.

6.0 Covering of Contaminated Surfaces

Radioactivity on equipment should not be covered by paint, plating, or other covering material unless contamination levels, as determined by a survey and documented, are below the "Removable" Criteria of Table 1 of DOE Order 5400.5, Ch. 2 (see below). A reasonable effort must be made to minimize the contamination prior to use of any covering.

If it is likely that contamination exists under a painted surface, it may be necessary to remove some of the painted surface to measure contamination levels below. Use a paint remover to collect paint samples from areas of approximately 200 cm^2 . Measure alpha and/or beta-gamma levels beneath paint. Check with Radiological Control personnel prior to using any paint remover to eliminate the generation of mixed waste.

Where potentially contaminated surfaces are not accessible for measurement, the equipment may be released after case-by-case evaluation and documentation based on both the history of its use and available measurements demonstrate that the unsurveyable surfaces are likely to be within the release criteria.

Radionuclides 2/	Average 3/, 4/	Maximum 4/, 5/	Removable 4/, 6/
Transuranics, I-125, I-129, Ra-226,	500	1500	20
Ac-227, Ra-228, Th-228, Th-230, Pa-231. Th-Natural, Sr-90, I-126, I-131,	1,000	3,000	200
I-133, Ra-223, Ra-224, U-232, Th-232 U-Natural, U-235, U-238, and associated decay product, alpha emitters.	5,000	15,000	1,000
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above. 7/	5,000	15,000	1,000

Figure IV-1 Surface Contamination Guidelines

1/ As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

2/ Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.

3/ Measurements of average contamination should not be averaged over an area of more than 1 m^2. For objects of less surface area, the average should be derived for each such object.

4/ The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm.

5/ The maximum contamination level applies to an area of not more than 100 cm^2.

6/ The amount of removable material per 100 cm^2 of surface area should be determined by wiping an area of that size with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wiping 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. It is not necessary to use wiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.

7/ This category of radionuclides includes mixed fission products, including the Sr-90 which is present in them. It does not apply to Sr-90 which has been separated from the other fission products or mixtures where the Sr-90 has been enriched.

APPENDIX G

ANIMAL FACILITIES

1.0 Objective

Describe the exposure potentials when handling animals that contain radionuclides during experiments.

2.0 Outline

- Exposure potentials.
- Methods of minimizing external exposures.
- Methods of minimizing internal exposures.
- Methods of minimizing cross contamination.
- Room contamination problems.

3.0 Dose Potentials

Animals that have had radionuclides administered to them can present a hazard both to the individuals working with them and to the success of the experiment as well. When using radionuclides in animals, one must be sure that the cages are well labeled, away from much foot traffic, and properly maintained to minimize the hazards arising from radionuclide use. Hazards that are likely to be encountered when using radionuclides in animals are listed below:

3.1 External personnel exposure resulting from gamma-emitting radionuclides that have been used in an animal.

3.2 Internal radiation exposure resulting from accidental ingestion of radionuclides.

3.3 Cross contamination of radionuclides from one radiological experiment to another.

3.4 Room contamination that can result in the spread of radionuclides to a non-radioactive use area.

4.0 Methods of Minimizing External Dose

4.1 <u>Distance</u>
Maintain the greatest distance possible between the worker and the gamma-emitting animal to make full use of the inverse square law. This law, simply stated, implies that if the distance from a radioactive source is doubled, the dose is reduced by a factor of four.

4.2 <u>Time</u>
When the distance cannot be minimized, the amount of time spent in the proximity of the radioactive animal should be kept at a minimum.

4.3 Shielding

When the above is not possible for any reason or when the dose rate is determined to be very high, lead shielding of the proper thickness should be placed between the worker and animal. This is a clumsy technique and should only be attempted following consultation with a health physicist.

4.4 Source Reduction

Following the experiment and/or the death the animal, proper waste disposal proceedings should be initiated.

5.0 Methods of Minimizing Internal Dose

When handling radioactive animals or applying radionuclides to animals, it is required that the handler wear gloves that can be thrown away when contaminated. This will prevent the transfer of radionuclides from hand to mouth and is equally important when handling excreta or animal parts that may be radioactive.

Procedures for handling of the animal should be implemented to reduce the possibility of animal bites. This would include such activities as sedation of the animal in some procedures and special handling techniques for specific animals in other procedures. Both the researcher and the animal handler should be trained in these procedures.

6.0 Methods of Minimizing Cross Contamination

Cross contamination may cause the radioactive materials used in one experiment to turn up unexpectedly in the results of another. Since some experiments utilize only minute amounts of radionuclides while others use large amounts, it is easy to visualize the confusion when large amounts of unknown radionuclides appear suddenly in a low-level experiment.

Cross contamination can result from mishandling; contaminated protective clothing; contaminated cages, food, and water supplies; and airborne materials being transferred from cage to cage.

Contaminated cages should be allowed to decay where possible, and then be thoroughly washed. Following washing, they must be surveyed before re-use.

7.0 Room Contamination Problems

These problems can best be avoided by maintaining radioactive animals in a separate room and maintaining high standards of housekeeping in the room. Feces, cage linings, and urine should be stored in the appropriate containers. These items should not be allowed to accumulate.

In case any of the above-mentioned items are spilled, they should be cleaned up immediately, utilizing absorbent, disposable materials. All materials used in cleaning up a spill should be placed in the appropriate containers to preclude the possibility of further contamination spread. It is essential that spills be cleaned up without delay.