Research Laboratory Safety Guidebook
Volume 2: Biological, Physical, and Radiation Safety

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Guidance

VHA CEOSH guidebooks are a “best practice” resource. For policy resources, refer to VA/VHA policy documents.

Executive Summary

The Research Laboratory Safety Guidebook was developed to provide Veterans Health Administration (VHA) facilities best practices to more effectively manage occupational safety and health and compliance in research laboratories. This guidebook is written for Occupational Safety and Health staff, Industrial Hygienists, and research laboratory staff, and includes guidelines and best practices applicable to Department of Veterans Affairs (VA) facilities within the scope of VHA and federal requirements. Additionally, it contains sample forms and templates, fact sheets, and references and resources for background information. The goals of this publication are to increase compliance, assist in developing successful research laboratory safety programs, recognize research laboratory hazards, and reduce exposures.

The guidebook addresses specific application of compliance programs to the research laboratory environment and cross-references to other VHA publications for additional compliance information. The Research Laboratory Safety Guidebook is being published sequentially in three volumes. The first volume focuses on chemical safety. Volume two covers biological, physical, and radiation safety for the research laboratory. Volume three addresses special topics for research laboratory safety programs including animal colony safety, research laboratory decommissioning, risk reduction, and environmental management.

Each chapter presents a general discussion of the section topic. Whenever possible, a URL to a Web site or VA's intranet site is provided for additional information or when further information is warranted. Links to commercial products or services are intended to enhance the topic content and are not an endorsement of any product or service. Each sub-heading within the chapter incorporates practical information, guidelines, and best practices as seen at VHA research laboratories from around the country. At the end of each chapter, a list of resources and enclosures is provided for quick reference.

This volume contains four chapters:

Chapter 1: Research Laboratory Safety: Roles and Responsibilities
Chapter 2: Biological Safety in Research Laboratories
Chapter 3: Physical Safety in Research Laboratories
Chapter 4: Radiation Safety in Research Laboratories

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How to Use This Guidebook

Veterans Health Administration (VHA), Center for Engineering & Occupational Safety and Health (CEOSH) guidebooks are "BEST PRACTICE" resources designed to assist health care facilities with the implementation and enhancement of programs, and to more effectively comply with current Department of Veterans Affairs (VA)/VHA policy and external regulatory standards.

Each guidebook has three sections:

- **Preface:** Disclaimers, Executive Summary *(summary of how this book supports each program)*, Acknowledgements, How to Use This Guidebook, Update Listing *(list of any online updates made to the guidebook before a new publication−check the online version of the guidebook for this information),* CD-ROM Instructions, and Acronyms and Abbreviations, *(list of acronyms and abbreviations used in the guidebook).*

- **Chapter Contents:** Each chapter contains a general discussion that provides VA-specific guidance on the topic.

- **Additional Reference Materials:** Enclosures and Appendices *(many enclosures are provided in their original format to be edited for each facility's use. Examples include templates, forms, samples, tools, and checklists.)*

Each guidebook is available in three formats:

Online Version: Can be accessed via the CEOSH Web site. The online version toolbar includes the following features:

- **Previous and Back Buttons** – These buttons allow you to page through the chapter contents.

- **Contents** – A hyperlinked table of contents that helps you navigate the guidebook quickly. Click this icon to return to the full table of contents from the Search or Favorites tools discussed below.

- **Search** – This feature allows you to type a specific word(s) to be found. Once the search is complete, a hyperlinked list of locations of the word(s) will be displayed.

- **Favorites** – This icon with the star lists your saved favorite guidebook sections.

- **Save Favorites** – This icon with the star and the green plus sign allows you to customize the favorites list for your needs by saving favorite sections. When you are in a location you want to save as a

favorite, click on the star with the green plus sign and that page will be saved in your favorites.

PDF Version (Printer-Friendly): Can be accessed via the CEOSH Web site. This version is designed for you to print locally on a network printer at your workplace or save to a disk for printing at a reproduction facility. Each enclosure is a separate document and must be printed separately.

CD-ROM Version: Information on content and use can be found in the CD-ROM Instructions section.

References and Web site links within each chapter and enclosures/attachments were current at the time of publication.

CD-ROM Instructions

The CD-ROM has an electronic version of the Research Laboratory Safety Guidebook. You can view these files directly from the CD-ROM with no installation, or copy them to your hard drive. The complete book can also be found on the CEOSH Web site (http://vaww.ceosh.med.va.gov).

The CD-ROM contains the following files:

File	Description
Research Laboratory Safety Guidebook Volume 2: Biological, Physical, and Radiation Safety	This folder provides access to this volume of the Research Laboratory Safety Guidebook.
Enclosures	This folder contains all of the enclosures.
Printer-Friendly Version	This folder contains guidebook information as it would appear in printed form. It can be used for printing selected information or full chapters at once.
Visit CEOSH Web site	This will take the user to the CEOSH Web site from which all guidebooks can be accessed

The CD-ROM should start automatically when inserted into the CD Drive. If it does not start automatically, right-click on Start, select Explore, select CD Drive, and select Autorun.exe to activate the CD options.

For Windows XP users:

If your internet explorer options automatically block active content, you will need to temporarily allow blocked content by right clicking on the information bar and selecting “Allow Blocked Content”. At the security warning dialog box, select “Yes” to allow content.

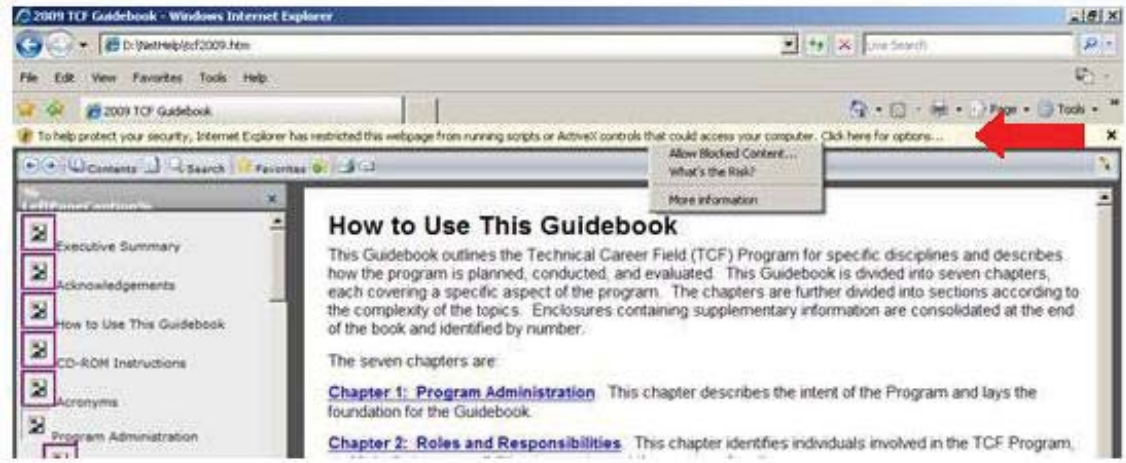

Figure 1: Internet Explorer Screen Shot Enabling ActiveX Controls

For Windows 7 users:

The CD-ROM should start automatically when inserted into the CD Drive. If it does not start automatically, right-click on the Windows Start Orb , select Explore, select CD Drive, and select Autorun.exe to activate the CD options.

If your Internet Explorer options automatically block active content, you will need to allow blocked content by selecting “Yes” at the security warning dialog box.

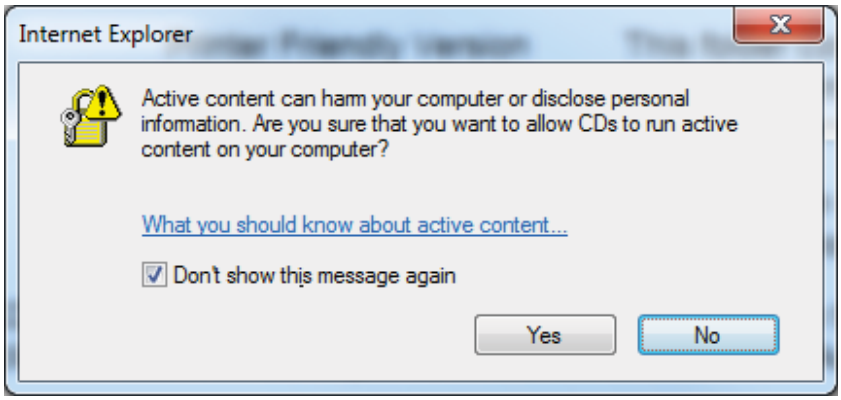

Figure 2: Security Warning Dialog Box

You will need to select “Allow blocked content” on the scripts or ActiveX controls warning bar that appears at the bottom of the screen.

Figure 3: Internet Explorer ActiveX Controls Warning Bar

Update Listing

The following listing identifies online updates since the initial publication of Volume 2: Biological, Physical, and Radiation Safety, of the Research Laboratory Safety Guidebook. It is designed to assist the reader in verifying the most current information available.

Update Number	Date Updated	Remarks	Chapter

Acronyms and Abbreviations

Acronym/Abbreviation	Definition
°C	Degrees Celsius
°F	Degrees Fahrenheit
µCi	microCurie
µl	microliter
µm	micrometer
^{14}C	Carbon-14
^{51}Cr	Chromium-51
^{3}H	Tritium/Hydrogen-3
^{3}He	Helium-3
^{125}I	Iodine-125
^{131}I	Iodine-131
^{133}I	Iodine-133
^{32}P	Phosphorus-32
^{33}P	Phosphorus-33
^{32}S	Sulfur-32
^{33}S	Sulfur-33
^{35}S	Sulfur-35
^{125}Te	Tellurium-125
^{131}Xe	Xenon-131
ACGIH®	American Conference of Governmental Industrial Hygienists
ACOS	Associate Chief of Staff
ACUP	Animal Care and Use Program
ALI	Annual Limit of Intake
ALRA	As Low As Reasonably Achievable

Acronym/Abbreviation	Definition
ANSI	American National Standards Institute
AO	Administrative Officer
ASISTS	Automated Safety Incident Surveillance and Tracking System
ASTM	American Society for Testing and Materials
AWE	Annual Workplace Evaluation
BEI	Biological Exposure Indices
BMBL	Biosafety in Microbiological and Biomedical Laboratories
Bq	Becquerel
BSC	Biological Safety Cabinet
BSL	Biological Safety Level
BSO	Biological Safety Officer
CaO	Calcium Oxide
cc	cubic centimeters
CDC	Centers for Disease Control and Prevention
CEDE	Committed Effective Dose Equivalent
CEOSH	Center for Engineering & Occupational Safety and Health
CFM	Office of Construction & Facilities Management
CFR	Code of Federal Regulations
CGA	Compressed Gas Association
CHO	Chemical Hygiene Officer
CHP	Chemical Hygiene Plan
Ci	Curie
cm	centimeter
cm^2	centimeters squared

Acronym/Abbreviation	Definition
CMO	Chief Medical Officer
CMOP	Consolidated Mail Outpatient Pharmacy
CO_2	Carbon Dioxide
COS	Chief of Staff
cpm	counts per minute
CPR	Cardiopulmonary Resuscitation
CRADO	Chief Research and Development Officer
dB	Decibel
DMSO	Dimethyl Sulfoxide
DNA	Deoxyribonucleic Acid
DOL	U.S. Department of Labor
DOT	U.S. Department of Transportation
dpm	disintegrations per minute
ELF	Extremely Low Frequency
EMF	Electric and Magnetic Fields
EMR	Electromagnetic Radiation
EMS	Environmental Management Service
EO	Executive Order
EOC	Environment of Care
EPA	Environmental Protection Agency
FCC	Federal Communications Commission
FDA	Food and Drug Administration
FMS	Facilities Management Service
ft^3	cubic feet
g	gram
GAO	General Accounting Office

Acronym/Abbreviation	Definition
GEMS	Green Environmental Management System
GFCI	Ground Fault Circuit Interrupter
GHz	Gigahertz
GI	Gastrointestinal
G-M	Geiger-Müller
Gy	gray
HBV	Hepatitis B Virus
HCP	Hearing Conservation Program
HCV	Hepatitis C Virus
HEPA	High-Efficiency Particulate Air
HHS	Department of Health and Human Services
HIV	Human Immunodeficiency Virus
HMR	Hazardous Materials Regulations
HMTA	Hazardous Materials Transportation Act
HPD	Hearing Protection Device
HPPOS	Health Physics Positions
hr	hour
HRPP	Human Research Protection Program
HVAC	Heating, Ventilation, and Air Conditioning
IACUC	Institutional Animal Care and Use Committee
IATA	International Air Transport Association
IBC	Institutional Biosafety Committee
IDLH	Immediately Dangerous to Life and Health
IEEE	Institute of Electrical and Electronics Engineers
IPMP	Integrated Pest Management Program
IR	Infrared

Acronym/Abbreviation	Definition
IRB	Institutional Review Board
kg	kilogram
kHz	kilohertz
LAI	Laboratory-Acquired Infection
lb	pound
LLRW	Low-Level Radioactive Waste
LSC	Liquid Scintillation Counter
mCi	milliCurie
MDVA	Multi-Disciplinary Vulnerability Assessment
MeV	Mega-Electron Volt
mg	milligrams
MgO	Magnesium Oxide
MHz	megahertz
ml	milliliter
mm	millimeter
MML	Master Materials License
mmole	millimole
MMWR	Morbidity and Mortality Weekly Report
MOT	Material of Trade
MOU	Memorandum of Understanding
MPE	Maximum Permissible Exposure
mR	milliroentgen
mrem	millirem
MRI	Magnetic Resonance Imaging
mW	milliWatts
NA_2O	Sodium Oxide

Acronym/Abbreviation	Definition
NF	National Formulary
NFPA®	National Fire Protection Association
NHPP	National Health Physics Program
NIH	National Institutes of Health
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards Technology
nm	nanometer
NRC	Nuclear Regulatory Commission
NRSC	National Radiation Safety Committee
OCAMES	Office of Capital Asset Management, Engineering, and Support
OH	Occupational Health
OIG	Office of the Inspector General
OLS	Optically Stimulated Luminescence
ORD	Office of Research and Development
ORO	Office of Research Oversight
OSH	Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
PHS	Public Health Service
PPE	Personal Protective Equipment
psi	pounds per square inch
R	Roentgen
R&D	Research and Development
rad	radiation absorbed dose
RC	Research Coordinator

Acronym/Abbreviation	Definition
RCEP	Research Compliance Education Program
RCHO	Research Chemical Hygiene Officer
RCO	Research Compliance Officer
rDNA	Recombinant DNA
rem	roentgen equivalent man
RF	Radio Frequency
RIPP	Research Information Protection Program
RNA	Ribonuleic Acid
rpm	revolutions per minute
RPSS	Research Protocol Safety Survey
RSC	Research Safety Coordinator
RSC	Radiation Safety Committee
RSO	Radiation Safety Officer
SAR	Specific Absorption Rate
SDS	Safety Data Sheet
SI	Système International
SOP	Standard Operating Procedure
SRS	Subcommittee on Research Safety
Sv	Sievert
T	Tritium
TIL	Technical Information Library
TLV	Threshold Limit Value
TMS	Talent Management System
TWA	Time-Weighted Average
UN	United Nations
USC	United States Code

Acronym/Abbreviation	Definition
USDA	United States Department of Agriculture
USP	United States Pharmacopeia
UV	Ultraviolet
VA	Department of Veterans Affairs
VAMC	VA Medical Center
VDT	Video Display Terminal
VHA	Veterans Health Administration
VISN	Veterans Integrated Service Network
W	Watt
WHO	World Health Organization
WOC	Without Compensation

Research Laboratory Safety: Roles and Responsibilities

1.1. Introduction

The following chapter describes the roles and responsibilities of program offices and staff that support safety and industrial hygiene functions in research laboratories at Veterans Health Administration (VHA) facilities. The chapter also provides guidance for some key issues that may impact safety programs in research laboratories.

Establishing an effective service-level safety program is a complicated process that requires interaction between various staff (medical center, university affiliates, and private research foundations), as well as service-level and facility committees and subcommittees. Research programs require the support of several Department of Veterans Affairs Medical Center (VAMC) services, departments, and/or entities, such as Facilities Management Service (FMS), Occupational Safety and Health (OSH), Occupational Health (Employee Health), Biological Safety, Infection Control, Radiation Safety, Laser Safety, VA Security, and Environmental Management Service (EMS), as well as other relevant local safety experts/committees. A clear understanding of the VHA organizational structure that includes well-defined roles and responsibilities for Research Service staff is critical to establishing a successful program.

1.2. VHA Organizational Overview

The VHA Research Program involves VHA Central Office, medical centers, academic affiliates, other federal agencies, non-profit organizations, and the private industry. VHA Research Programs and practices are reviewed by national and local offices including:

- The Office of Research Oversight (ORO): The principle VHA office that advises the Under Secretary for Health in regards to compliance and assurance in research programs.
- The Office of Research and Development (ORD): The office that establishes national polices for all research activities in VHA facilities and reports to the Deputy Under Secretary for Health for Policy and Services. Research Programs are aligned under ORD.
- The National Center for Ethics in Health Care: The primary VHA office that addresses complex ethical issues and serves as a resource for research ethics.
- The Office of Occupational Safety, Health, and Green Environmental Management System (GEMS) Programs: The office that reports to the

Assistant Deputy Under Secretary for Health for Policy and Services and oversees the implementation of occupational safety, industrial hygiene, life safety, and GEMS Programs throughout the 21 Veterans Integrated Service Networks (VISNs).

- VISN and VAMC OSH offices: The offices responsible for developing and sustaining safety programs at the local level. The VISN assesses the implementation of research safety programs through annual workplace evaluations (AWEs). Ultimately, all facilities with research laboratory functions are responsible for administering effective safety programs that address organizational structures, staffing levels, the complexity of the Research Program, and the type of research being conducted.

1.2.1. ORO

Mandated by legislation in 2003, ORO reports directly to the Under Secretary for Health and provides programmatic oversight on research compliance and assurance concerns, including human subject protections, laboratory animal welfare, research laboratory safety, research laboratory security, research information security, research laboratory misconduct, debarment for research laboratory impropriety, and other matters that the Under Secretary for Health may assign. ORO is also responsible for developing and conducting Research Compliance Officer education programs as directed by the Under Secretary for Health. ORO has working relationships with VISNs and VHA facilities, and serves as the VA liaison to other federal agencies, such as the Department of Health and Human Services (HHS), U.S. Department of Agriculture (USDA), and the U.S. Department of Labor (DOL).

ORO is comprised of a central office and regional offices. ORO evaluates operational policies and procedures related to VHA research compliance with laws, regulations, and policies. The Central Office staff conducts routine reviews of VA Research Safety Programs and Animal Care and Use Programs (ACUPs), Research Information Protection Programs (RIPPs), Research Compliance Education Programs (RCEPs), and Research Misconduct. ORO staff identifies research compliance and assurance issues that could potentially result in adverse outcomes and ensures implementation of policies and procedures throughout VHA research facilities. The Regional Office personnel serve as subject matter experts for Human Research Protection Programs (HRPPs) and Research and Development (R&D) Committee program reviews. The Regional Offices conduct periodic routine or issue-driven site evaluations to identify problem areas and emergent compliance issues. ORO staff oversees implementation of abatement action plans for deficiencies identified during routine reviews and self-reports from facilities or other federal regulatory agencies. Information about ORO is available online at: http://www.va.gov/oro/.

1.2.2. ORD

The mission of ORD is to discover knowledge, develop VA researchers and health care leaders, and create innovations that advance health care for our Veterans and the nation. ORD develops policies, allocates funds, and creates and implements educational programs that support the research mission. ORD functions include providing consultative support to field research staff and funding opportunities to sustain research. ORD is organized into the following four services:

- Biomedical Laboratory Research and Development Service.
- Clinical Science Research and Development Service.
- Health Services Research and Development Service.
- Rehabilitation Research and Development Service.

ORD investigates all areas of Veterans health care concerns, and each service reports to the Chief Research and Development Officer (CRADO). The CRADO is responsible for the overall policy, planning, coordination, and direction of R&D activities within VHA. He or she reports to the Deputy Under Secretary for Health for Policy and Services and is responsible for the supervision of the four ORD research services directors. An organizational chart and additional information about ORD can be found online at: http://vaww.research.va.gov/default.cfm.

1.2.3. VISN Directors

It is the responsibility of VISN Directors to ensure that all VHA workers and volunteers within the VISN have a safe and healthful working environment and to guarantee employees' rights to report unsafe or unhealthful working conditions without fear of reprisal. VISN Directors are also responsible for monitoring compliance with various entities and regulatory agencies, including OSH requirements contained in federal laws, regulations, and Executive Orders (EOs); VA and VHA directives; and Union agreements. The VISN Director ensures that R&D committees and subcommittees are established by Facility Directors, that the committees are supported throughout the VISN, and that the programs are accredited by relevant external credentialing organizations.

The VISN Director monitors the status of the research OSH Program through AWEs conducted by VISN OSH Program Managers to identify hazardous worksite conditions in research laboratories and other areas of the VAMC. AWE findings are reported through the Facility Director to the Research Service. Abatement measures are coordinated through the facility Safety Office, and corrective actions are tracked by the VISN.

1.2.4. Facility Directors

Facility Directors are responsible for the implementation of all applicable safety policies and procedures in the Research Program as well as the establishment of all required research committees. The Facility Director ensures that staff, utilities, telephones, and information technology services are provided for research

programs and provides access to facility services, such as radiation safety, infection prevention and control, hazardous waste management, and facility engineering.

1.3. Associate Chief of Staff (ACOS)/R&D

The ACOS/R&D (or equivalent) is responsible for the proper functioning of all aspects of the Research Program at his or her designated site. At facilities with smaller research programs, a Research Coordinator (RC) may be assigned the ACOS/R&D duties as an adjunct function of another administrative position. The ACOS or the RC reports through the Chief of Staff (COS) or Chief Medical Officer (CMO) to the Facility Director and plays an important role in communicating safety-related information from the CRADO to appropriate personnel.

1.3.1. Research and Development Committee

As advised in VHA Handbook 1200.01, Research and Development (R&D) Committee, every VAMC involved in the conduct of research must have an R&D Committee of record to oversee all Research Service program functions. This committee serves at the facility level and is responsible through the COS to the Facility Director. The ACOS/R&D and the Administrative Officer (AO) for R&D assist the R&D Committee in the execution of its duties. The R&D Committee focuses on the overall local Research Service (rather than individual protocols) and assigns responsibilities for related issues, such as compliance, to more appropriate subcommittees and/or individuals at the facility. However, the R&D Committee is not limited to serving only as a local committee. A facility may share an R&D Committee with another facility, or a multi-site R&D Committee may be established to regionally serve multiple VHA facilities, through a written Memorandum of Understanding (MOU) that describes the roles and responsibilities of all parties. The R&D Committee may fulfill all R&D Committee responsibilities at another facility, including oversight of its subcommittees, but cannot serve as the R&D Committee of a non-VA institution.

To ensure effective oversight of the Research Program, the R&D Committee establishes several subcommittees that pertain to various aspects of research, including, but not limited to, care and use of research laboratory animals, human studies, and research safety. The R&D Committee is required to establish:

- A Subcommittee on Research Safety (SRS).
- An Institutional Biosafety Committee (IBC) if non-exempt recombinant deoxyribonucleic acid (rDNA) research subject to the National Institutes of Health (NIH) Guidelines is performed.
- An Institutional Animal Care and Use Committee (IACUC) if the research conducted involves the use of animals.
- An Institutional Review Board (IRB) if the research conducted involves human subjects.

Other subcommittees may be established to ensure effective and efficient oversight of the Research Service. In lieu of establishing a subcommittee, the R&D Committee may obtain these services through an MOU with another VA, with an affiliate institution, or with other sources as allowed by VA policies. Representatives to these "in-lieu-of" committees must be appointed by the Facility Director. The R&D Committee may use agreements or contracts to supply program expertise for research programs.

1.3.2. SRS

The SRS is a subcommittee of the R&D Committee that identifies and manages safety and security risks for the Research Service. The SRS reviews all research activities involving biological, chemical, physical, and/or ionizing and nonionizing radiation hazards prior to submission for funding and must grant approval prior to the start of the project. The SRS reviews and approves Research Protocol Safety Surveys (RPSSs) submitted by Principal Investigators and conducts annual reviews of all active research protocols. The SRS coordinates with other local or affiliated regulatory programs, personnel, or committees, such as the Environment of Care (EOC) Committee, the Radiation Safety Committee, and GEMS Committee. The SRS identifies individual projects that require hazard monitoring and/or medical surveillance for affected personnel and ensures that effective training and safety and health programs are in place. Incident reports are reviewed by the SRS to ensure that appropriate action has been taken.

The SRS addresses the root cause for each deficiency identified during research laboratory inspections and coordinates follow-up evaluations to ensure that effective abatement solutions are implemented. The SRS reviews reports of lost time, injuries and illnesses, and significant adverse environmental events, and reports trends in injuries and illnesses to the R&D Committee as appropriate.

The SRS establishes and annually reviews the Research Chemical Hygiene Plan (CHP) and other research-specific plans as required, including the Research Safety Plan, the Research Security Plan, and the Research Emergency Preparedness Plan. The SRS also ensures that annual drills are conducted to test the effectiveness of each of the plans. The SRS is also responsible for evaluating and mitigating security concerns related to the Research Program.

1.4. Occupational Health (OH) Services

OH services are integral to research safety and health programs. Although not a requirement, OH participation on the SRS can enhance the overall safety program. OH services include pre-employment physicals, treatment of minor employee injuries, and medical clearance to work with laboratory animals or for the use of a respirator, if required. OH protocols are available in the VHA Employee Occupational Health Guidebook on the Center of Engineering & Occupational Safety and Health (CEOSH) Web site at: http://vaww.ceosh.med.va.gov/01hp/pages/guidebooks.shtml.

1.5. Research Safety Officials

At some facilities, the Research Service may employ staff dedicated to the oversight of specific safety functions. Research safety officials work in concert with the facility OSH staff but are only responsible for Research Service-level programs. Research safety officials report directly to the Research Service.

- Research Safety Officer: In some of the larger VHA research facilities, the ACOS or CRADO may appoint a Research Safety Officer to manage safety issues associated with research laboratories. The Research Safety Officer position can be full time, part time, or assigned as a collateral duty.
- Research Safety Coordinator (RSC): The R&D Committee appoints an RSC to supervise the operation of the Research Safety Program. Responsibilities of the RSC must be specified in the local written policies of the Research Safety Program.
- Biological Safety Officer (BSO): The R&D Committee may also appoint a BSO if the Research Safety Program has projects meeting hazard levels for rDNA, specifically:
    - The use of rDNA at biosafety level three, or
    - Large scale (greater than 10 liters of culture) research or production activities involving viable organisms that contain rDNA molecules.
- Chemical Hygiene Officer (CHO): A CHO must be appointed by the R&D Committee to serve as a technical expert for development and implementation of the Research CHP.

1.6. Research Compliance Officer (RCO)

The RCO is responsible for reviewing and auditing research projects as specified by ORO. The reviews and audits are conducted to ensure compliance with applicable federal requirements and VHA policies. The RCO may not serve as a member of research review committees but may serve as a non-voting consultant as needed or specified in standard operating procedures (SOPs). RCOs are also responsible for conducting periodic audits of research activities in accordance with VA requirements. The RCO reports directly to the Facility Director. Additional information for RCOs can be found online at: http://www1.va.gov/ORO/Research_Compliance_Education.asp.

1.7. Principal Investigator

Principal Investigators are accountable for all research activities in their assigned areas, including scientific, management, and administrative duties. Principal Investigators ensure that all research protocols are submitted to the SRS for review using VA Form 10-0398, Research Protocol Safety Survey, available

online at: http://www.va.gov/vaforms/medical/pdf/10-0398.pdf, or an equivalent local form.

As leaders of research teams, Principal Investigators must ensure that all safety principles and rules of conduct are followed within research laboratory areas. Principal Investigators must set good examples by establishing safe work practices, monitoring compliance, and implementing effective corrective actions. In addition, Principal Investigators must identify research laboratory-specific hazards and provide training on all procedures performed within their area of responsibility, as well as on safety precautions for each research protocol. They must ensure that research laboratory staff is adequately trained, has appropriate scopes of practice, and is competent in the performance of assigned duties. The Principal Investigators are also responsible for the safe use of engineering controls, such as chemical fume hoods and biological safety cabinets (BSCs), and the use of appropriate personal protective equipment (PPE) by research laboratory staff.

Principal Investigators must ensure that a current inventory of all hazardous chemicals is readily available for research laboratory staff. Principal Investigators are responsible for compliance with the Research CHP and for providing access to Safety Data Sheets (SDSs). Principal Investigators must notify the facility Safety Office and the SRS of all occupational injuries or illnesses incurred by staff under their supervision and ensure that all incidents are entered into the agency's accident reporting system.

1.8. Safety Office

The facility Safety Office is primarily responsible for anticipating, recognizing, evaluating, and controlling safety, health, and environmental regulatory issues throughout the facility and for achieving compliance with relevant federal, state, and local regulations. The facility Safety Office interfaces with regulatory enforcement agencies during announced and unannounced inspections. The facility Safety Office coordinates medical surveillance with OH and ensures assessment of hazardous materials, environmental stressors (chemical, biological, and physical), life safety, environmental compliance, and emergency management concerns within research areas.

The facility Safety Office maintains or has access to occupational safety and health records. The records include inspections and abatement reports, complaints, adverse events, and the appropriate Occupational Safety and Health Administration (OSHA) injury/illness logs. A record of all safety training and attendees should be maintained in the VHA-approved Talent Management System (TMS). Compliance with research safety policies is the responsibility of the Principal Investigator, but the facility Safety Office should help identify unsafe behaviors and conditions and assist Principal Investigators in developing effective solutions. Accident and incident investigation, root-cause analyses, evaluating indoor air quality complaints, exposure monitoring, and respirator fit testing are the combined responsibilities of Research Service and the facility Safety Office.

The GEMS Coordinator may be a member of the facility Safety Office staff and is often responsible for hazardous waste management. GEMS Coordinators typically oversee management and disposal of waste streams and provide solutions to waste issues in research laboratories.

The Radiation Safety Officer (RSO) may or may not be assigned to the facility Safety Office. The RSO is responsible for all issues pertaining to ionizing radiation safety and disposal of radioactive wastes and, at some facilities, may be the Laser Safety Officer.

1.9. FMS

The Safety Office and FMS work together to maintain a safe and healthful research laboratory environment. Heating, ventilation, and air conditioning (HVAC); plumbing; water supply; gas; sewer; and electrical services are provided by the facility and maintained by FMS. General ventilation is an important part of research laboratory safety because it ensures adequate air flow, appropriate number of air changes, and relative positive/negative room pressure relationships. Further, the correct balance of the room ventilation system is critical to proper functioning of research laboratory fume hoods and exhausted BSCs.

The Office of Construction & Facilities Management (CFM) provides design manuals and specifications for research laboratory spaces and equipment locations. FMS uses this information to ensure optimal work space and functional equipment in the research laboratory. These publications are available in the CFM Technical Information Library (TIL) online at: http://www.cfm.va.gov/TIL/.

1.10. Key Issues

1.10.1. Communication

Good communication between research sites and ORO is important. Adverse events, incidents, and exposures resulting in, or likely to result in, adverse health effects in research laboratories must be reported in compliance with VHA Handbook 1058.01, Research Compliance Reporting Requirements, available online at:
http://vaww1.va.gov/vhapublications/ViewPublication.asp?pub_ID=2463. Items that require reporting include:

- Serious unanticipated problems involving risks to workers or the environment.
- Work-related and other injuries: Any work-related injury to personnel involved in VA research or any research-related injury to any other person that requires more than first aid.
- Work-related exposures: Any work-related exposure of research laboratory staff to pathogens or hazardous materials resulting in health

symptoms that require more than minor medical intervention or that could lead to serious complications or death.

- Serious or continuing non-compliance: Any serious or continuing non-compliance with VA or other federal requirements related to research safety.
- Near misses: Voluntary reporting of near misses (an event that could have resulted in an adverse event).

The facility Safety Office must be notified 30 days prior to decommissioning a research laboratory. The notification applies to research laboratory space that is being reassigned, vacated, or converted to non-laboratory use and requires identification, removal, and disposal of hazardous chemicals, radioactive materials, hazardous wastes, and/or equipment. If the facility Safety Office is not notified of the decommissioning of a research laboratory, it is considered non-compliant and is reportable to ORO.

Additional reporting information can be found in VHA Handbook 1058.01, available online at: http://www1.va.gov/vhapublications/ViewPublication.asp?pub_ID=2463.

1.10.2. Without Compensation (WOC) Staff

WOC staff plays a large role in VHA research. Typically, they are academic affiliate personnel performing research on VA property and, at some research laboratories, may comprise up to 75 percent of the research staff. It is important for WOC staff to be aware that when they use any VHA resource, they are subject to all of the same regulations, requirements, and policies as federal employees. WOC staff is also subject to VHA training requirements, OSHA regulations, and reporting requirements. Some facilities have established an MOU that describes training reciprocity with their academic affiliate.

1.10.3. External Inspections

Officials authorized by the VA, the Secretary of HHS, the Secretary of the USDA, General Accounting Office (GAO), or other authorized federal agencies or entities may conduct inspections of all VHA research laboratories. Such agencies or entities include the Centers for Disease Control and Prevention (CDC), Environmental Protection Agency (EPA), OSHA, VA Office of the Inspector General (OIG), accrediting agencies, ORD, and ORO. Inspections may be either announced or unannounced.

1.11. References and Resources

1. ORD Policies: http://www.research.va.gov/resources/policies/by_number.cfm.
2. VHA Directive 7701, Occupational Safety and Health (OSH): http://www1.va.gov/VASAFETY/AugStuff/VHADirective.pdf.

3. VHA Handbook 7701.01, Occupational Safety and Health (OSH) Program Procedures: http://www1.va.gov/vhapublications/ViewPublication.asp?pub_ID=2282.

4. VHA Handbook 1058.01, Research Compliance Reporting Requirements: http://www1.va.gov/vhapublications/ViewPublication.asp?pub_ID=2463.

5. VHA Handbook 1200.01, Research and Development (R&D) Committee: http://www1.va.gov/vhapublications/ViewPublication.asp?pub_ID=2038.

6. VHA Handbook 1200.06, Control of Hazardous Agents in VA Research Laboratories: http://www1.va.gov/vhapublications/ViewPublication.asp?pub_ID=1336.

7. VHA Handbook 1200.08, Safety of Personnel Engaged in Research: http://www1.va.gov/vhapublications/ViewPublication.asp?pub_ID=1850.

1.12. Enclosures and Fact Sheets

Enclosure 1 Fact Sheet Listing

The following fact sheets contain quick-reference information relevant to this chapter:

1.1 Applicable Regulations
1.2 Applicable VHA Policies
1.3 Research Laboratory Audits and Inspections

Biological Safety in Research Laboratories

2.1. Introduction

Biological agents commonly used in research laboratories present a risk of exposure to research workers. The Veterans Health Administration (VHA) Handbook 1200.08, Safety of Personnel Engaged in Research (http://vaww1.va.gov/vhapublications/ViewPublication.asp?pub_ID=1850) clearly states that individual research laboratories must adhere to Centers for Disease Control and Prevention (CDC) Biosafety in Microbiological and Biomedical Laboratories (BMBL), 5th edition (http://www.cdc.gov/biosafety/publications/bmbl5/) and National Institutes of Health (NIH) safety and health guidelines for recombinant deoxyribonucleic acid (rDNA) (http://oba.od.nih.gov/rdna/nih_guidelines_oba.html).

A study of clinical and research laboratories (Harding and Byers, 2006) found that 51 percent of laboratory-acquired infections (LAIs) originated from exposures in research laboratories, with some of the occupationally acquired infections proving fatal. Most laboratory exposures are known to occur at biological safety level (BSL)-2 containment and involve common biological agents. Some common infectious organisms include, but are not limited to:

- *Escherichia coli.*
- Hepatitis B (HBV).
- Hepatitis C.
- Human immunodeficiency virus (HIV).
- *Mycobacterium tuberculosis.*
- *Neisseria meningitides.*
- *Salmonella spp.*
- *Shigella spp.*

2.2. VHA Biological Safety Program and Policy

VHA Handbook 1200.08 requires every Department of Veterans Affairs (VA) Research Program in which research involving hazards is performed to establish and implement a research-specific safety plan. For research programs in which work with biological hazards is conducted, the safety plan must include biological safety practices and procedures. Additionally, research laboratories that involve work in BSL-3 containment are required to maintain a separate biological safety research laboratory manual that includes specific standard operating procedures (SOPs) and emergency procedures for that laboratory. The requirement also exists for manuals to be reviewed and updated annually by the Subcommittee on Research Safety (SRS). Additional information can be found on the VHA

Research and Development Web site online at:
http://www.research.va.gov/programs/biosafety/default.cfm.

2.2.1. Research Laboratory Manuals

A research laboratory manual should include provisions for engineering controls, work practice controls or administrative controls, standardized procedures, and personal protective equipment (PPE) necessary to protect workers from potential exposures in research laboratories. These should include mechanisms to minimize or eliminate exposures to biological hazards and coordination with the Occupational Health unit to provide workers with immunizations and/or post-exposure treatment, if available. Additionally, all research laboratory workers must be aware of and utilize universal precautions in the handling of biological materials that may be contaminated with bloodborne pathogens. These procedures must follow Code of Federal Regulations (CFR) 29 CFR 1910.1030, Bloodborne Pathogens, available online at:
http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10051.

2.2.2. Biohazard Emergency Procedures

Emergency procedures must be in place for biohazardous spills and post-exposure protocols. Spills of biohazardous material must be dealt with promptly by an individual properly trained to manage such spills. An example of an SOP for dealing with a biohazardous spill can be found in Enclosure 2, Sample Biological Spill Response Procedures.

Post-exposure prophylaxis guidelines for bloodborne pathogens are covered in 29 CFR 1910.1030. Anyone exposed to biological hazards in the research laboratory setting should report to an emergency department and/or Occupational Health immediately for evaluation and possible treatment.

2.2.3. Biosecurity

The objectives of biosecurity are focused primarily on administrative controls and physical security to prevent loss, theft, or misuse of microorganisms, biological materials, and research-related information. Biosecurity differs from biosafety in that the goal of a biosecurity program is to protect against the mishandling of pathogens by individuals with potentially dangerous or criminal intentions, while a biosafety program is designed to reduce or eliminate exposure of research laboratory workers and the environment to potentially hazardous agents. Biosecurity is accomplished by limiting access to facilities, research materials, and information to authorized individuals. Appendix E, Research Laboratory Security and Emergency Response for Microbiological and Biomedical Laboratories, from VHA Handbook 1200.08 (http://vaww1.va.gov/vhapublications/ViewPublication.asp?pub_ID=1850), includes the VHA policy on biosecurity and emergency response. Heightened security requirements apply to research laboratories in which work is conducted with select agents and toxins or that involves high-containment (BSL-3).

The five step process for a biosecurity risk assessment provided in the BMBL, 5th edition, is as follows:

1. Identify and prioritize biological materials.
2. Identify and prioritize the threat to biological materials.
3. Analyze the risk of specific security scenarios.
4. Develop an overall risk management program.
5. Re-evaluate the institution's risk posture and protection objectives.

VHA Handbooks 1200.06, Control of Hazardous Agents in VA Research Laboratories, and 1200.08, provide security guidelines for all research laboratories. The basic principles are:

- Prepare a research-specific security plan and review it annually.
- Verify the status of research workers with without compensation (WOC) status or VISA status annually.
- Perform background and security clearances on all personnel authorized to access research areas and verify the continued need for personnel access on a semi-annual basis.
- Restrict access to research areas by means of key-card access or a state-of-the-art security system that includes permanent/dated records of persons entering and times of entrance.
- Adhere to the requirement for the Associate Chief of Staff (ACOS) for Research and Development (R&D), or designee, to review all access records weekly and document any findings.
- Establish a procedure for reporting incidents involving research laboratory security.
- Ensure provisions for conducting annual drills to test the effectiveness of security plans and for conducting annual multi-disciplinary vulnerability assessments (MDVAs):
    - Security risks, including high-risk areas, sensitive materials, and any other potential physical security issues, are evaluated.
    - Results of the drills and MDVAs are reported to the SRS and the R&D Committee.
    - Corrective actions are implemented to assess any vulnerability identified.
    - The multi-disciplinary team includes, at a minimum, representatives of the Research Service, Police Service, and the facility Safety Office.

Research laboratory workers are required to know who is in the research laboratory area at all times. Workers, guests, visitors, repair personnel, and vendors must wear identification badges. Workers should politely question any person without an escort or proper identification and notify the Police Service or a member of the Research Service immediately of any suspicious individuals or activity. In addition, research laboratory workers must be aware of what materials (hazardous wastes, equipment, sensitive data, cultures, etc.) are being removed from the research laboratory area. VHA policies, as well as site-specific institutional policies, that govern access control to the research laboratory must be enforced. Section 2.8, Work Practices and Controls, discusses these requirements in detail.

2.3. BSLs and Risk Groups

2.3.1. Biological Safety Levels

There are four BSLs of containment from least (BSL-1) to most hazardous (BSL-4). The term containment refers to the mechanisms used to manage infectious organisms in the research laboratory setting to minimize the risk(s) of exposure, both to workers and the environment. The main risk criteria used to define BSLs are the infectivity of the organism, the severity of the disease(s) caused by the organism, the likelihood of disease transmission, the availability of effective immunizations or treatments, and the work being conducted with the organism. The four BSLs define the safety requirements, standard microbiological practices, any special practices or procedures, required protective equipment, and facility safeguards for the corresponding level of risk associated with a particular organism. Standard microbiological practices should be common to all research laboratories. However, special practices and procedures may be needed to enhance worker safety and environmental protection and to address the risk of handling more hazardous organisms. The BMBL, 5th edition, has identified combinations of standards, special microbiological practices, safety equipment, and facility safeguards that should be used to prevent exposure and/or release of hazardous organisms. Additional information on BSLs can be found in the BMBL, 5th edition, Table 2: Summary of Recommended Biosafety Levels for Infectious Agents (http://www.cdc.gov/biosafety/publications/bmbl5/BMBL.pdf).

Standard microbiological practices, including prohibition of mouth pipetting, eating, drinking, and applying cosmetics in the research laboratory; good housekeeping techniques; and washing hands after working with potentially hazardous materials, are important regardless of the research laboratory type and should be exercised at all BSLs. Standard microbiological practices have some commonalities with the research laboratory practices found in the VHA Research Laboratory Safety Guidebook, Volume 1, Chapter 5, Chemical Safety in Research Laboratories, available online at: http://vaww.ceosh.med.va.gov/01HP/Pages/guidebooks.shtml. PPE requirements must be followed with more stringent requirements as the BSL increases.

Universal precautions must be followed when working with contaminated sharp materials. Whenever practical, Research Laboratory Supervisors should adopt improved engineering controls and work practices or administrative controls that reduce risk of sharps injuries. Policies for the safe handling of sharps, such as needles, scalpels, pipettes, and broken glassware, must be developed and implemented. Needles must not be bent, sheared, broken, recapped, removed from disposable syringes, or otherwise manipulated by hand before disposal. Used disposable needles and syringes must be carefully placed in conveniently-located, puncture-resistant containers used for sharps disposal. Non-disposable sharps must be placed in a hard-walled, leak-proof container for transportation to a processing area for decontamination.

2.3.1.a. Biological Safety Level 1 (BSL-1)

BSL-1 research laboratories are suitable for working with organisms that have been well-characterized and are not known to cause disease or to pose serious exposure risks to research laboratory workers or the environment. Work with BSL-1 organisms requires standard microbiological practices sufficient to minimize associated risks and is typically conducted on open bench tops. Special containment equipment or facility containment design features are generally not required in BSL-1 research laboratories unless determined appropriate based on a risk assessment. Research laboratory workers must have specific training in the procedures conducted in the research laboratory and must be supervised by a scientist with training in microbiology or a related science. BSL-1 facility requirements include research laboratory doors for access control, a sink for hand washing, and windows fitted with screens if they open to the exterior.

2.3.1.b. Biological Safety Level 2 (BSL-2)

Requirements for BSL-2 research laboratories build on the specifications for BSL-1. BSL-2 research laboratories are suitable for working with organisms that pose moderate hazards to both personnel and the environment. Differences between BSL-1 and BSL-2 include the requirement for all personnel to be trained specifically in the handling of biological agents, for access to the research laboratory to be restricted when work is in progress, and for work that may generate infectious aerosols or splashing to be performed in a Class II biological safety cabinet (BSC) or similar containment device. Detailed information about BSCs can be found in Section 2.15.

BSL-2 special practices require all persons entering the research laboratory to be advised of the potential hazards and to meet specific entry and exit requirements. Research laboratory workers must be provided medical surveillance and offered appropriate immunizations for agents handled, or potentially present, in the research laboratory. The Principal Investigator or Research Laboratory Supervisor must ensure that research laboratory workers demonstrate proficiency in microbiological practices before working with BSL-2 agents. BSL-2 research laboratory doors should be self-closing and have locks in accordance with local policies. Research laboratories must have a sink available for hand washing.

BSL-2 barriers and safety equipment, including properly maintained BSCs, appropriate PPE, and other physical containment devices, must be used whenever procedures with a potential for creating infectious aerosols or splashes are conducted. Aerosol and droplet-producing operations include pipetting, centrifuging, grinding, blending, shaking, mixing, sonicating, opening containers of infectious materials, animal inoculations, and harvesting infected tissues from animals or eggs.

BSCs should be installed away from doors and air-supply registers. BSCs with a properly maintained high-efficiency particulate air (HEPA) exhaust filter can recirculate filtered air back into the research laboratory or be vented directly to the outside. BSCs are certified annually (semi-annually when working with airborne pathogens). Waste vacuum lines and pumps should be protected from contamination when using for aspiration of biohazardous material. A disinfectant trap, overflow flask, and a hydrophobic filter should be installed to prevent fluid and aerosol contamination of central vacuum systems or vacuum pumps. The filter will also prevent microorganisms from being exhausted by a vacuum pump into the environment.

Work surfaces must be decontaminated with a suitable disinfectant at the completion of work, as well as after any splash or spill. Similarly, all cultures, stocks, and other potentially infectious materials must be decontaminated before disposal using an effective method (disinfectant, autoclave, etc.). Materials to be decontaminated outside of the immediate research laboratory, but within the facility, must be placed in a durable, leak-proof container and secured for transportation. Methods for decontaminating research laboratory equipment should be described in the facility's Research Laboratory Biosafety Manual. Equipment must be decontaminated after potential contamination and before repair, maintenance, or removal from the research laboratory. A form for declaring equipment to be free of all hazards is provided in Enclosure 3.

Spills involving infectious materials must be contained, decontaminated, and cleaned up by properly trained staff equipped to work with infectious materials. This action must take place as soon as possible after a spill occurs. Any potential exposure to infectious materials must be immediately evaluated and treated according to procedures described in the facility's Research Laboratory Biosafety Manual. All such incidents must be reported to the Principal Investigator and Research Laboratory Supervisor. Medical evaluation, surveillance, and treatment should be provided as appropriate for the agent, and associated records must be maintained.

2.3.1.c. Biological Safety Level 2 with Enhanced Practices (BSL-2 E)

BSL-2 E was formally referred to as BSL-2 Plus in the 4th edition of the BMBL. This designation was developed to allow work with slightly more hazardous organisms and procedures in a BSL-2 environment using enhanced procedures and work practices that exceed standard BSL-2 requirements, including appropriate safety equipment (BSCs, safety centrifuge cups, etc.). This

designation is no longer used in the VA. Research laboratories that need enhanced safety practices should be upgraded to BSL-3.

2.3.1.d. Biological Safety Level 3 (BSL-3)

Requirements for BSL-3 research laboratories follow all of the specifications for BSL-2, but the additional required practices and controls are more stringent because BSL-3 organisms pose greater hazards. BSL-3 research laboratories are designed to support work with agents that are characterized by their potential to cause serious or even lethal disease through inhalation exposure. Research laboratory workers in a BSL-3 environment must receive specific training in handling pathogenic and potentially lethal agents. Research laboratory workers must be supervised by scientists competent in handling infectious agents and in performing associated procedures. Additionally, a BSL-3 Research Laboratory Biosafety Manual must be developed and made accessible to research laboratory workers. The Principal Investigator must ensure that research laboratory workers demonstrate proficiency in standard and special microbiological practices before working with BSL-3 agents.

BSL-3 research laboratories have special design, construction, and commissioning requirements (performance and operation) that must be verified and documented prior to start-up. Performance and operations must be re-verified and documented at least annually.

A dedicated air ventilation system is required and must provide sustained, continuous, inward directional air flow from clean areas into the research laboratory toward potentially contaminated areas. This keeps any hazardous bioaerosol that may escape a BSC contained within the BSL-3 research laboratory. The research laboratory must be designed such that under power failure, the air flow will not be reversed. Research laboratory workers must be able to verify directional air flow. A visual monitoring device that confirms ventilation operation must be provided at the research laboratory entrance. Audible and/or visual alarms should indicate when air flow is disrupted.

BSL-3 primary containment requirements include the use of a Class II or Class III BSC or other approved physical-containment devices, such as a centrifuge, safety cup, or sealed rotors, for all procedures involving manipulations of open vials or vessels with the potential for creating aerosols or droplets of infectious materials. Work with agents that require BSL-3 containment is not permitted on an open bench. Protective research laboratory clothing with a solid front, such as tie-back or wrap-around gowns, scrub suits, or research laboratory coveralls, must be worn by workers when in the research laboratory.

BSL-3 secondary containment is used to separate the research laboratory from areas that are open to unrestricted traffic flow within the building. Access to the research laboratory must be restricted by a series of two self-closing doors, with a clothing change room (anteroom) included in the passageway between the doors. Some newer research laboratory buildings may have a series of interlocks that

will not allow the door into the research laboratory to open until the outer door has completely closed and latched. Windows in BSL-3 research laboratories must be sealed.

Equipment that may produce infectious aerosols must be contained in devices that exhaust air through HEPA filtration. These HEPA filters must be tested, replaced per manufacturer instructions (at least annually), and monitored for pressure drop or minimum air flow (filter loading).

2.3.1.e. Biological Safety Level 4 (BSL-4)

Under current VHA research policy, *VHA researchers are not permitted to perform VA research with organisms that require BSL-4 containment*; this applies both to work performed on VA property and at affiliates. BSL-4 research laboratories are designed to support work with dangerous/exotic agents that pose high individual risk of aerosol-transmitted research laboratory infections that are frequently fatal, and for which there are no immunizations or treatments. Agents with unknown risk of transmission require BSL-4 designation.

2.3.1.f. Determining a BSL

There are several steps in determining a BSL. The first step is to identify the hazards of the agent and to conduct a risk assessment on attributes such as the ability to infect, susceptibility to the human host, available preventive and/or therapeutic measures, and related risk group assignment information. The second step is to identify hazards related to research laboratory procedures, including agent concentration, the likelihood of aerosol or droplet generation, and equipment required. The third step is to review the risk assessment with a biological safety professional, subject matter expert, and the SRS.

After determining the BSL, select precautions indicated by the risk assessment. Staff should be evaluated for proficiency with safety and equipment practices and procedures.

2.3.1.g. Risk Groups

The risk group classification of an organism is based on its hazardous characteristics, including the ability to cause disease in a human or animal host, the severity of the disease, as well as any preventive measures and effective treatments available for the disease. The World Health Organization (WHO)-recommended risk group classifications, which are the four general risk groups (Risk Group 1 to 4) based on the hazardous characteristics of an organism and the route of transmission of the natural disease, are outlined in the BMBL, 5th edition. The NIH Guidelines established a similar classification and assigned organisms into four risk groups based on associated hazards. The descriptions of both WHO and NIH risk classifications are presented in the BMBL, 5th edition, Table 1: Classification of Infectious Microorganisms by Risk Group, available online at: http://www.cdc.gov/biosafety/publications/bmbl5/BMBL.pdf. It is important to note that while risk group assignments are similar to BSLs, the two

designations are not equivalent, and a risk assessment is required to determine the association between risk group and BSL for a given organism.

2.4. Routes of Exposure

Infectious material may be transmitted by one of the following four methods:

- Direct Contact: In this case, the entry point for infectious material is contact with non-intact skin, eyes, or mucosal tissue.
- Inhalation: Inhalation exposure typically occurs when an aerosol or fine droplets of infectious material is generated. Many common research laboratory procedures, such as centrifuging, opening capped tubes, sonication, vortexing, or expelling material from a pipette tip, can result in the generation of an aerosol or fine droplets.
- Ingestion: Ingestion of infectious materials can occur as the result of poor personal hygiene, improper research laboratory practice(s), or by hand to mouth contact.
- Injection: Injection could occur during animal injections or during the transfer of material using a needle and syringe or any sharp object that could puncture the skin and transfer infectious materials. Injection incidents have also occurred when working with glass pipettes.

2.5. Medical Surveillance

Research laboratory workers may want to participate in a voluntary medical surveillance program that includes a health screening and, in some cases, periodic medical examinations by an Occupational Health professional. The screenings provide an initial baseline that can be used to assess the research worker's risk and monitor future health status with respect to potential occupational exposures. Health status can impact susceptibility to infection, ability to receive immunizations, or effectiveness of other prophylactic measures. It is a good practice to evaluate immune competence and conditions that may present a predisposition to infection for all research laboratory workers.

All exposure incidents must be reported to the Principal Investigator, Research Laboratory Supervisor, and the SRS. Medical evaluation, surveillance, and treatment should be provided and appropriate records maintained. Occupational exposures must be recorded in the Automated Safety Incident Surveillance and Tracking System (ASISTS). Pursuant to the requirements of 29 CFR 1910.1020, Access to Employee Exposure and Medical Records, all exposure records must be kept for at least the duration of employment plus 30 years. Detailed requirements are available online at:
http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10027.

Additionally, the SRS must evaluate the exposure and determine if it must be reported to the Office of Research Oversight.

2.6. Biological Safety Risk Assessment

The Biological Safety Risk Assessment is a tool that attempts to account for as many hazards associated with experimental research laboratory procedures as possible. A research laboratory in which work with biological agents is conducted must have established provisions to manage risks to research laboratory workers and to the surrounding community. The biological safety risk assessment process involves the evaluation of intrinsic hazards and available controls such as engineering controls, work practices or administrative controls, and the use of PPE. Most biological safety risk assessments are based on risk group classifications, but the results are often subjective and variable due to the nature of the parameters. The descriptions of WHO and NIH risk classifications are presented in the BMBL, 5th edition, Table 1: Classification of Infectious Microorganisms by Risk Group, available online at: http://www.cdc.gov/biosafety/publications/bmbl5/BMBL.pdf.

The Principal Investigator bears the primary responsibility of ensuring that risk assessments are conducted; however, the SRS, other relevant research oversight committees (Institutional Animal Care and Use Committee, Institutional Review Board, Institutional Biosafety Committee), infection prevention professionals, and safety staff should also be involved in the process. As a dynamic process, risk assessments are agent-specific and should be updated as the project evolves and new factors, such as research laboratory workers, biological agents, or new procedures, are introduced.

The biological safety risk assessment involves five basic steps:

1. Identification of the biohazards (risk of the agent).
2. Prioritization of risks based on potential harmful effects for research laboratory workers, the community, and the environment.
3. Identification of the safety controls (containment) required to conduct work safely.
4. Establishment of SOPs and required training.
5. Continual evaluation of research laboratory procedures, containment, and staff competency.

The Principal Investigator should use the risk assessment to evaluate the training and competency of the research laboratory workers who handle the pathogens or perform procedures and to inform personnel of the hazards associated with working with potentially infectious agents. The assessment is the basis for establishing training on safety measures, equipment, and required PPE. The training of research staff, their demonstrated competency, and compliance with work operations helps to minimize exposure potential.

The aspects for risk assessments are correlated and influence the risk or level of controls needed to mitigate potential hazards. The interaction of the agent, research laboratory workers, and environment defines the basic biological safety risk. The risk assessment results should account for numerous parameters including:

- Route of transmission: Inhalation (most significant route), inoculation, ingestion, or skin or mucous membrane exposure.
- Risk group:
    - Pathogenicity: The ability of an agent to cause disease.
    - Virulence: The magnitude or degree of disease.
    - Infectious dose: The dose required to cause infection.
    - Concentration: The number of infectious organisms per unit volume.
    - Agent stability: Survival in environment or spore formation.
    - Treatment and prophylaxis: Availability of immunizations and/or therapeutic treatment.
- Management oversight:
    - Research laboratory biosafety manuals.
    - Plans for incident response (i.e., spills, equipment failure, medical emergencies).
    - Compliance with operating procedures.
    - Inventory and recordkeeping.
    - Medical surveillance.
    - Staff training and skill level.
- Hazard vulnerability assessment: Natural disasters, severe weather, and HVAC redundancy and reliability.
- Personnel health status: Medical conditions, immunocompetence, age, immunizations, fatigue.

2.7. Personnel Training

The Principal Investigator and Research Laboratory Supervisor are responsible for ensuring that all staff members who work in their areas are appropriately trained regarding their responsibilities, the precautions needed to prevent exposures, and exposure evaluation. According to 29 CFR 1910.1030(g), research laboratory workers who have not demonstrated proficiency in handling pathogens must be assigned a progression of work activity until competency is verified. Training must be provided whenever there are changes in procedures, policies, or individual worker health status.

2.8. Work Practices and Controls

VHA Handbook 1200.08 requires compliance with CDC and NIH safety and health guidelines. Containment is essential to the safe handling of potentially infectious material. A key component of effective containment is adherence to standard microbiological practices, which are required at all BSLs. Unless proper equipment and techniques are in place and followed, many common research laboratory procedures could result in an occupational exposure. The technical expertise of the Principal Investigator and research laboratory workers, as well as engineering controls and PPE, are critical when manipulating potentially biohazardous material.

2.8.1. Safe Personal Practices

Eating, drinking, smoking, handling contact lenses, applying cosmetics, and mouth pipetting are not permitted in research laboratory areas. Food intended for human consumption must be stored outside the research laboratory in designated areas.

Individuals must wash their hands after working with potentially hazardous materials, whenever gloves are removed, and before leaving the research laboratory. VHA Directive 2011-007, Required Hand Hygiene Practices (http://vaww1.va.gov/vhapublications/ViewPublication.asp?pub_ID=2367), provides VHA policies for hand washing. Although this directive was created for the clinical environment, hand washing techniques and policies referenced therein are also applicable to the research laboratory environment. Under some circumstances, alcohol-based hand sanitizers may be an acceptable alternative to hand washing.

2.8.1.a. Aerosols

Of the four routes of exposure discussed in Section 2.4, Routes of Exposure, inhalation is of particular concern. Typically with a splash or injection, the individual is immediately aware of the exposure and can take the proper steps to reduce the risk of infection. However, since aerosols are not usually visible or felt on the skin, exposure can go unnoticed.

Certain equipment may require HEPA filtration or use in a BSC because their use can cause aerosolization. Proven sources of aerosols include:

- Vortex mixers.
- Pipettors.
- Sonicators.
- Blenders.
- Grinders.
- Lyophilizers.
- Centrifuges.
- Scraping solid cultures.

Potentially infectious material should never be centrifuged in uncapped tubes. If the worker suspects that a tube has broken during centrifugation, the centrifuge lid should not be opened until any aerosols that may have been generated are allowed to settle. A 15-30 minute wait is generally considered to be sufficient depending on the organism. If centrifuge safety caps (Figure 2-1) are in use, the aerosols will be contained. The centrifuge bucket should be placed in a BSC prior to opening.

Figure 2-1: Centrifuge Safety Caps Installed Over Samples
(Source: University of Texas, Austin, 2011:
http://www.utexas.edu/safety/ehs/lab/manual/4_guidelines.html)

Vortexing is a common research laboratory procedure used to re-suspend cells or mix materials. Although the amount of aerosol produced is less than during centrifugation, tubes containing biohazardous material must be capped during vortexing.

Forcefully expelling material from a pipette can also result in the generation of aerosols. Drips from improperly attached tips and contamination of the mechanical device are additional concerns.

2.8.1.b. Splashes

Protective eyewear or a protective splash shield should be used whenever there is a potential for a splash or splatter, such as during the pouring or transfer of infectious material outside a BSC.

2.8.2. Pipetting

A manual pipettor or electronic pipetting device (Figure 2-2) must be employed when pipetting. Plastic tips and disposable barrels used with pipettors should be disposed of in rigid biohazard containers.

Figure 2-2: Electronic Pipetting Device (Source: John Morris Scientific, 2011: http://www.ferret.com.au/c/John-Morris-Scientific/Motorised-electronic-pipette available-from-John-Morris-Scientific-n775289)

2.9. Sharps

Sharps include objects that can cause a puncture or laceration, such as needles, scalpels, pipettes, and broken glass. In addition to the potential for physical injuries, occupational exposures may occur from sharps that are contaminated with biological agents and chemicals. Therefore, caution must be used when handling and disposing of sharps. Disposal must be in containers that are leak-proof, puncture-resistant, and labeled as biohazardous.

Broken glassware must not be handled directly and should be removed using a brush and dustpan, tongs, or forceps, and disposed of in a puncture-proof double-lined container. If the glass is not contaminated, disposal in a cardboard box specifically designed and labeled for glassware may be used. Contaminated broken glass must be decontaminated or disposed of in a manner to prevent the spread of contamination. Plasticware should be used in place of glassware whenever possible. Engineered safety devices must be evaluated annually to see if improved devices are available as replacements.

Details regarding contaminated sharps are discussed in 29 CFR 1910.1030 (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10051).

2.9.1. Needle Stick Prevention Program

VHA policy requires that contaminated needles and other contaminated sharps not be bent, recapped, or removed. Shearing or breaking of contaminated needles is prohibited. If the needle or sharp instrument is *reusable*, it must be placed in a rigid puncture-resistant, leak-proof, and properly-identified container until it can be decontaminated and reprocessed. All *disposable* sharps must be placed in a rigid leak-proof, biohazard-labeled container. These containers are usually called sharps containers (Figure 2-3).

Figure 2-3: Sharps Containers (Source: Princeton University, 2008, http://web.princeton.edu/sites/ehs/biosafety/livevirusworker/decontamination.htm)

Sharps containers that are an appropriate size for the work location should be selected and positioned so that the opening is visible to research laboratory workers. Sharps containers should remain covered unless in use and stabilized to minimize the potential for tipping and spilling the contents. The contents of a sharps container should not exceed the 3/4 line and, when full, must be closed with a locking mechanism that will not allow re-opening. If outside contamination occurs, the primary container should be placed within a second container that prevents leakage during handling, processing, storage, transportation, or shipping. The secondary container must also be labeled according to stated requirements and color-coded according to local procedures.

2.10. Working with Bloodborne Pathogens

29 CFR 1910.1030 covers all employees who could reasonably become infected as a result of contact with blood and other potentially infectious materials as the result of performing their job duties. The standard defines universal precautions as an approach to infection prevention. According to this concept, all human blood and certain human body fluids are to be managed as if known to contain HBV, HIV, or other bloodborne pathogens. After collection, specimens of blood or other potentially infectious materials should be placed in a secondary container that prevents leakage during handling, processing, storage, transportation, or shipping. Additional information on infectious bloodborne diseases is available online at the National Institute for Occupational Safety and Health (NIOSH): http://www.cdc.gov/niosh/topics/bbp/.

Research laboratories used for the experimentation or manipulation of HBV and HIV have additional requirements. Experience with human pathogens or tissue culture is required and proficiency must be shown in standard microbiological practices and other research laboratory techniques prior to working with these pathogens. If the employee has no prior experience, the employer must provide

training. The employee is not permitted to begin work with these materials until training is complete and proficiency is demonstrated.

Work with these potentially infectious materials must be completed in a BSC or other physical containment device. Non-disposable PPE must be decontaminated before being taken from the research laboratory. All waste from work areas must either be incinerated or inactivated before disposal. The use of sharps should be avoided or limited to the use of sharps or devices that have been engineered for safety. Management of spills is covered in Section 2.14.2, Spill Clean Up.

2.10.1. Biohazard Signs

A biohazard sign must be posted at the entrance to the research laboratory when infectious agents are present. The sign must include the name and phone number of the Principal Investigator and/or the Research Laboratory Supervisor or other appropriate emergency contact, the BSL of the research laboratory, special requirements for entering the area, and the biohazard warning symbol. Specific agent information should be posted in accordance with local policies. Figure 2-4 shows two examples of biological safety signs.

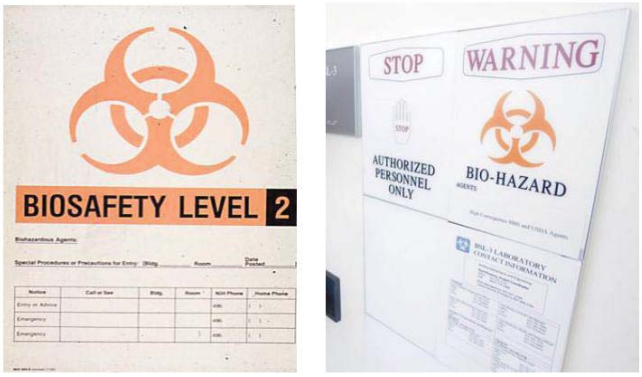

Figure 2-4: Biological Safety Signs

2.10.2. Hazard Communication Requirements

In accordance with 29 CFR 1910.1030, any containers used for infectious waste, transportation of infectious materials, or storage of infectious materials must be labeled with a characteristic biohazard warning label. The label must be affixed so that it is readily visible and cannot be easily removed. The background color of the label must be either fluorescent orange or orange-red, and the icon and warning must be printed in a distinct contrasting color (see Figure 2-5).

Figure 2-5: Biohazard Label (Source: OSHA, 2011: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10051)

A biohazard label must also be placed on any equipment, refrigerator, or freezer that contains infectious material. Information indicating the potentially-infectious contents may be included on the equipment label. A biohazard label is not required on equipment or infectious waste that has been decontaminated. The Principal Investigator or Research Laboratory Supervisor must guarantee that items removed from the primary storage containers remain identified as biohazards when used in the research laboratory.

Red bags or red containers can be used only for infectious material storage, transportation, or disposal. The Principal Investigator or Research Laboratory Supervisor must ensure that all research laboratory workers understand the color code system. Infectious waste removed from the research laboratory must be easily identifiable. As a best practice, the biohazard warning label can be printed on red bags or affixed to red containers. Individual containers of infectious materials do not need biohazard labels if they are placed in a labeled container.

2.11. Biohazardous Waste

When dealing with biohazardous waste, infection control and leakage containment are key concerns. Labeling, sterilization, and decontamination procedures must be developed for the handling and storage of biohazardous waste. BSL-1 and BSL-2 biohazards must be disposed of in accordance with federal, state, and local regulations, after appropriate decontamination in the research laboratory, elsewhere at the facility, or at a properly licensed off-site vendor location. BSL-3 biohazards must be decontaminated in the research facility, preferably in the laboratory.

Biohazardous wastes should be disposed of in appropriately-labeled containers (such as bags or rigid containers) that remain closed and upright until removed from the research laboratory. Wastes are collected at the site of generation and then moved into a designated collection/storage area until they are picked up for

disinfection and/or disposal. Storage areas for sealed biohazardous containers should be secure and easy to clean.

If biohazardous waste is incinerated on site, the Environmental Protection Agency (EPA) requirements related to air emissions apply. Additional information on the EPA requirements can be found online at: http://www.epa.gov/ttn/atw/129/hmiwi/rihmiwi.html.

2.12. PPE

PPE including, but not limited to, gloves, gowns, laboratory coats, respiratory protection, and face shields or other eye protection, must be readily accessible in appropriate sizes. Goggles, safety glasses, face shields, or other face and eye protection devices should be worn when there is a risk of splash, spatter, or droplets. Contact lenses or prescription glasses are not considered eye protection and must be accompanied by appropriate eye protection.

Protective laboratory coats or gowns must be worn while working with biohazardous materials. Impervious aprons or laboratory coats should be worn in areas where there is a high likelihood of liquid contamination. Laboratory coats are not to be worn outside of research laboratories and must not be taken home. There should be provisions for non-disposable laboratory coats to be laundered at the facility. It should be noted that laboratory coats have a life expectancy determined by the coat material, number of washings, amount of wear, and possible exposure to chemicals.

Gloves should be worn to protect against contact with biohazardous materials. Nitrile, vinyl, and neoprene gloves are preferred due to possible latex allergies. If hazardous chemicals are also in use, the correct glove material choice must be made. Information about glove selection can be found in the Research Laboratory Safety Guidebook Volume 1, Chapter 5, Chemical Safety in Research Laboratories (http://vaww.ceosh.med.va.gov/01HP/Pages/guidebooks.shtml).

Based on a risk assessment, double gloves may be required to reduce the potential for penetration of biohazardous materials. Gloves must be changed when contaminated or damaged in any way, and disposable gloves should not be washed or reused. Research laboratory workers should wash their hands after removing gloves. Contaminated gloves cannot be disposed in the regular trash; local procedures for disposal of contaminated waste must be followed. Sleeve protectors may be necessary during high-risk BSC manipulations. Skin rashes or defects can become irritated by wearing PPE, and sensitive areas should be covered or otherwise protected prior to donning gloves.

Use of respiratory protection should be based on a risk assessment. Some activities, such as working with toxic or highly-infectious biological materials, may *require* the use of a respirator that is appropriate for the type of hazard involved. 29 CFR 1019.134, Respiratory Protection, requires a facility Respiratory Protection Program to be implemented when respirator use is required. This

includes medical evaluation, training, and fit testing. An N-95 filtering face piece or higher-protection respirator should be used. Further information on respiratory protection programs is available in the VHA Industrial Hygiene Guidebook (http://vaww.ceosh.med.va.gov/01HP/Pages/guidebooks.shtml). Dust masks and surgical masks are not acceptable respiratory protection devices unless the masks are NIOSH-approved.

When respirator use is not required, 29 CFR 1910.134, Appendix D, Information for Employees Using Respirators When Not Required Under the Standard (https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9784), must be provided to employees who *elect* to wear a respirator as an additional precaution.

2.13. Housekeeping

The worksite is to be maintained in a clean and sanitary condition. All equipment and work surfaces shall be cleaned and decontaminated after contact with blood or other potentially infectious materials. Special training is required for housekeeping staff who are assigned to clean research laboratories where potentially infectious materials are handled.

An Integrated Pest Management Program (IPMP) is also important in research laboratories because some pests can transmit diseases and compromise the integrity of the work. While pest control is a facility-wide issue, research laboratory workers can contribute by keeping work and break areas clean and limiting the storage of cardboard and other paper products in the research laboratory.

2.14. Principles of Disinfection and Methods of Decontamination

There are various levels of reducing microbial load, ranging from clean to sterile. The process of rendering an area, device, item, or material safe to handle and minimize potential disease transmission is called decontamination, as stated in Appendix B of the BMBL, 5th edition (http://www.cdc.gov/biosafety/publications/bmbl5/BMBL.pdf). Decontamination can involve disinfection of work surfaces in which microbial load is reduced, or sterilization in which all microorganisms, including highly resistant forms, are eliminated. Research laboratories should develop a decontamination plan based on the type of research activities that are performed.

Some disinfectants kill vegetative microorganisms and deactivate viruses but are not effective against bacterial spores. These disinfectants may be capable of sterilization only when the contact time is relatively long (e.g., 6 to 10 hours). Mid-level disinfectants kill vegetative microorganisms, including *Mycobacterium tuberculosis*, all fungi, and most viruses. The EPA approves and registers antimicrobial products commonly used as disinfectants in research laboratories for disinfection of benches and housekeeping purposes. Information on EPA-approved antimicrobial products is available online at: http://www.epa.gov/oppad001/chemregindex.htm.

The effectiveness of a disinfection procedure is influenced by a number of factors, including the agent (Table 2-1), biological load, contact time, temperature, etc. These factors and the intended use should be considered in the selection of a disinfectant (Table 2-2).

Table 2-1: Examples of Microorganisms and Disinfectant Effectiveness

	Chlorine Compounds	**Alcohol**	**Phenolics**	**Quaternary Ammonium Compounds (Quats)**
Bacteria	Very good	Good	Good	Good for gram positive
Envelope Viruses	Very good	Good	Good	Good
Non-Envelope Viruses	Very good	Fair**	Fair**	Not effective
Fungi	Good	Fair	Good	Fair
Bacterial Spores	Good with high concentration	Not effective	Not effective	Not effective
Protozoa Parasites*	Moderate with high concentration and long contact time (hours)	Not effective	Not effective	Fair (some quats at high concentration)

*Hydrogen peroxide most effective.
**Check disinfectant efficacy for individual viruses.

Text description of this table is available on a separate page.

Table 2-2: Major Groups of Disinfectants: Advantages and Disadvantages

Type	Advantages	Disadvantages	Notes
Chlorine Compounds	Low cost. Fast acting. Broad spectrum effectiveness.	Corrosive. Irritant. Produces toxic gas if mixed with acids or ammonia compounds. Can be less effective in the presence of large amounts of organic materials.	Must be made fresh daily. 1:10 ratio of bleach to water. Use to decontaminate liquid culture media, for spill clean-up, and to wipe down work surfaces.
Alcohols	Non-corrosive.	Flammable. Not effective against spores. Limited effective exposure time due to high rate of evaporation.	Solutions less than 50% volume for volume in water are ineffective as a disinfectant. Disinfectant of choice when working with HBV and HIV.
Phenolics	Effective in organic material. Has some residual effectiveness.	Not effective against spores. Corrosive. Toxicity varies with the specific phenolic compound. Can be absorbed through the skin.	Useful in areas, such as cabinet ridges, where organic material cannot always be removed.
Quaternary Ammonium Compounds (Quats)	Strong surface activity. Non-corrosive. Low-toxicity.	Easily inactivated by organic materials, anionic detergents, and the metal salts found in hard water.	Commonly used to clean walls, floors, etc. Surface must first be rinsed free of anionic soap or detergents.

Text description of this table is available on a separate page.

Chemicals that are potent sporicides are classified by the Food and Drug Administration (FDA) as sterilant/disinfectants. They are formulated for use on medical devices but not on environmental surfaces, such as research laboratory benches or floors. The FDA regulates high-level disinfectants and sterilants. A list of products is available online at: http://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/ReprocessingofSingle-UseDevices/ucm133514.htm. Additional information and principles for disinfection and sterilization are provided in the CDC publication "Guideline for

Disinfection and Sterilization in Healthcare Facilities" (2008), available online at: http://www.cdc.gov/ncidod/dhqp/pdf/guidelines/Disinfection_Nov_2008.pdf.

2.14.1. Factors Affecting Decontamination

There are certain factors that can influence the decontamination of surfaces and equipment, including, but not limited to:

- Sufficient contact time, as specified on the disinfectant label.
- Removal of organic material prior to disinfecting.
- Surface type (porous, uneven surfaces, hard surface, etc.):
    - Porous surfaces are more difficult to decontaminate and in some cases may not be successfully decontaminated.
    - Hard surfaces are easier to decontaminate.
    - Total decontamination of uneven surfaces may be difficult due to unequal distribution of the disinfectant.
    - Disinfectant must reach all surfaces of equipment with ridges and/or small apertures.
- Temperature, which can affect contact time for thorough decontamination and/or the effectiveness of the disinfectant.

Furnishings in research laboratories should be constructed of impervious material and surfaces that can be disinfected. Carpet and cloth chairs should not be used in research laboratories.

2.14.2. Spill Clean-Up

Spills involving infectious materials must be contained, cleaned, and decontaminated by appropriate professional staff or others properly trained and equipped to work with infectious material. A spill procedure must be developed and available within the research laboratory. A sample biological spill response procedure can be found in Enclosure 2. Additional information can be found in the Mount Sinai School of Medicine General Guide For Biological Spill Responses, available online at: http://www.mssm.edu/static_files/Test2/06081716/www.mssm.edu/biosafety/policies/pdfs/spill_responses.pdf.

2.15. BSCs

BSCs are the primary containment devices used when working with infectious materials. There are three types of BSCs designed for working with low to moderate risk biological agents (Class I and II) and high risk biological agents (Class III). Class II BSCs are most commonly used in VHA research laboratories and provide protection for research laboratory workers, work surfaces, and the environment from exposure to biohazards and/or cross contamination during routine procedures.

Research laboratory workers should use BSCs when procedures involving infectious materials are likely to create aerosols. All experiments involving highly-infectious or airborne-transmitted pathogens must be conducted inside BSC units. Good research laboratory techniques and preventive maintenance are essential to ensure effective containment within the BSC.

A risk assessment should be conducted by the Research Chemical Hygiene Officer (RCHO) or facility Safety Office prior to working with chemicals in BSCs. Additional information on primary containment in research laboratories can be found in Appendix A, Primary Containment for Biohazards, of the BMBL, 5th edition (http://www.cdc.gov/biosafety/publications/bmbl5/BMBL.pdf#page=312).

2.15.1. Class I BSC

Class I BSCs are used to protect the product, but not the user or environment, from contamination and have limited uses in VHA research laboratories. The BMBL, 5th edition (http://www.cdc.gov/biosafety/publications/bmbl5/) provides detailed information on Class I BSCs.

2.15.2. Class II BSC

Class II BSCs have three key features:

- Front access with inward air flow to protect the user.
- HEPA-filtered air blowing down from inside the cabinet to protect the work surface and materials.
- HEPA-filtered air exhausted to the room.

Air exhausted to the outside must be HEPA-filtered for Class IIB BSCs, but it is recommended for all Class II BSCs.

It is important for the front grills and back vents to remain free of obstructions (e.g., arms, papers, equipment) to allow the required air circulation within the cabinet. Figure 2-6 is an illustration of airflow in a Class II BSC.

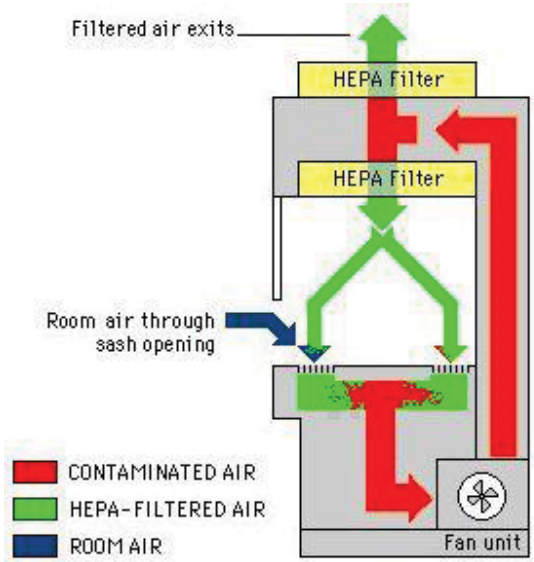

Figure 2-6: Airflow in Class II BSC (Source: U.S. Department of Agriculture (http://www.ars.usda.gov/sp2userfiles/ad_hoc/19000000SafetyHealthandEnvironmentalTraining/graphics/BioCabinetClassII.jpg)

2.15.3. Class III BSC

Class III BSCs is designed for work with highly infectious microbiological agents and highly toxic compounds. These cabinets provide maximum protection for the environment and the worker and have limited uses in VHA research laboratories. Four key features associated with Class III BSCs include:

- Totally enclosed gas-tight construction fitted with glove and material interchange ports.
- Operation under negative pressure.
- HEPA-filtered supply and exhaust air.
- Cabinet exhaust air is filtered through two HEPA filters in series to the outside of the building.

2.15.4. Work Practices for Proper Use of BSCs

Effective containment depends on a well-maintained BSC and good microbiological technique. Certain work practices, if performed before and while working in BSCs, can help ensure the safe handling of biological materials.

Prior to working in a BSC:

- Plan experiments in advance and gather all necessary materials.
- Verify that BSC certification is current.
- Wear appropriate PPE, such as laboratory coat, gloves, and eye protection.
- If an ultraviolet (UV) lamp unit is being used, turn it off as soon as you enter the room.

- Turn on all blowers and cabinet lighting at least 3-5 minutes prior to starting work.
- Verify that safety features (e.g., sash, alarm, filter pressure gauge) are operational.
- If present, drain valves should be closed.
- Decontaminate all interior surfaces of the BSC with an appropriate disinfectant (e.g., 70 percent ethanol or 1:10 dilution of bleach).
- All containers and materials (supplies, equipment, etc.) placed inside the BSC should also be wiped with an appropriate disinfectant.
- Place the minimal amount of materials necessary to complete the experiment inside the BSC.

When working in a BSC:

- Minimize all movement into, out of, and near the BSC.
- Arm movements in and/or out of the BSC should be slow and perpendicular to the face opening.
- Do not block the front grill or back vents with papers or materials.
- Work at least 4 inches from the inside edge of the front vent.
- Minimize spills and splatters when working with infectious materials and keep all waste and contaminated articles inside the BSC until disposal.
- Use horizontal pipette containers. Upright pipette collection containers should not be used in the BSC or placed on the floor outside the BSC.
- Maintain sash at appropriate height.
- Disposable pre-sterilized equipment, flameless, or on-demand sterilization methods should be used as much as possible.
- Work should flow from clean supplies to contaminated areas (as shown in Figure 2-7) to prevent cross-contamination of experimental materials.

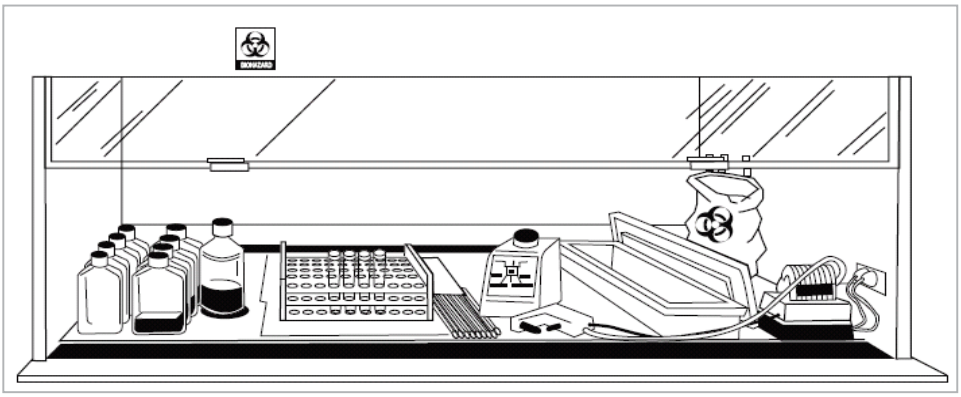

Figure 2-7: BSC Diagram with Items Arranged to Reduce Contamination
(Source: BMBL, 5th edition: http://www.cdc.gov/biosafety/publications/bmbl5/)

- Use of Bunsen burners is not permitted in BSCs. Electric furnaces should be placed in the back third of the BSC.
- Laboratory personnel must be aware of fire hazards associated with alcohol-based disinfectant vapors because Class II BSCs typically do not have spark-proof fans and electrical outlets.
- As illustrated in Figure 2-8, aspirators or vacuum lines should be connected to a labeled collection trap containing an appropriate disinfectant, an overflow flask, and an in-line HEPA filter to prevent particulate aerosols from contaminating the vacuum system.

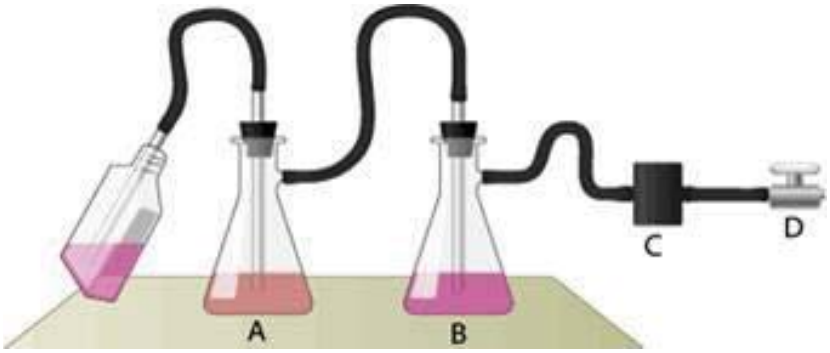

Figure 2-8: House Vacuum Diagram with a Waste Collection Flask (A), Overflow Flask (B), In-Line HEPA Filter (C), and Vacuum Source (D)
(Source: Columbia University: http://ehs.columbia.edu/Policy2.3d.html)

- Surfaces should be disinfected immediately after working with infectious agents.
- For major spills, follow local procedures for reporting and decontamination.

When work in the BSC is completed:

- Collect waste materials inside the BSC. Be sure to seal bags and cover open containers.
- Decontaminate the exterior surface of all items prior to removing them from the BSC.
- After all decontaminated waste containers are removed, wipe the interior surfaces with an appropriate disinfectant.
- Allow BSC blowers to run for at least 5 minutes before shutting the unit down.
- Do not use the BSC to store equipment or supplies.

The BMBL, 5th edition, Appendix A (http://www.cdc.gov/biosafety/publications/bmbl5/BMBL.pdf#page=312), provides information on selection, installation, and use of BSCs.

2.15.5. UV Lamps

In general, the use of UV lamps in BSCs is not recommended because it is not effective on opaque porous surfaces. In addition, UV does not penetrate shadowed areas; material covered by dirt, dust, or organic matter; or inside grills or vents. However, if a UV lamp is used in a BSC, the following procedures should be followed:

- Post a warning sign to turn off the UV lamp before working.
- Train staff in potentially harmful UV effects such as burns, eye injuries, deterioration of equipment/materials (especially electrical cords), and potential for skin cancer with over-exposure.
- Periodically monitor the UV lamp intensity (e.g., semi-annually).

A detailed discussion of the use of UV lamps can be found in the Meechum and Wilson article "Use of Ultraviolet Lights in Biological Safety Cabinets: A Contrarian View," available online at: http://www.absa.org/abj/abj/061104meechan.pdf.

2.15.6. BSC Certification

A BSC must be certified annually and after installation, repair, relocation, or replacement of the HEPA filter. BSCs used for airborne pathogens must be certified semi-annually. The VHA adopted NSF®/American National Standards Institute (ANSI) 49, Biosafety Cabinetry: Design, Construction, Performance, and Field Certification, as the certification criteria for BSCs.

Certifications should be conducted by qualified individuals. The NSF® International Web site provides links to NSF®-accredited certifiers online at: (http://www.nsf.org/Certified/Biosafety-Certifier/).

A good practice is to maintain an inventory of all BSCs for scheduling preventive maintenance and re-certification. The results of the certification should be documented and signed by the certifier. A certification label should be applied with the certification date, inflow air velocity, filter pressure gauge reading, and name of the certifier. A record of the certification results should also be maintained according to the facility policy.

2.16. Biohazardous Material Transportation

Transportation of all hazardous substances is regulated by the U.S. Department of Transportation (DOT) and the International Air Transport Association (IATA).

DOT regulations apply to vehicular transportation of hazardous materials and personnel who package, transport, and receive these goods. The regulations primarily apply to commercial transportation but also include transportation in private vehicles or between institutions. Employees are required to be specifically trained for the task they perform *every 3 years*. An overview of these

requirements can be found online at:
http://www.fmcsa.dot.gov/safety-security/hazmat/complyhmregs.htm.

However, if transported by air, IATA requirements apply, and training is required *every 2 years*. Current information can be found on the IATA Infectious Substances Web site online at:
https://www.iata.org/whatwedo/cargo/dgr/pages/infectious_substances.aspx. All transported specimens must meet 29 CFR 1910.1030 labeling and packing requirements.

Basic considerations for safe transport include:

- Biohazardous material should be placed in a sealed and labeled primary specimen container.
- The sealed primary container should be placed into a dedicated secondary container with absorbent packing to cushion the primary container and to absorb liquids in the event of a leak or spill.
- The secondary container must be sealed and labeled with a biohazard symbol.

2.16.1. Non-Commercial Transportation

When being transported by hand, hazardous materials should be identified and securely packaged in primary and secondary containers. In addition, the transportation route should not be in public areas, and dedicated elevators should be used whenever possible. Individuals transporting hazardous materials should be aware of their environment at all times to avoid slips, trips, and falls.

Transportation of hazardous materials in official government or personal vehicles carries specific personal and institutional liability issues and should be discouraged. However, any transportation on a public road requires proper packaging, identification, and labeling (consistent with DOT regulations) as well as training of personnel involved.

2.17. References and Resources

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2. 42 CFR 72, Interstate Shipment of Etiologic Agents, Health and Human Services Parts 71, 72: http://www.cdc.gov/od/ohs/pdffiles/DOTHazMat8-14-02.pdf.

3. 49 CFR 171, et al., Hazardous Materials: Revision to Standards for Infectious Substances and Genetically Modified Microorganisms; Proposed Rule: http://www.phmsa.dot.gov/staticfiles/PHMSA/DownloadableFiles/Files/Federal%20Regi ter%20Historical%20Files/63fr_1998/63fr-46844.pdf.

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11. U.S. Department of Health, Education, and Welfare, Public Health Service, National Institutes of Health. Laboratory Safety Monograph: A Supplement to the NIH Guidelines for Recombinant DNA Research: http://orf.od.nih.gov/NR/rdonlyres/6D8AAB74-2FF5-430B-A553-B9410474B1A4/16202/LaboratorySafetyMonograph1979.pdf.

12. World Health Organization. (2000). WHO Infection Control Guidelines for Transmissible Spongiform Encephalopathies. WHO, Geneva, Switzerland:

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2.18. Enclosures

Enclosure 1 Fact Sheet Listing

The following fact sheets contain quick-reference information relevant to this chapter:

5.1 General Precautions
5.2 Control of Biological Hazards
5.3 Bloodborne Pathogens

Enclosure 2 Sample Biological Spill Response Procedures

Enclosure 3 Sample Form for Declaration of Equipment as Free of All Hazards

Physical Safety in Research Laboratories

3.1. Introduction

There are many physical hazards found in research laboratories that have the potential to cause injury to research laboratory workers. This chapter is intended to provide an overview and understanding of significant physical hazards including:

- Fire safety
- Slips, trips, and falls
- Housekeeping
- Noise
- Electrical
- Glassware
- Compressed gases
- Cryogenic agents
- Oxygen
- Research laboratory equipment

The physical hazards associated with the use of radiation are covered in Chapter 4, Radiation Safety in Research Laboratories. Ergonomics is covered in the Veterans Health Administration (VHA) Ergonomics Guidebook, available online at: http://vaww.ceosh.med.va.gov/01HP/Pages/guidebooks.shtml.

3.2. Fire Safety, Access, and Egress

Fire is a significant concern in research laboratories because it can cause severe injuries to staff and result in the destruction of property. There is a high fire risk in research laboratories because flammable liquids are commonly used, flammable vapors can be generated, and flames and heating elements are common. Minimizing the storage and use of flammable chemicals reduces the risk of large fires. More information on flammable chemical handling and management can be found in the VHA Research Laboratory Safety Guidebook, Volume 1: Managing Chemical Safety (http://vaww.ceosh.med.va.gov/01HP/Pages/guidebooks.shtml).

3.2.1. Fire Safety Codes

The determination of applicable fire safety codes is based on building classification, types of flammable or combustible materials, quantities of hazardous materials present, and occupancy type. Fire safety code compliance is evaluated by the facility Safety Office with support from Veterans Integrated Service Network (VISN) Fire Protection Engineers or VISN Safety Managers. For more information, please consult the VHA Fire Safety Guidebook, available online at: http://vaww.ceosh.med.va.gov/01HP/Pages/guidebooks.shtml.

Requirements for emergency access and egress and fire protection planning are addressed in Code of Federal Regulations (CFR) 29 CFR 1910.36-1910.39, available online at: http://www.osha.gov/pls/oshaweb/owasrch.search_form?p_doc_type=STANDARDS&p_toc_level=1&p_keyvalue=1910.

The most recent version of the National Fire Protection Association (NFPA®) 101, Life Safety Code, is VHA policy and accepted by the Occupational Safety and Health Administration (OSHA). NFPA® 45, Standard on Fire Protection for Research Laboratories Using Chemicals, provides specific instruction on fire safety in the research laboratory. Both codes are available through the Center for Engineering & Occupational Safety and Health (CEOSH) Web site: http://vaww.ceosh.med.va.gov/01FS/Pages/NFPAWarning.shtml.

Basic guidelines for fire safety include:

- Ensure that the research laboratory staff is aware of procedures to be followed during a fire.
- Ensure that emergency exit routes are clearly marked and free of obstructions.
- Encourage employees to identify issues that might impede emergency access and egress.
- Illuminate and identify evacuation routes with an exit sign.
- Establish an interim evacuation plan for research laboratories that are under renovation or construction.
- Keep fire doors closed.
- Properly store and limit the total volumes and flammable chemicals used in the research laboratory. Keep containers closed when not in use.
- Prohibit the disposal of flammable liquids or incompatible chemicals into drains.
- Inspect electrical equipment, especially power cords, for defects and other potential ignition sources prior to use.
- Limit the use of extension cords, power strips, or similar devices unless approved in advance by the facility Safety Officer.
- Report any deficiencies to the facility Safety Office or Engineering.

Fire drills are required at least once annually and should include simulation that test workers' knowledge. For example, during a fire drill, a person can be stationed at a stairwell entrance and inform evacuees that the stairwell is filled with smoke in order to test participants' familiarity with alternative exit routes.

In addition to flammable and combustible chemicals, objects such as wooden furniture, cardboard boxes, and paper all contribute to the fire load in research laboratories. Research laboratory equipment can serve as ignition sources if not properly operated, maintained, and attended. Controlling ignition sources in the research environment is critical; therefore, open flames should be minimized.

3.2.2. Fire Extinguishers

Employees expected to use fire extinguishers must be trained annually on the location of fire extinguishers, when and how to use fire extinguishers, and the limitations of extinguisher classes. The use of fire extinguishers in research laboratories should be limited to individuals who have had proper training. A standard fire extinguisher found in research laboratories is a dry powder extinguisher for Class A, B, and C fires. Class A fires involve ordinary combustible materials, such as cloth, wood, paper, rubber, and several types of plastics. Class B fires involve flammable and combustible liquids, such as gasoline, alcohols, diesel oil, oil-based paints, and flammable gases. Class C fires involve energized electrical equipment. Dry powder residue from Class ABC or BC extinguishers can contaminate research laboratory equipment or samples; therefore, a Class BC fire extinguisher that contains *carbon dioxide* (CO_2) is often preferred for fires in or near sensitive research laboratory equipment. However, CO_2 extinguishers should never be used in a very small room or in a confined space because they can deplete oxygen.

Two other types of fire extinguisher classes are D and K. Class D fire extinguishers may be needed in research laboratories that contain combustible metals (e.g., magnesium, sodium) and should be located near the area where the metal is used or stored. Class K fire extinguishers are used for kitchen fires involving oil and grease. Research laboratories that contain powerful magnets, such as in magnetic resonance imaging (MRI) equipment, require a non-metallic fire extinguisher.

Additional information from OSHA regarding portable fire extinguishers is available in the Evacuation Plans and Procedures eTool (https://www.osha.gov/SLTC/etools/evacuation/portable_placement.html) and in 29 CFR 1910.157, Portable Fire Extinguishers (https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9811).

3.3. Slips, Trips, and Falls

Slip, trips, and falls are one of the top five causes of injuries in the research laboratory setting. Slips, trips, and falls are caused by a number of hazards, including poor housekeeping, poor floor and aisle maintenance, wet floors, uneven surfaces, improper storage of equipment and supplies, and employee behavior.

29 CFR 1910 Subpart D, Walking and Working Surfaces, 1910.23, General Requirements

(https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9715), is intended to reduce accidents including slips, trips, and falls by setting minimum requirements for floors, ladders, stairs, and housekeeping.

Highlights of these requirements include:

- Keeping all work areas clean and orderly.
- Maintaining floors in a clean and dry condition. Where wet floors are not avoidable (cage washing areas), drainage shall be maintained and/or false floors, platforms, mats, or other dry standing places shall be provided when practicable.

Personnel should avoid behaviors that frequently contribute to slips, trips, and falls, including:

- Wearing inappropriate footwear.
- Carrying excessive boxes or other materials that inhibit line of sight.
- Using unapproved step aids (chairs, boxes, stools, etc.).
- Leaving electrical or phone lines on the floor.
- Ignoring wet or slippery floors.
- Storing heavy objects on high shelves.
- Leaving drawers or cabinets open.

3.3.1. Controls

Prevention of slips, trips, and falls should include:

- Training employees to recognize and report slip, trip, and fall hazards.
- Attending to floor spills quickly by placing a wet floor sign and cleaning the spill.
- Using non-slip matting, wet floor drain mats, and slip-resistant footwear in wet locations.
- Avoiding the storage of items on the floor except in designated areas.

For more information, see the OSHA Slips, Trips, and Falls e-Tool online at: http://www.osha.gov/SLTC/etools/hospital/hazards/slips/slips.html.

3.4. Housekeeping

In addition to contributing to fire hazards and slips, trips, and falls, excessive clutter and poor housekeeping can also impede access to emergency equipment. The following are common safety violations that must be avoided:

- Blocked emergency eyewash and shower stations.
- Blocked electrical panels.
- Fire extinguishers blocked.
- Permanent storage of chemicals in fume hoods.
- Long term storage of items in unapproved areas.
- Failure to remove surplus equipment.
- Dirty surfaces that attract vermin or pests to the work area.

3.4.1. Controls

Minimize clutter by only ordering material in quantities that can be used within a 3-6 month period. Cluttered spaces and crowded shelves (Figure 3-1) play a significant role in workplace injuries. Principal Investigators should periodically remove excess materials and equipment, and all safety inspections should target clutter.

Figure 3-1: Cluttered Research Laboratory

3.5. Noise Hazards

Noise associated with the operation of chemical fume hoods, biological safety cabinets, and automated samplers are generally in the range of 60-75 decibels (dB), which is considered safe by OSHA as documented in 29 CFR 1910.95, Occupational Noise Exposure (https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9735). However, other equipment emits noise at higher levels that can exceed the OSHA action level of 85 dB, including sonicators, blenders, grinders, homogenizers, compressors, and cage washing units. Therefore, anticipated noise levels should be considered when purchasing these types of equipment. Noise levels above the action level can also be associated with areas where large animals used in research (e.g., pigs, dogs, non-human primates) are housed. Additional information on noise levels can be found in OSHA Fact Sheet, Laboratory Safety Noise, available online at: https://www.osha.gov/Publications/laboratory/OSHAfactsheet-laboratory-safety-noise.pdf.

Noise levels in research laboratories are usually intermittent and do not typically approach levels near, or in excess of, permissible exposure limits (PELs). The noise standard and the Hearing Conservation Amendment define the PEL as the noise dose that would result from a continuous 8-hour exposure to a sound level of 90 dB. This is a dose of 100 percent. Duties where workers are known to be exposed to noise levels above the action level will require the use of hearing protection devices (HPDs), including ear plugs, ear muffs, or both when engineering or administrative controls do not effectively reduce the exposure. Noise exposure measurements are reported as time-weighted averages (TWAs), meaning louder noises have a shorter acceptable period of exposure (Table 3-1).

Table 3-1: OSHA Permissible Noise Exposures

Duration per Day in Hours	8.0	6.0	4.0	3.0	2.0	1.5	1.0	0.5	0.25
Sound Level, Decibels	90	92	95	97	100	102	105	110	115

Text description of this table is available on a separate page.

When noise exposures exceed 85 dB or above, a written Hearing Conservation Program (HCP) must be implemented that includes:

- Medical monitoring, including baseline and annual audiograms.
- A detailed evaluation of exposure(s).
- Proper selection of HPDs, such as ear plugs or ear muffs.
- Requirement to use f HPDs when noise exposures exceed 90 dB. Best practice is to wear HPDs at 85 dB or above.
- Training to educate workers on hearing conservation techniques (e.g., proper use, care, and cleaning of hearing protection devices).
- Engineering controls, such as equipment enclosures, noise damping materials, and isolation devices to reduce exposures.
- Signage that identifies hazardous noise areas and processes.

3.5.1. Controls

Controls for noise hazards include:

- Engineering controls, such as laboratory design or structures or barriers to contain or isolate noise (e.g., noise baffles, insulation in ductwork).
- Administrative controls, including training, eliminating or minimizing worker exposure time, and identifying safe work distances.
- HPDs.

3.6. Electrical Hazards

The major hazards associated with electricity are electrical shock and fire. Shock occurs when an individual comes in contact with both wires of an electrical circuit, one wire of an energized circuit and the ground, or a part of a piece of equipment that has become energized. Additional information and VHA electrical safety requirements can be found in the VHA General Safety Guidebook online at: http://vaww.ceosh.med.va.gov/01HP/Pages/guidebooks.shtml.

Electrical hazards can be reduced by taking reasonable precautions such as:

- Equipment should be double insulated with a 2-prong plug, have a grounded 3-prong plug, or be used in a 3-prong outlet. An adapter plug

(Figure 3-2) should never be used, and the 3rd prong (grounding post) should never be removed.

Figure 3-2: 3-Prong Plug Adaptor for 2-Prong Outlet

- Any outlet within 6 feet of a sink, in wet areas, or in any area where electricity and water may come in contact must have ground fault circuit interrupter (GFCI) protection (Figure 3-3). The GFCI should be periodically tested by verifying that equipment will shut off when the test button is pressed.

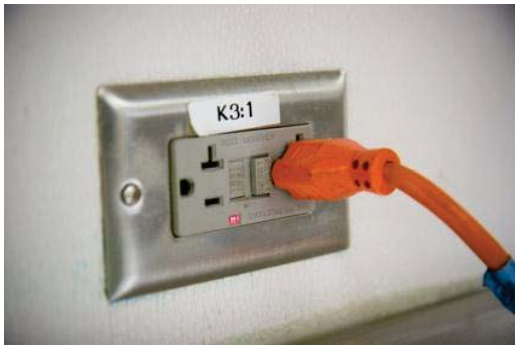

Figure 3-3: 3-Prong Outlet with GFCI

- Maintain electrical equipment and instrumentation in good working order, so that insulation is not frayed or wiring exposed.
- Never unplug equipment by pulling or yanking the cord.
- If liquids are spilled on equipment, shut off power at the main switch or circuit breaker and unplug the equipment.
- Never connect multiple power strips together (e.g., daisy-chaining; Figure 3-4).

Figure 3-4: Power Strips Daisy-Chained Together

- Pay close attention to wiring/cords in areas where ultraviolet (UV) light is used for disinfection (such as biological safety cabinets) because UV light can cause rapid deterioration of electrical insulation.
- Never run power cords through doors, ceilings, walls, windows, damp areas, etc.
- Keep electrical panel doors closed and readily accessible.

3.6.1. Controls

Electrical hazards controls include:

- Inspect electric cords on equipment before use. Damaged cords and equipment must not be used and must be reported immediately to the facility Safety Office and Engineering.
- Never use extension cords for routine work in the research laboratory.
- Do not overload power strips by using high-amperage equipment (refrigerator, microwave oven, hot plate, coffee pot, space heater), and exceeding the maximum rating of 15 to 25 amps.
- Keep flexible power cords off the floor.

3.7. Glassware Hazards

3.7.1. Description

Broken glass is the major hazard associated with research laboratory glassware. Glass bottles or other research laboratory equipment can break when dropped or can explode when strained from experimental conditions, such as heating. Cuts from broken glass can range from relatively minor contusions to severe impacts from flying shards. Injuries from broken glassware can be avoided through adherence to safety protocols, careful inspection and manipulation of glassware, and diligent use of protective equipment.

Surface scratches and chips are common defects that cause weakness and breakage in the glass; therefore, it is important to check each piece prior to use. A less visible hazard is glass stress, which can result when glass is heated unevenly above its strain point. Star cracks, glass stress, and other small defects can be repaired by annealing, but this process must only be performed by a qualified glass repair person. Repair of damaged glassware is generally not recommended.

Inserting a glass stem into a rubber stopper is another common research laboratory practice that can be dangerous without proper precautions because glass tubing can often break when pressure is applied during the insertion process. Understanding the properties of glass tubing and connecting materials can reduce the incidence of accidents and improve research laboratory safety. For more information on the safe handling of glass tubing, see Enclosure 4, Sample SOP: Glass Tubing, provides steps to safely work with glass tubing.

Borosilicate glass is commonly recommended for most research laboratory applications except for special experiments that use UV or other light sources. This glassware combines strength and clarity with chemical and heat resistance. Research laboratory borosilicate glassware can commonly be found under brand names such as Pyrex® (Corning 7740) and Duran® (Schott 8830). While borosilicate glass items will break if dropped, some glassware can be purchased with plastic coating to eliminate the sharp edges of broken glass and contain liquid contents. Reagent bottles, measuring equipment, stirring rods, and tubing are not usually made of borosilicate glass.

3.7.2. Controls

General precautions for preventing glassware hazards include:

- Using appropriate glassware according to written research laboratory procedures.
- Avoiding the use of glass when a stronger material or apparatus can suffice.
- Handling glassware carefully to minimize damage and protect the integrity of the glassware.
- Avoiding impacts, scratches, and intense heating of glassware.
- Inspecting glassware for cracks and defects before using.
- Properly disposing of glassware that is chipped, cracked, or otherwise damaged or worn.
- Providing cut-resistant gloves to personnel performing operations where glassware is likely to be broken.

- Wearing heavy, synthetic, water-resistant gloves when washing glassware by hand.

- Using a broom and pan to clean up broken glass instead of handling broken shards.

Broken glass should be disposed of properly in a labeled cardboard box or other rigid container that will protect housekeepers and other personnel from sharps exposures. Contaminated broken glass may require disposal as a hazardous waste in a properly-labeled container. Broken glass containment boxes are pictured in Figure 3-5. Broken glassware contaminated with biological or chemical hazards must be disposed of in compliance with hazardous/infectious waste regulations.

Figure 3-5: Broken Glass Containment Boxes (Source: Krackeler Scientific, 2011: http://www.krackeler.com/products/1331-Cleanup-Waste/12227-Broken-Glass-Disposal-Box.htm)

Glassware under either positive or negative pressure is at risk for explosion or implosion. Pressurized glass vessels are also susceptible to cracking or rupture from mechanical blows or rising temperature. Examples of pressurized glassware include Dewar flasks, desiccators, thick-walled Erlenmeyer flasks, and round-bottom flasks.

Positive or negative pressurized glassware hazards controls include:

- Discontinue use of glassware beyond the recommended safety limit and do not subject it to sudden pressure changes. Round vessels will generally tolerate more pressure or vacuum than flat-sided vessels of similar construction.

- Use a safety screen or impact-resistant shielding and personal protection when using mechanically pressurized or vacuum pump systems. A chemical fume hood sash can also be used as a safety screen.

- Reinforce glassware for vessels that may implode, such as Dewars or desiccators, with friction tape applied in a single layer in a pattern that guards against flying glass.

- Place a warning sign on apparatus under pressure.

Heating glass at high temperatures may create permanent stresses in the glass because continued heating or localized hot spots can cause the glassware to break. Repaired glassware often has weak spots that may rupture under changes in temperature or pressure. Since hot glass looks like cool glass, precautions must be taken while working with heated glassware.

Heated glassware hazards controls include:

- Using tongs or heat-resistant gloves to remove glassware from sources of heat.

- Using a soft flame with a Bunsen burner, as well as a wire gauze or diffuser to prevent localized heating.

- Heating the whole lower hemisphere of a flask to prevent localized hot spots.

- Avoiding the use and heating of volumetric cylinders and flasks on hot plates.

- Establishing procedures to cool hot glass items prior to removal from heated equipment, such as autoclaves or ovens.

3.8. Compressed Gases

A wide variety of compressed gases are used in the research laboratory setting. Some uses of compressed gases include fuel gases for instruments, inert gases as carrier gases within instruments, oxygen and nitrous oxide in animal surgeries, CO_2 for euthanasia of small rodents or to create a slightly acidic and oxygen-deficient atmosphere in incubators, and ethylene oxide for sterilization. *Note: Chemical hazards are covered in Chapter 5 of the VHA Research Laboratory Safety Guidebook, Volume 1: Managing Chemical Safety (http://vaww.ceosh.med.va.gov/01HP/Pages/guidebooks.shtml).*

3.8.1. Description

Compressed gases are stored in cylinders manufactured according to the U.S. Department of Transportation (DOT) regulations, which specify the material of construction, method of manufacture, testing, and compatible product fill. Compressed gas cylinders come in different sizes and are typically composed of a single piece of steel with a shape ideally suited to withstand internal pressures to which the cylinders are routinely subjected. Compressed gas cylinders have a pressure-relief device installed to prevent rupture if a normally pressurized cylinder is inadvertently exposed to fire or high temperatures.

The valve stem is the most vulnerable part of a compressed gas cylinder and should be protected with a valve cap or cover that remains securely in place at all times when the cylinder is being stored or moved. Without a valve cap, a dropped cylinder may dislodge or damage the valve, and the pressurized cylinder could become a missile that is capable of penetrating walls, concrete blocks, and other structures, as well as expelling the gaseous contents along the way. Likewise, movement of compressed gas cylinders should be performed only after securing the cylinder to an appropriately-sized four-wheel compressed gas cylinder cart (Figure 3-6).

Figure 3-6: Four-Wheel Compressed Gas Cylinder Carts
(Sources: Left: Airgas, 2011: http://www.airgas.com/browse/productDetail.aspx?Category=404&product=Y99231400; Right: Princeton University, 2011: http://web.princeton.edu/sites/ehs/cylinder%20cart.jpg)

When receiving gases, it is important to perform a basic inspection of each cylinder. This inspection should include at least the following:

- Confirm that the cylinder appears to be in good condition with no significant physical defects (e.g., dents) and no significant rust (a minor scratch with rust is acceptable).
- Ensure that the cylinder cap is securely in place but can be removed by hand.
- Check that the cylinder has an intact label that identifies its contents and DOT hazard classification.
- Ensure that the cylinder is secured in the upright position, as illustrated in Figure 3-7, at all times.

Figure 3-7: Proper Cylinder Restraint
(In a seismic area, two chains are required.) (Source: University of California, San Diego, 2011: http://blink.ucsd.edu/safety/research-lab/chemical/gas/storage.html#Basic-storage-guidelines-for-al)

3.8.2. Equipment Regulators

Pressure regulators (Figure 3-8) reduce the high pressures of gas stored in the cylinder to lower pressures that can be used safely in an operating system. Proper regulator selection is critical for both safety and effectiveness of operating systems. Selection is based on the type of cylinder, specific gas, and pressure.

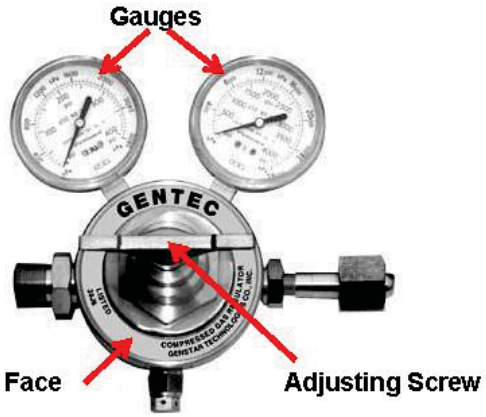

Figure 3-8: Regulator

Regulators can explode. Always stand to the side of the regulator face, preferably with the valve between your body and the regulator. Avoid reaching in front of the regulator face to open the valve. The face of the regulator should always be angled upward (provided a flow meter is not attached), so that if there is an explosion, the adjusting screw and debris will fly away from your face. Regulator connections to cylinder valves must be completely free of dirt, dust, oil, and

grease. ***Warning: Petroleum grease on an oxygen cylinder fitting can cause an explosion!***

Before attaching the regulator, open the cylinder valve slowly to release a small amount of the contents, which will clear dust and debris from the valve opening. *Note: Skip this step for cylinders containing toxic or corrosive gases.*

Regulators are attached to the cylinder or manifold at the inlet connection. This connection should be tested for leaks with a non-petroleum based product. The connection is marked with a Compressed Gas Association (CGA) number and will be left-hand or right-hand threaded to match the nut or fitting to prevent a regulator from being connected to the wrong gas supply. Right-handed CGA fittings will have a smooth nut surface and have an even number for the second digit. Left-handed CGA fittings will have a notched groove in the surface and have an odd number for the second digit.

Never use damaged or defective equipment.

3.8.2.a. Tips for Using Regulators

Eye protection must be worn and a face shield is recommended when opening a regulator. Stand on the *valve* side of the cylinder at arm's length to avoid reaching in front of the regulator face. Turn away from the regulator and open the valve, turning counter-clockwise, to blow out dust and debris, and then reclose the valve (Figure 3-9).

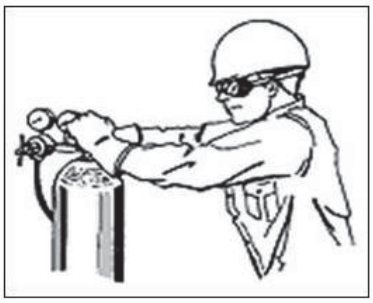

Figure 3-9: Proper Position for Opening a Regulator
(Source: Virginia Tech Environmental Health and Safety, 2011: http://www.ehss.vt.edu/programs/CGC_equipment.php)

When changing a regulator, close the valve and drain the regulator by backing out the adjusting screw. When closing a regulator, turn the valve clockwise. Drain the regulator by opening the adjusting screw to release any gas and then reclose the adjusting screw.

3.8.2.b. Tips for Using Valves

The following are best practices for using valves:

- Do not attempt to open a corroded valve because it may not reseal completely.

- Ensure that cylinders without fixed hand wheels have keys, handles, or non-adjustable wrenches on the valve stem while they are in service.

- Do not open acetylene valves more than one and a half turns.

- Close valves before moving a cylinder, when work is completed, and when the cylinder is empty.

3.8.3. Physical Hazards of Compressed Gases

Some physical hazards associated with compressed gases include:

- Pressure: Compressed gas cylinders are designed to hold gases with varying pressures. The cylinder and valve assembly should be matched to the specific gas contents and have pressure-release devices that must remain unobstructed. If a cylinder is bulging or otherwise deformed, it should be taken out of service. Cylinders with valve-protection caps must have the caps in place when the cylinder is in storage or in transport. If a cylinder falls and the valve is damaged, the cylinder can become a projectile and cause significant damage in the immediate area if the gas is released.

- Simple asphyxiants: Some compressed gases can cause suffocation by displacing oxygen in the air. Examples of asphyxiants used in the research laboratory include CO_2 and nitrogen. For detailed information, see the VHA Research Laboratory Safety Guidebook, Volume 1: Managing Chemical Safety, (http://vaww.ceosh.med.va.gov/01HP/Pages/guidebooks.shtml), Chapter 5, Chemical Safety in Research Laboratories, Enclosure 10, Additional Toxicology Information.

- Flammability: Flammable gases should be stored and secured in places where there is good ventilation, no ignition sources, and appropriate mechanisms for fire detection and suppression. Examples of flammable gases used in the research laboratory are propane (heavier than air) and hydrogen (lighter than air). Flammable gases that are heavier than air may pool or concentrate in low spots, such as along the floor. Similarly, flammable gases that are lighter than air can pool along the ceiling or under ceiling tiles. Remember that each flammable gas has its own unique level of risk based on its flammable range. All flammable gas connections and tubing should be periodically inspected for potential leaks.

- Corrosion: The acid gases classified as corrosives by DOT degrade metal and damage human tissue. Examples of corrosive gases used in the research laboratory are hydrogen chloride and ammonia. Corrosive gases should always be handled using an appropriate corrosive-resistant apparatus in a chemical fume hood.

- Pyrophoric gases: Pyrophoric gases are compressed gases that have an auto-ignition temperature below 54.4 degrees Celsius (°C) [130 degrees Fahrenheit (°F)] that are rarely used in research laboratories. Examples of pyrophoric gases used in the research laboratory include saline and diborane.

3.8.4. Compressed Gas Storage

Cylinders must be stored properly as follows:

- Cylinders must be stored in compatible groups (flammables should be separate from oxidizers and corrosives; highly toxic gases may require a ventilated gas cabinet).
- Full cylinders must be separated from empty cylinders.
- Empty cylinders must be clearly marked and stored carefully because residual gas may remain in the cylinder.
- Never rely on the color of the cylinder for identification because color-coding is not standardized and may vary between the manufacturer and supplier.
- Return old, unclaimed, or unused compressed gas cylinders to the compressed gas supplier at least annually.

An *interior* compressed gas storage room is a separately ventilated, fully enclosed room in which only compressed gas equipment and supplies are stored and/or used. Other requirements for interior storage include:

- The walls, floors, and ceiling must be constructed of non-combustible materials and have a fire-resistant rating of not less than 1 hour. In some cases where flammable gases are being dispensed, a 2-hour rating or greater may be necessary, as well as pressure-relief explosion blow out venting panels.
- The entrance to the room should be labeled in accordance with NFPA® 704, Standard System for the Identification of the Hazards of Materials for Emergency Response.
- The lighting, heating, and electrical appliances should be rated for hazardous atmosphere per NFPA® 45.
- Gas storage areas shall be kept free of all combustible materials (i.e., cardboard boxes).

A gas detection system should be installed in a room where toxic, flammable, or asphyxiant gases are being dispensed or used.

Exterior compressed gas storage rooms must be located in a secure area, protected from weather conditions, and ventilated. Other requirements for exterior storage include:

- Securing stored cylinders in place in an upright position.
- Locking the storage area and limiting access to authorized personnel only.
- Ensuring that the area is free of debris accumulation (e.g., leaves and other combustible materials).
- Posting a “No Smoking” sign in the area.
- Labeling the entrance to the room in accordance with NFPA® 704.

3.8.5. Controls

The following are some of the general actions that can be taken to ensure an acceptable level of safety associated with the use of compressed gases:

- Compressed gases shall be handled only by properly trained persons. Individuals without previous compressed gas experience will be provided on-the-job training and be supervised by an experienced employee.
- Training must be documented and include both safe compressed gas handling and the specifics of the health hazards and dangerous physical properties.
- Cylinders should never be dragged, rolled, or lifted by their valve caps.
- Employees moving gas cylinders should wear appropriate footwear and work gloves.
- Compressed gas shall not be delivered, picked up, stored, or put into service in exits, stairwells, or egress routes.
- A bench clamp (Figure 3-10), a cylinder base stand (Figure 3-11), or chains are possible ways compressed gas cylinders can be secured when in use. Bench clamps may not attach properly to smooth work benches and may be dislodged in a high traffic area.

Figure 3-10: Bench Clamp (Source: OpticsPlanet.com, 2011: http://www.opticsplanet.net/troemner-henry-vwr-talon-cylinder-bench-clamp-972056.html)

Figure 3-11: Cylinder Base Stands (Source: Magmedix, 2011: http://www.magmedix.com/products/respiratory/non_magnetic_cylinder_stand.html)

- Cylinders that require a wrench to open the main valve should have the wrench left in place on the cylinder valve while open. Never apply excessive force when trying to open valves. Cylinders with stuck valves should be returned to suppliers for service.
- Do not attempt to open a corroded valve. Return the cylinder to the manufacturer for repair.
- Wear protective eyewear when changing out cylinders.
- Do not stand facing the regulator or valve when removing or attaching a regulator.
- Cylinder valves should be turned off and regulators drained when the gas is not in use.
- Follow local policies and standard operating procedures (SOPs) when using regulators (see Enclosure 5, Sample SOP: Operating Compressed Gas Systems).

The following guidelines for labeling and identifying the status of cylinders should be adhered to:

- Cylinder contents should be identified by the supplier's crescent-shaped adhesive identification label.
- Fixed research laboratory lines (plumbed) in gas manifold systems should be labeled to identify the contents.
- Affix a status label (full, in service, or empty) to each cylinder when received so that its progressive status can be tracked.

3.9. Cryogenic Agents: Liquefied Compressed Gas

Cryogenic liquids are primarily used in the preservation of biological material and in cold traps (often under vacuum). Hazards associated with cryogenic liquids include the transfer of cryogenic liquid, removal of materials from cryogenic containers, pressurization of cryogenic containers, and displacement of atmospheric oxygen. (See Section 3.10, Oxygen, for detailed information on oxygen-deficient atmospheres.)

3.9.1. Description

A cryogenic liquid is defined as a liquid with a normal boiling point (at normal, ambient pressure) below -150°C (-240°F). The most common cryogenic liquids include argon, helium, hydrogen, nitrogen, and oxygen. All of these substances are odorless, tasteless, and generally colorless.

The hazards of cryogenic agents can be considered from two perspectives. First, the hazards associated with the substance being in a cryogenic state (e.g., frostbite/burn hazard, oxygen displacement) and second, the hazards associated with the substance itself (e.g., flammable, reactive, and toxic). Cryogenic agents share the following hazards:

- Cryogenic liquids and their gases can rapidly freeze common materials such as steel, rubber, and plastics to the point that they become brittle or break under stress.
- Direct contact with cryogenic liquids can cause burns, frostbite, and more significant cellular damage resulting in irreversible tissue damage. The eyes are more sensitive to damage from cryogens or evolving cold gas than are the hands or face. Direct contact often results from the use of improper transfer equipment or techniques, as well as leaks or spills.
- Cryogenic liquids undergo a volume expansion when converting from the liquid to gas phase. This can create two significant hazards, physical stress on the container and displacement of oxygen in poorly-ventilated or enclosed areas.

- Screw-top cryovials can explode upon removal from storage if the liquid has penetrated the seal and becomes trapped in the vial. A quick, partial turn of the screw top will often release the expanding gas without compromising the contents.

Cryogenic liquids must be stored in vessels (such as Dewars) that can contain the cryogenic liquid under some amount of pressure. Portable tanks (Figure 3-12) used for storage and bulk cryogenic liquids are commonly seen in the research laboratory setting.

Figure 3-12: Portable Storage Tanks (Source: Cryo-News, 2009, http://cryonews.blogspot.com/2009_01_01_archive.html)

Like the fixed bulk storage tanks, portable tanks have sophisticated systems for pressure relief and dispensing bulk liquid cryogens. These cylinders may be affixed to larger equipment, such as imaging equipment, gradual freezing units, or used to fill Dewars or freezers directly. The pressure relief mechanism for all cryogenic containers should be inspected on a routine basis to ensure that icing (frozen water vapor from the air or frozen air) is not interfering with the proper function.

Dewars (Figure 3-13) are non-pressurized containers similar to a thermos (a bottle in a bottle) used for transferring smaller amounts of bulk liquid from a tank to a freezer or to a piece of equipment. Dewars themselves may also be used for temporary storage of a sample at cryogenic temperatures. Dewar openings are most often protected by a dust cap to allow expanding gas to escape and to prevent ice from forming inside the neck, which can also create the potential for pressure build-up. For transfer purposes, Dewars can have a dispensing device, dippers, or a pressurized dispensing device.

Figure 3-13: Dewar Vessels (Source: Medical Supermarket, 2011: http://www.medical-supermarket.com/Shop/ProductPage.aspx?productID=59797)

Cryogenic freezers are storage vessels designed for the long-term storage of samples under cryogenic conditions. They are typically constructed from more robust materials, have additional insulation properties, and are often designed to receive specific types of carriers, holders, or other rack systems in which samples may be placed and immersed down into the cryogen. With samples in place, cryogenic freezers are often filled to 80 percent volume with cryogenic liquid. Some units are gas-tight with pressure relief devices similar to bulk storage units, while others allow gas to passively leak out. Examples of freezer/storage units and a suspended rack storage system are pictured in Figure 3-14.

Figure 3-14: Freezer/Storage Units and Suspended Rack Storage System (Source: Vindon Scientific Limited, 2011: http://www.hospital-int.net/suppliers/vindon-scientific-limited.html)

Appropriate personal protective equipment (PPE), such as chemical splash goggles, face shield, apron, and gloves of insulated material should be used when

handling cryogens. Wearing a research laboratory coat or long sleeves and cuff-less trousers/slacks is also recommended. Figure 3-15 shows examples of protective gloves and an apron that could be used when working with cryogenic materials.

Figure 3-15: Cryoprotective Gloves and Apron
(Sources: Left: Cardinal Health, 2011: http://www.cardinal.com/us/en/distributedproducts/ASP/G7201-16.asp?cat=research laboratory; Right: Tempshield Cryo-Protection, 2008: http://www.tempshield.com/aprons.html)

NFPA® 55, Compressed Gases and Cryogenic Fluids Code, provides additional guidance on cryogenic systems and management. NFPA® 55 can be accessed through the CEOSH Web site at: http://www.NFPA®.org/aboutthecodes/list_of_codes_and_standards.asp.

3.9.2. Controls

Controls for cryogenic liquid hazards include:

- Training employees on the hazards, proper PPE, and safe work practices prior to working with cryogens. Training must be documented. An SOP for the safe handling of liquid nitrogen, a representative cryogen, is provided in Enclosure 6.
- Ensuring that transfer systems, containers, and storage devices are approved for cryogens in use.
- Installing, maintaining, inspecting, and using cryogenic systems according to manufacturer instructions by qualified personnel.
- Providing fixed and/or portable oxygen monitors in locations where cryogen use may result in oxygen-deficient atmospheres.
- Dispensing and storing cryogenic liquids in well-ventilated areas.
- Using appropriate filling funnels, transfer devices, and/or transfer tools for pouring or transfers of cryogenic liquids.

- Ensuring that appropriate PPE is available and used by personnel when handling cryogenic agents.

3.10. Oxygen

3.10.1. Oxygen-Deficient Atmosphere

OSHA defines oxygen-deficient atmospheres as those with less than 19.5 percent oxygen. The OSHA limit is widely accepted because of the significant health effects (including death) that can occur, as well as the fact that depleted oxygen concentrations affect the ability of a person to self-rescue or otherwise rationally assess their situation. Health effects due to exposure to oxygen-deficient atmospheres are provided in Table 3-2.

Table 3-2: Health Effects Due to Exposure to Oxygen-Deficient Atmospheres

Percent Oxygen Concentration	Health Effects
19%	Some adverse physiological effects occur, but they may not be noticeable.
15-19%	Impaired thinking and attention. Increased pulse and breathing rate. Reduced coordination. Decreased ability to work strenuously. Reduced physical and intellectual performance without awareness.
12-15%	Poor judgment and coordination. Abnormal fatigue upon exertion. Emotional upset.
10-12%	Very poor judgment and coordination. Impaired respiration that may cause permanent heart damage. Possibility of fainting within a few minutes without warning. Nausea and vomiting.
<10%	Inability to move. Fainting almost immediately. Loss of consciousness. Convulsions. Death.

Text description of this table is available on a separate page.

Virtually any gas can act as a simple asphyxiant and dilute the concentration of atmospheric oxygen. In the indoor atmosphere of the research laboratory, this mixing of gases may not be immediate or uniform. Issues of density, temperature, and source may cause the offending gas or gases to settle, mix, or

rise. In the research laboratory, oxygen-deficient atmospheres occur when there is a leak of an oxygen-displacing gas in poorly-ventilated areas. For detailed information about asphyxiants, see the VHA Research Laboratory Safety Guidebook, Volume 1: Managing Chemical Safety (http://vaww.ceosh.med.va.gov/01HP/Pages/guidebooks.shtml), Chapter 5, Enclosure 10, Additional Toxicology Information.

An oxygen-deficiency hazard calculator that can be used for compressed gases is available online at: http://www.bnl.gov/esh/shsd/SEG/SMEToolsExt/ODHCompressGasR3.aspx. Additionally, an oxygen-deficiency hazard calculator that can be used for gases that liquefy when compressed (cryogens) is available online at: http://www.bnl.gov/esh/shsd/SEG/SMEToolsExt/ODHCryogenR4.aspx.

3.10.1.a. Dry Ice

Solid CO_2, referred to as dry ice, should be stored and used in a well-ventilated area because it evaporates by sublimation (phase change from a solid to a gas without passing through the liquid state). Dry ice can cause frostbite, thermal burns, and possible asphyxiation. ***Warning: Dry ice must NOT be stored in cold rooms or walk-in freezers because it can create an immediately dangerous to life and health (IDLH) atmosphere.*** Warning signs should be posted accordingly to prevent accidental use during emergency situations.

Other hazards of dry ice include:

- Dry ice in a research laboratory sink may cause composite material to crack or the plumbing to freeze.
- Dry ice stored in a refrigerator could cause the thermostat to cycle off.
- Sublimating dry ice expands over 500 times [(1 pound (lb) ice = 8.8 cubic feet (ft^3) of CO_2 gas]. Because of dry ice off-gassing, it should be stored in a container with a loose-fitting cover to avoid pressure build up that could rupture the container.
- Insulated containers containing dry ice, or areas where dry ice is stored should be labeled with a dry ice warning label (Figure 3-16).

Figure 3-16: Dry Ice Warning Label

3.10.1.b. Controls

Some of the controls that can prevent oxygen-deficient atmospheres from occurring include:

- Training personnel on the physical hazards of the gas being used and the compressed gas system.
- Providing a calibrated oxygen-monitoring device when using chemicals that can displace oxygen.
- Verifying that ventilation controls are operating properly to ensure that fresh make-up air is being supplied to the work area.
- Checking cylinder and container safety devices to ensure that there are no leaks.
- Placing signage to warn people about atmospheric hazards.
- Prohibiting the placement of dry ice or cryogenic liquids in cold rooms or walk-in freezers.

3.10.2. Oxygen-Enriched Atmospheres

OSHA defines an oxygen-enriched atmosphere as containing more than 23.5 percent oxygen. The source of elevated oxygen levels can be an oxygen cylinder leak, oxygen generator, a chemical reaction byproduct, piped-in oxygen gas, or liquid oxygen. When there is too much oxygen in the air, there is a higher potential for materials to combust and burn more easily. Oxygen should not come in contact with petroleum products or other chemicals that can generate heat and auto-ignite.

3.10.2.a.Controls

Some of the controls that can prevent oxygen-enriched atmospheres from occurring include:

- Training personnel before they work with oxygen from a compressed gas supply system or compressed gas cylinders.

- Preventing the use of cryogenic liquid oxygen if possible. If it is not possible, implementing the controls outlined in Section 3.9, Cryogenic Agents: Liquefied Compressed Gas.
- Checking for oxygen leaks in all connections prior to turning on a fixed system or an oxygen gas cylinder.
- Using a calibrated oxygen-monitoring device to detect leaks.
- Posting "No Smoking" signs in areas where oxygen is being stored or used.

3.11. Research Laboratory Equipment Hazards

A partial list of equipment commonly used in research laboratories that pose recognized physical hazards is provided in Sections 3.11.1-3.11.5.

3.11.1. Autoclaves and Steam Sterilizers

Autoclaves are commonly used in research laboratories to decontaminate heat-stable materials by steam sterilization. This process generates pressurized steam within a sealed chamber. The primary hazards of autoclaves are associated with the high pressure, high heat, and steam generated during use. Secondary hazards include potential exposures to infectious agents, contaminated materials, or sharps. Exposure to sharps most often results from handling materials or debris produced by the explosion of improperly filled and sealed liquid containers or equipment failure.

Autoclaves can be safely used when operated and maintained in the manner prescribed by the manufacturer. A regular preventative maintenance cycle should be established and maintenance performed by a qualified person based on manufacturer requirements. The performance of all equipment components must be regularly evaluated, including temperature and pressure gauges, autoclave chamber, door gaskets, safety interlocks, and relief valves. Other aspects for inspection include dedicated electrical power, drain capacity, and venting. Following the failure of a biological indicator, the autoclave should be evaluated to identify and correct the problem. Autoclaves with damaged components or safety controls should be removed from service until repairs are completed.

Training should be provided to research laboratory staff on autoclave operation, research laboratory-specific written SOPs, administrative controls, and appropriate PPE. Some controls to protect staff from physical autoclave hazards include:

- Checking autoclave drain screens for accumulation of debris (clean as necessary) before each run.
- Packaging materials to prevent exposure to sharp objects while loading and unloading the autoclave.

- Filling bags loosely and placing in autoclave-safe plastic or metal trays.
- Loosening caps on containers with liquids to prevent shattering from over-pressurization. Large bottles with narrow necks may also explode if too full of liquid.
- Locking out and tagging out an autoclave that is not in safe working order to prevent accidental use while waiting for repair.
- Ensuring that the autoclave is de-energized and locked out from all energy sources whenever maintenance or repairs are being performed.
- Ensuring that the pressure in the autoclave chamber is near zero before opening the door at the end of a cycle to prevent exposure to steam and shattered glassware.
- Allowing steam to escape and items to cool before reaching inside and removing items from the autoclave chamber.
- Never putting solvents, volatile or corrosive chemicals (such as phenol, chloroform, bleach, etc.), or radioactive materials in an autoclave.
- Wearing proper PPE, including:
    - Laboratory coat.
    - Rubberized apron.
    - Eye protection.
    - Closed-toe shoes.
    - Heat-resistant gloves.
- Establishing a quality assurance program to verify autoclave function on a regular basis.

3.11.2. Centrifuges

The hazards associated with centrifuges are due mostly to the amount of centrifugal energy generated in their operation. Proper operation of a centrifuge relies on balance of the rotor. Balance is achieved by uniform weight of the tubes and proper arrangement within the centrifuge rotor. Operating a centrifuge with unbalanced rotors may result in reduced equipment life, broken tubes, and movement of the centrifuge unit, or even disintegration of the rotor.

Proper centrifuge operation includes clearly defining the safe operating parameters for specific rotors in multiple rotor machines. Centrifuges with multiple rotors and centrifuge adjustments can create the possibility of placing the wrong rotor in a device (such as a rotor from another manufacturer), or operating a rotor outside of its design tolerance. Either of these conditions can result in catastrophic failure. Rotors used beyond the useful lifetime (beyond manufacturer's recommendation) can fail, while unguarded rotors can make contact with the fingers, hands, and clothing of personnel. Staff should never use

their hands to slow spinning rotors. When hazardous materials, such as carcinogens, highly toxic, or infectious agents are placed in a centrifuge, precautions (such as using sealed rotors or sealed rotor cups) must be taken to prevent exposure to aerosols or liquids.

A sample SOP for the safe operation of centrifuges is provided as Enclosure 7.

For safe operation of centrifuges:

- Ensure that the load is balanced (evenly distributed inside the chamber) and does not exceed maximum loads, filling levels, and maximum sample density for the equipment.
- Operate and maintain the centrifuge according to manufacturer instructions.
- Turn the equipment off immediately if an unusual condition (noise or vibration) occurs.
- Do not use damaged devices or components until inspection, maintenance, and/or repair can be carried out by the manufacturer.
- Ensure that staff is properly trained prior to operation, and training is documented.

3.11.3. Electrophoresis

The presence of high voltage and conductive fluid in electrophoresis equipment can create significant electrical hazards. This equipment can potentially operate at 2000 volts and more than 800 milliamps. A leak in the buffer tank can cause a change in flow of electricity and result in a serious shock. A lethal shock can be delivered by standard electrophoresis units operating at 100 volts and 25 milliamps. The following precautions minimize hazards when working with electrophoresis equipment:

- Using physical barriers (a guard) to prevent accidental contact with energized electrodes or the buffer.
- Using gel chamber lids or covers equipped with safety interlocks.
- Inspecting equipment to ensure that all switches and indicators are functioning.
- Ensuring that all power cords and electrical leads are undamaged and properly insulated.
- Connecting power supplies to GFCI.
- Using warning signs such as “Danger Electrical Hazard” to alert others.

- Ensuring that power supplies have safety features that detect no-load, overload, sudden load change, short circuit, arc or ground leak, etc.
- Turning off power before connecting or disconnecting electrical leads.
- Connecting electrical leads individually with dry, gloved hands, using one hand only.
- Ensuring that leads are securely connected before operating the equipment.
- Never leaving energized equipment unattended.
- Operating equipment away from unintentional grounding points and conductors (e.g., sinks or other water sources, metal plates, jewelry, aluminum foil, pipes, or other electrical/metal equipment).
- Following the manufacturer's instructions while operating electrophoresis equipment.
- Never wearing low hanging metal jewelry or an identification card on a metal chain when working around electrophoresis equipment.

3.11.4. Cold Storage

Cold storage equipment used in research areas includes refrigerators, freezers, walk-in cold rooms, and walk-in freezers.

Research laboratory refrigerators and freezers may have explosion protection, humidity control, and rapid recovery systems to maintain constant temperature during frequent door openings. Ideally, the internal temperature should stay within the set range, which is established based on the contents. It is recommended that a temperature-tracking system (automated or manual) and alarm system be installed to alert staff when freezers or refrigerators deviate from the set range.

Storage of flammable materials in a refrigerator has the potential to cause vapor accumulation and a potential explosion in the presence of a source of ignition (light or compressor motor). Poorly-sealed containers allow the release and accumulation of vapors within the sealed space. Only explosion-proof refrigerators and freezers can be used for storage of flammable materials. Additional information on storing flammables can be found in the VHA Research Laboratory Safety Guidebook, Volume 1, Chapter 5, Chemical Safety, Section 5.5.7, Flammable Materials. Volume 1 can be accessed online at: http://vaww.ceosh.med.va.gov/01HP/Pages/guidebooks.shtml. A label stating "Flammable Materials Refrigerator: Keep Fire Away," can identify such refrigerators.

To control hazards associated with cold storage:

- Post appropriate warning signs and labels to identify hazardous contents.
- Do not use compressed gases or hazardous chemicals in walk-in cold rooms and/or freezers.
- Equip walk-in cold room and freezer doors with emergency push handles on the inside.
- Inspect equipment and areas used for cold storage regularly to verify that they are properly labeled/posted and free of surplus items.
- Monitor equipment for excess condensation that can contribute to slippery surfaces and mold.
- Ensure that appropriate PPE is available and used by personnel working in cold storage.

3.11.5. Heating Equipment

Heating equipment is used in research laboratories to support reactions or handle glassware, exclusive of on-demand water heaters. Most research laboratories contain one or more heating apparatus including ovens, hot plates, heating mantles, water baths, oil baths, salt baths, sand baths, air baths, hot-tube furnaces, hot-air guns, and/or microwave ovens. It is preferred that research laboratory-grade equipment be purchased when possible because of built-in safety features.

Hazards associated with heating equipment include burns, electrical shock, and fire.

Heat-related accidents can be prevented by:

- Using heating devices and other electrical equipment away from water sources, emergency eyewashes, and shower stations.
- Ensuring that heating devices have a temperature-limiting controller to prevent overheating.
- Posting caution signs near heat sources stating “Caution: High Temperature.”
- Prohibiting the use of residential or commercial space heaters in the research laboratory, unless they are specifically approved for laboratory use.

3.11.5.a. Ovens

Precautions for working with ovens include:

- Ensuring that ample clearances are maintained around the oven to reduce heat build-up.

- Using ventilated ovens with a single pass-through design to remove hazardous vapors that may be generated. Exhausted air should be vented outside of the building and away from occupied areas and electrical components.
- Using explosion-proof ovens, hot plates, or heat mantles when heating flammable chemicals.

3.11.5.b. Heating Baths

Guidelines for safe usage of heating baths include:

- Locating equipment on a firm, level surface.
- Managing power cords to prevent damage and exposure to water.
- Plugging waterbaths into GFCI outlets.
- Ensuring that heating temperatures are compatible with the materials being heated.
- Prohibiting the use of mercury thermometers.

3.11.5.c. Microwave Ovens

Microwave ovens have unique hazards, including leakage of nonionizing radiation, rapid changes in temperature and pressure, super heating of liquids, arcing, and boil-over. Radiation hazards are addressed in Chapter 4, Radiation Safety in Research Laboratories.

Controls for reducing hazards when using microwaves include:

- Periodically checking for microwave leakage with a microwave leak detector.
- Making sure the entire unit is clean and working properly.
- Prohibiting the use of steel containers in microwaves unless they have a pressure-relief device.
- Removing screw-caps from containers while being microwaved.
- Covering containers with cotton or foam stoppers to maintain sterility and prevent splatters.

3.12. References and Resources

1. 29 CFR 1910, Occupational Safety and Health Standards (https://www.osha.gov/pls/oshaweb/owasrch.search_form?p_doc_type=STANDARDS&p_toc_level=1&p_keyvalue=1910):
    - 1910.95 Occupational Noise Exposure.

- 1910.101, Compressed Gases.
- 1910.103, Hydrogen.
- 1910.104, Oxygen.
- 1910.110, Storage and Handling of Liquefied Petroleum Gases.
- 1910 Subpart I, Personal Protective Equipment.
- 1910.157, Portable Fire Extinguishers.
- 1910.301-335, Electrical Safety.

2. Beckman-Coulter Centrifuge Homepage and Calculator: https://www.beckmancoulter.com/wsrportal/wsr/research-and-discovery/products-and-services/centrifugation/rotors/index.htm?t=3.

3. Compressed Gas Association (CGA): http://www.cganet.com/:

    - CGA P-1-2008, Safe Handling of Compressed Gases in Containers.
    - CGA P-12-2005, Safe Handling of Cryogenic Liquids.

4. NFPA®: http://vaww.ceosh.med.va.gov/01FS/Pages/NFPAWarning.shtml:

    - NFPA® 45, Standard on Fire Protection for Research Laboratories Using Chemicals.
    - NFPA® 55, Compressed Gases and Cryogenic Fluids Code.
    - NFPA® 99, Health Care Facilities Code.
    - NFPA® 101, Life Safety Code.
    - NFPA® 704, Standard System for the Identification of the Hazards of Materials for Emergency Response.

5. Stanford University provides guidance and information on purchasing autoclaves online at: http://www.stanford.edu/dept/EHS/prod/researchlab/bio/docs/autoclave.html.

6. University of California, San Diego, provides an overview of autoclaves at: http://blink.ucsd.edu/safety/research-lab/biosafety/autoclave/index.html.

7. VHA General Safety Guidebook, Chapter 9, Compressed Gases: http://vaww.ceosh.med.va.gov/01HP/Pages/guidebooks.shtml.

3.13. Enclosures

Enclosure 1 Fact Sheet Listing

The following fact sheets contain quick-reference information relevant to this chapter:

12.1 Compressed Gases
12.2 Cryogenic Agents
12.3 Compressed Gas Storage
12.4 Portable Appliance Electrical Safety

Enclosure 4 Sample SOP: Glass Tubing

Enclosure 5 Sample SOP: Operating Compressed Gas Systems

Enclosure 6 Sample SOP: Safe Handling of Liquid Nitrogen

Enclosure 7 Sample SOP: Safe Operation of Centrifuges

Enclosure 8 Sample Centrifuge Log Sheet

EOSH

Radiation Safety in Research Laboratories

4.1. Introduction

The use of radioactive materials in the research setting is a physical hazard that can cause significant health hazards to workers who have excessive exposure. The local Radiation Safety Program must be followed when working with radioactive materials, radiation-generating equipment, and nonionizing radiation. This chapter provides an overview of the Veterans Health Administration (VHA) policy for working with radioactive materials and radiation-generating equipment, hazards of ionizing and nonionizing radiation, and safety practices to protect workers.

The majority of this chapter addresses ionizing radiation produced by radioactive elements called isotopes, with a focus on the hazards and safety issues in the research laboratory. Nonionizing radiation is discussed in detail in Section 4.9, Nonionizing Radiation.

4.2. Radiation Safety Policy Overview

The following section provides a summary of VHA policies, procedures, and responsibilities that pertain to the management of radioactive materials.

The U.S. Nuclear Regulatory Commission (NRC) establishes regulatory requirements for the use of radiation in VHA programs through Code of Federal Regulations (CFR) Title 10. For legal and compliance purposes, radioactive material used for medical or research purposes is defined as byproduct material. VHA ensures compliant acquisition, possession, use, and disposal of radioactive materials and radiation-generating equipment by adhering to the Master Materials License (MML) issued by NRC. Primary implementation guidance on the use of radiation is outlined in VHA Directive 1105.01, Management of Radioactive Materials (http://www1.va.gov/vhapublications/ViewPublication.asp?pub_ID=2092).

As low as reasonably achievable (ALARA) is the overarching concept in any application involving radiation or radioactive material. Use the smallest amount of the least harmful isotope for the shortest duration possible. VHA is required by the NRC MML to maintain a formal ALARA program and achieve radiation exposures as far below the maximum permissible dose as practical.

4.2.1. The Department of Veterans Affairs (VA) MML

Rather than issuing individual licenses to each facility, VHA has an MML at the administration level. The Under Secretary for Health is the named license official for the MML and establishes policy through VHA Directive 1105.01.

The Under Secretary for Health established the National Radiation Safety Committee (NRSC) to serve as the oversight committee for VA facilities that use radiation. The NRSC maintains and implements the MML through the National Health Physics Program (NHPP). The NRSC issues individual NHPP permits to VHA facilities that allow the local use of radiation-generating equipment, directs the day-to-day implementation of the MML, and coordinates other NRSC activities.

4.2.2. VHA Facility Director

The VHA Facility Director holds administrative responsibility for the safe use of radiation-generating equipment at VHA research facilities in accordance with the MML permit. The VHA Facility Director issues policies that follow NRC and NHPP guidance, while technical support of key staff and local committees constitute the facility Radiation Safety Program.

4.2.3. Subcommittee on Research Safety (SRS)

The SRS is a subcommittee of the Research and Development (R&D) Committee. All research projects involving radiation hazards must be approved by the SRS and then by the R&D Committee using VA Form 10-0398, Research Protocol Safety Survey (http://www.va.gov/vaforms/medical/pdf/10-0398.pdf). The Radiation Safety Committee (RSC) is separate and distinct from the SRS Committee and has facility-wide authority over the use of radiation. Research involving radiation-generating equipment must be approved by the RSC prior to SRS approval.

4.2.4. RSC and Radiation Safety Officer (RSO)

VHA Directive 1105.01 tasks the RSC and RSO jointly with taking all actions necessary to ensure regulatory compliance and the safe use of radiation-generating equipment. The RSO completes day-to-day compliance and monitoring actions with oversight by the RSC. A primary role of the RSC and RSO is to provide oversight for the safe use of radiation-generating equipment by ensuring that occupational and other doses are ALARA, and to ensure a safety-conscious work environment.

The RSC is established by the Facility Director as the administrative body for the safe use of radiation. The RSC is responsible for reviewing and authorizing all proposed uses of radiation-generating equipment and for setting radiation safety policy. *Note: Some facilities may establish additional research oversight committees (Laser Safety Committee, Physical Security Committee, etc.) that may have shared responsibilities with the RSC.*

The RSC and RSO provide local program guidance and coordinate with other radiation safety staff to develop a Radiation Safety Handbook tailored for the unique capabilities and requirements of each facility. Information on current radiation safety program and regulatory issues is provided to VHA through the NHPP Intranet Web site (http://nhpp.med.va.gov).

Additional RSC and RSO responsibilities include:

- Conducting an annual program review, site inspections, evaluations, and training of authorized users.
- Coordinating the transfer of radiation-generating equipment.
- Investigating spills and suspected overexposures.
- Managing the employee exposure prevention plan and review of occupational and public doses at least every 6 months.
- Providing security oversight of radiation-generating equipment.
- Ensuring the accuracy of sealed-source inventories.

4.2.5. Principal Investigator/Research Laboratory Supervisor

The Principal Investigator and/or Research Laboratory Supervisor are responsible for ensuring that research staff remains compliant with all aspects of the Radiation Safety Program and Research Safety Program. Management responsibilities include:

- Establishing and enforcing standards of practice that prevent personnel and environmental exposures to radiation hazards.
- Ensuring that research laboratory personnel receive appropriate radiation safety training and that the training is documented.
- Mitigating any concerns identified by the RSO during the annual inspection.

The Principal Investigator must provide the following to the RSC and RSO:

- Information regarding lasers, ultraviolet (UV), and radiofrequency radiation in use, including type, quantity, location, energy level, etc.
- Location, inventory, and procedures of radiation-generating equipment.
- Identification of staff working with radiation-generating equipment.

4.2.6. Authorized User

Each individual requesting to work with radiation-generating equipment must complete training requirements and be approved by the RSO to become an authorized user. Projects involving radiation-generating equipment must be approved by the RSC, SRS, and R&D Committee prior to initiation.

4.2.7. Training

The NRC defines radiation workers as individuals who, in the course of their employment, are likely to receive a dose of more than 100 millirem (mrem) of

radiation in a year from byproduct materials. Radiation workers must receive adequate training to protect themselves against radiation and comply with NRC and VHA radiation protection policies regarding security, training, and safety. Radiation workers have the right to ask the NRC to conduct an inspection if they believe safety concerns exist in their working environment.

Research laboratory workers must be trained in the specific hazards associated with the procedures they will be performing in a given protocol. In general, training must describe all known hazards and the required exposure controls. Exposure controls may include ventilation hoods and shielding (engineering controls), use of regulated areas or exposure time limits (administrative controls), or the use of gloves and safety goggles (personal protective equipment). Training and the specific topics covered during each session must be documented.

4.2.8. Common Research Laboratory Citations

The NHPP and/or the NRC may perform periodic on-site inspections to evaluate the facility's compliance with its NHPP permit and regulatory requirements. The RSO should routinely audit user compliance with radiation safety rules and policies. Any corrective actions must be tracked to completion through the RSC.

Some examples of regulatory violations commonly identified during a radiation safety inspection include:

- Failure to restrict access to only trained and authorized personnel.
- Inventory discrepancies of radioactive materials.
- Failure to store or discard radioactive waste properly.
- Failure to complete radiation worker training.
- Obtaining radioactive materials without specific RSC or RSO approval.
- Failure to maintain safety equipment (fume hoods) for proper operation.
- Failure to perform routine radiological surveys of areas and personnel.
- Failure to secure and properly label containers of radioactive material.
- Failure to wear personal radiation dosimetry devices.
- Failure to properly decommission a radiation laboratory prior to reassignment.

4.3. Overview of Basic Radiation Principles

This section provides a general introduction to the basic principles, terms, and types of radiation that may be encountered in a research laboratory. It is intended to provide safety and research personnel with the basic terminology and concepts needed to understand and implement the requirements of the Radiation Safety Program.

4.3.1. Radiation Concepts and Theory

Radiation is a general term used to describe the propagation or movement of energy across distance. The air around us is filled with electromagnetic radiation in the form of light, radio signals, microwave communications from cell phone

towers, x-rays, and gamma rays from space. When radiation carries enough energy to eject or kick an electron from orbit, it is called ionizing radiation. All radiation below this energy level is called nonionizing radiation.

Radiation consists of packets of energy called photons. The terms wavelength and frequency are inversely related terms used to express the magnitude of energy carried by the photon; (high-energy correlates to radiation with a high-frequency and short wavelength). For simplicity, frequency or wavelength is used to describe lower-energy electromagnetic radiation, such as a radio station playing at 101.5 megahertz (MHz) or visible green light at 500 nanometers (nm).

The majority of this section will address ionizing radiation produced by radioactive elements called isotopes, with a focus on the hazards and safety issues in the research laboratory. Nonionizing radiation is discussed in more detail in Section 4.9, Nonionizing Radiation.

Radiation produced during decay is emitted in all directions. If a person is close enough to an unshielded sample, the radiation will interact with their bodies in a process known as radiation exposure. Some of the interactions will lead to deposits of energy within the body (a variable effect that depends on the type of radiation). This results in a radiation dose. As particles and photons interact with matter, the energy is transferred. In a living cell, this extra energy can alter or break chemical bonds in molecules of the cell, causing cell death or, more rarely, permanent genetic change in the cell nucleus.

While it is important to understand the difference between exposure and dose, for the types of radiation produced in a research laboratory, the terms are often interchangeable. Roentgen equivalent man (rem) is the unit used to describe dose with biological effects taken into account.

4.3.2. Types of Radiation

4.3.2.a. Alpha Particles

An alpha particle (symbol α), consists of two neutrons and two protons ejected as a single unit from the nucleus of an unstable atom. The alpha particle is relatively large and heavy but strongly ionizing to electrons in a narrow region around the particle track. Because they are so much heavier than an electron, they do not deviate from a straight path.

The alpha particle steadily loses energy and slows down. The net result is that alpha particles transfer their energy within a short distance and are not very penetrating; a sheet of paper or 3 centimeters (cm) of air is sufficient to completely stop them. Since alpha particles cannot penetrate the outer layer of human skin, they do not present a risk from exposure external to the body. Alpha emitters do present a serious hazard if they are placed in close proximity to cells and tissues, such as the lungs or digestive tract; therefore, special precautions

are taken to ensure that alpha emitters are not ingested, inhaled, absorbed, or injected.

4.3.2.b. Beta Particles

The beta particle (symbol β), is an energetic electron emitted from the nucleus of unstable isotopes. They have a negative charge and are about 8000 times smaller than the alpha particle, allowing deeper penetration. They can penetrate human tissue deep enough to damage living skin cells, resulting in characteristic beta burns. They can be stopped by an aluminum sheet or low-density material, such as Plexiglas®, a few millimeters thick or by 3 meters of air. Beta particles are produced by several important research isotopes such as Carbon-14 (^{14}C), Phosphorus-32 (^{32}P), Phosphorus-33 (^{33}P) and Iodine-133 (^{133}I).

4.3.2.c. Gamma and X-Ray

Gamma and x-ray radiation (symbol γ) are pure electromagnetic energy without charge or mass that interact only minimally with matter. Gamma and x-ray are the most penetrating type of radiation. Gamma rays are emitted from the nucleus while x-rays are released as a result of changes in the outer electron cloud. In general, gamma rays are more energetic. Nearly all unstable isotopes emit some gamma radiation except for pure beta particle emitters, such as ^{14}C and ^{32}P. Attenuation (either through shielding material or absorption within the body) occurs by several different means depending on the energy of the incident photon.

4.3.3. Terms Used to Describe Radioactive Decay

The following definitions are from the NRC Web site (http://www.nrc.gov/reading-rm/basic-ref/glossary.html).

Activity: The rate of disintegration (transformation) or decay of radioactive material per unit time. The units of activity (also known as radioactivity) are the Curie (Ci) and the Becquerel (Bq).

Becquerel (Bq): One of three units used to measure radioactivity, which refers to the amount of ionizing radiation released when an element (such as uranium) spontaneously emits energy as a result of the radioactive decay (or disintegration) of an unstable atom. Radioactivity is also the term used to describe the rate at which radioactive material emits radiation, or how many atoms in the material decay (or disintegrate) in a given time period. As such, 1 Bq represents a rate of radioactive decay equal to 1 disintegration per second, and 37 billion (3.7 x 1010) Bq equals 1 Ci.

Curie (Ci): One of three units used to measure the intensity of radioactivity in a sample of material. This value refers to the amount of ionizing radiation released when an element (such as uranium) spontaneously emits energy as a result of the radioactive decay (or disintegration) of an unstable atom. Radioactivity is also the term used to describe the rate at which radioactive material emits radiation, or how many atoms in the material decay (or disintegrate) in a given time period. As

such, 1 Ci is equal to 37 billion (3.7 x 1010) disintegrations per second, so 1 Ci also equals 37 billion (3.7 x 1010) Bq. A Curie is also a quantity of any radionuclide that decays at a rate of 37 billion disintegrations per second (1 gram of radium, for example). The Curie is named for Marie and Pierre Curie, who discovered radium in 1898.

Half-life: The time required for half the atoms of a particular radioisotope to decay into another isotope. A specific half-life is a characteristic property of each radioisotope. Measured half-lives range from millionths of a second to billions of years, depending on the stability of the nucleus. Radiological half-life is related to, but different from, the biological half-life and the effective half-life.

Radioactive decay: The spontaneous transformation of one radioisotope into one or more different isotopes (known as "decay products" or "daughter products") accompanied by a decrease in radioactivity (compared to the parent material). This transformation takes place over a defined period of time (known as a "half-life"), as a result of electron capture; fission; or the emission of alpha particles, beta particles, or photons (gamma radiation or x-rays) from the nucleus of an unstable atom. Each isotope in the sequence (known as a "decay chain") decays to the next until it forms a stable, less energetic end product. In addition, radioactive decay may refer to gamma-ray and conversion electron emission, which only reduces the excitation energy of the nucleus.

4.3.4. Terms Used to Quantify Exposure and Dose

Careful assessment and tracking of dose is required by NRC and VHA to ensure the safety and health of anyone exposed to ionizing radiation. Doses can be expressed in Curies. Other units include:

Roentgen: A unit of exposure to ionizing radiation. It is the amount of gamma or x-rays required to produce ions resulting in a charge of 0.000258 coulombs/kilogram of air under standard conditions. Named after Wilhelm Roentgen, the German scientist who discovered x-rays in 1895.

Radiation absorbed dose (rad): One of the two units used to measure the amount of radiation absorbed by an object or person, known as the "absorbed dose," which reflects the amount of energy that radioactive sources deposit in materials through which they pass. The rad is the amount of energy (from any type of ionizing radiation) deposited in any medium (e.g., water, tissue, air). An absorbed dose of 1 rad means that 1 gram of material absorbed 100 ergs of energy (a small but measurable amount) as a result of exposure to radiation. The related international system unit is the gray (Gy), where 1 Gy is equivalent to 100 rad.

Roentgen equivalent man (rem): One of the two standard units used to measure the dose equivalent (or effective dose), which combines the amount of energy (from any type of ionizing radiation that is deposited in human tissue), along with the medical effects of the given type of radiation. For beta and gamma

radiation, the dose equivalent is the same as the absorbed dose. By contrast, the dose equivalent is larger than the absorbed dose for alpha and neutron radiation, because these types of radiation are more damaging to the human body. Thus, the dose equivalent (in rems) is equal to the absorbed dose (in rads) multiplied by the quality factor of the type of radiation [see Title 10, Section 20.1004, 10 CFR 20.1004), Units of Radiation Dose]. The related international system unit is the Sievert (Sv), where 100 rem is equivalent to 1 Sv.

Gray (Gy): One of the two units used to measure the amount of radiation absorbed by an object or person, known as the "absorbed dose," which reflects the amount of energy that radioactive sources (with any type of ionizing radiation) deposit in materials (e.g., water, tissue, air) through which they pass. One gray (Gy) is the international system of units equivalent of 100 rads, which is equal to an absorbed dose of 1 Joule/kilogram. An absorbed dose of 0.01 Gy means that 1 gram of material absorbed 100 ergs of energy (a small but measurable amount) as a result of exposure to radiation.

Sievert (Sv): The international system unit for dose equivalent equal to 1 Joule/kilogram. 1 Sievert = 100 rem. Named for physicist Rolf Sievert.

Note: These definitions are from the NRC Web site (http://www.nrc.gov/reading-rm/basic-ref/glossary.html).

4.3.4.a. Occupational Dose Limits

NRC and Occupational Safety and Health Administration (OSHA) have established maximum limits for worker occupational exposure. NRC limits are derived from cumulative internal and external exposures. OSHA limits are more focused on external exposures (skin). The whole body dose cannot exceed 3 rem over 3 consecutive months or 5 rem per year.

4.3.5. Biological Effects of Radiation Exposure

Short exposures to low doses of ionizing radiation are usually clinically insignificant. However, higher exposure time and/or doses may rupture chemical bonds or form new ones, altering molecules, including deoxyribonucleic acid (DNA) sequences. Doses above 100 rem (1 Sv) cause immediate, systemic health effects including nausea, hair loss, and severe damage to the bone marrow and digestive tract. Ionization may also create toxic free radicals that damage cellular components and is known to induce cancer at high doses and high dose rates. An increased risk of cancer has not been demonstrated at low doses (10,000 mrem).

Since rapidly dividing cells are highly sensitive to radiation, special considerations are given to pregnant workers particularly in the first 20 weeks of pregnancy. Genetic effects may appear in an exposed person's direct offspring or may appear several generations later depending on whether the altered genes are dominant or recessive.

4.3.6. Dosimetry and Personnel Exposure Record

Dosimeters are small devices used to measure radiation exposure or dose over a period of time. The dosimeters most commonly used by research laboratory workers are a small piece of film (film badge) within a plastic case and measure whole-body exposures. The results obtained from these devices are retrospective and do not differentiate between acute (brief) and chronic (extended time) exposures.

Whole-body dosimeters can detect x-ray and gamma radiation above 1 mrem and high-energy beta radiation above 10 mrem. It cannot detect radiation emitted from low-energy beta emitters such as Tritium/Hydrogen-3 (^{3}H), ^{14}C, or Sulfur-35 (^{35}S).

Figure 4-1 is a diagram of a Luxel® optically stimulated luminescence (OSL) dosimeter badge.

Figure 4-1: Luxel® OSL Whole Body Dosimeter with Labeled Parts
(Source: University of Washington, Environment and Health Safety: https://www.ehs.washington.edu/rsotrain/radiation_safety_state_rules/page19.shtm)

A ring dosimeter is used to measure an individual's extremity dose equivalent, usually to the fingers, and is worn on the hand that is most likely to receive the highest radiation exposure.

Safe-use and handling practices of any dosimetry device include:

- Wear dosimetry badges whenever exposures may occur (when working with radiation-generating equipment).
- Do not tamper with the dosimeter or remove the film from the plastic case.
- Notify the RSO immediately if your dosimeter becomes lost or damaged.
- Store dosimeters away from sources of ionizing radiation.
- Do not leave your dosimeter near a heat source or direct sunlight.
- Badges should never be shared.

Under the direction of the RSO, other types of dosimeters may be used for special monitoring applications.

Monitoring records must be maintained according to 29 CFR 1910.1020, Access to Employee Exposure and Medical Records (https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10027).

4.4. Ionizing Radiation Safety Principles

4.4.1. Hazard Control: Time, Distance, and Shielding

Radiation dose is directly proportional to the time an individual is exposed to a source of ionizing radiation. Time spent handling radiation sources should be minimized as much as possible. Distance is also very important. Less exposure occurs with more distance between a research laboratory worker and a radiation source. For point sources, such as a source vial, doubling the distance from the source reduces exposure by a factor of 4. The use of remote handling tools can significantly reduce dose, especially to fingers.

The use of shielding will reduce the amount and dose of radiation that reaches the body. Sufficient shielding will completely block alpha and beta radiation, while photon radiation penetration follows an exponential decay depending on energy. Use syringe and vial shields, lead blocks, lead foil and leaded glass, or lead-lined syringe carriers to reduce radiation exposure.

Time, distance, and shielding are illustrated in Figure 4-2.

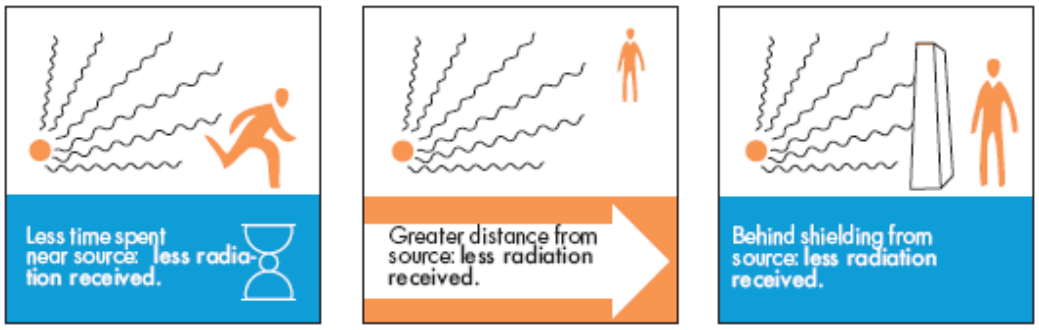

Figure 4-2: Time, Distance, and Shielding Diagrams (Source: NRC, 2011: http://www.nrc.gov/about-nrc/radiation/protects-you/protection-principles.html)

4.4.2. ALARA

ALARA is the overarching concept in any application involving radiation or radioactive material. Use the smallest amount of the least harmful isotope for the shortest duration possible. VHA is required by the NRC MML to maintain a formal ALARA program and achieve radiation exposures as far below the maximum permissible dose as practical.

4.4.3. Posting and Labeling

NRC Form 3, Notice to Employees (http://www.nrc.gov/reading-rm/doc-collections/forms/form3_us.pdf) provides information on employee rights and

contact information for the NHPP and must be prominently displayed where workers can see it. Posting requirements are listed in VHA Directive 1105.01 (http://www.va.gov/VHAPUBLICATIONS/ViewPublication.asp?pub_ID=2092).

Authorized users must post areas where radiation-generating equipment is used or stored with warning signs bearing the radiation symbol and "CAUTION, RADIATION AREA." Label the bench, radioisotope containers, disposal sinks, waste containers, and contaminated equipment with radiation caution tape.

4.4.4. Bench Safety

Work involving any radioactive materials must be conducted within a dedicated radiation containment area. Equipment used in the radiation containment area should never be moved or used outside of the research laboratory prior to being surveyed for radioactive contamination.

Specialized equipment is necessary and required for radiation protection. For work with beta-emitters for instance, such specialized equipment could include:

- A portable, hands-free Geiger-Müller (G-M) detector (tube and counter) to screen for contamination of the working area.
- A large, plastic spill tray with raised sides and plastic-backed absorbent disposable liners to contain any spills and prevent contamination.
- Acrylic plastic shielding with a minimum thickness of 1 cm (Figure 4-3).

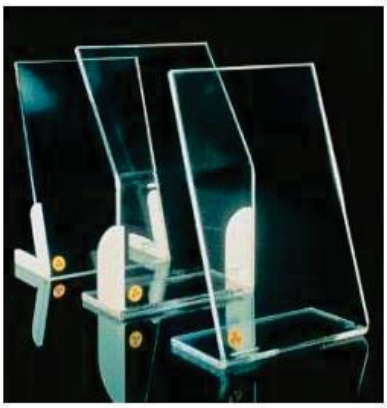

Figure 4-3: Bench-Top Radiation Shields (Sources: Left: Lab Supply Outlaws, 2010: http://www.labsupplyoutlaws.com/products/Lab-Equipment/Radiation-Protection/Radiation-Shields/Nalgene-Maximum-Protection-Benchtop-Beta-Radiation-Shields.htm; Right: Anachem, 2013: http://www.anachem.co.uk/catalogue/product/itemNo/SL1030)

Best work practices include:

- Avoid working in heavy traffic areas and near doorways.

- Clear the bench area of unnecessary items and cover with an absorbent material with impervious backing.
- Keep contaminated containers and equipment to the rear of the research laboratory bench.
- Use disposable plastic pipette tips, Petri dishes, centrifuge tubes, etc.
- Carefully clean and decontaminate all surfaces after use.

4.5. Management Practices

All research projects involving radiation hazards must be approved by RSC, SRS, and the R&D Committee prior to commencement. The SRS must annually review all active research protocols involving radiation hazards regardless of funding status or source. Each Facility Director with an NHPP permit must ensure protection of the health and safety of workers and the environment and achieve regulatory compliance.

4.5.1. Ordering, Receipt, and Transfer of Radioactive Materials

Ordering radioactive materials must occur according to established facility protocols in accord with NHPP permit commitments. A procedure for receipt and transfer of radioactive materials should be included in the local Radiation Safety Program.

4.5.2. Inventory

The authorized user must develop a current record and inventory of radioactive material that includes:

- Compliance with the facility Radiation Safety Program. A sample inventory record of isotope use form is provided as Enclosure 9.
- Provisions to update the inventory when a product is used or changed.
- Frequency of verifying inventory (type and quantities).
- RSO and/or facility Safety Officer verification inventories at least semi-annually.
- RSO approval of all acquisitions and uses of radiation-generating equipment.

4.5.3. Security of Radioactive Material

10 CFR 20.1801, Security of Stored Materials and 1802, Control of Material not in Storage (http://www.gpo.gov/fdsys/pkg/CFR-1999-title10-vol1/pdf/CFR-1999-title10-vol1-sec20-1801.pdf) covers storage and control of licensed material. These sections state that radioactive material in controlled or unrestricted areas shall be secure from unauthorized removal or access, and that research laboratory workers must control and maintain constant surveillance of radioactive material that is not in storage in a controlled or unrestricted area.

VHA Directive 1105.01 authorizes the RSC and RSO provide local oversight for security of radioactive material.

4.5.4. Transportation of Radioactive Material

Transportation of radioactive material is a complex process that will require coordination with the RSO prior to shipping or receiving any byproduct material. Research laboratory workers should follow the policy in the facility Radiation Safety Program. Several agencies have overlapping authorities for regulating shipments of radioactive materials, including:

- NRC 10 CFR 71, Packaging and Transportation of Radioactive Material, (http://www.gpo.gov/fdsys/pkg/CFR-2011-title10-vol2/pdf/CFR-2011-title10-vol2-part71.pdf).
- The U.S. Department of Transportation (DOT), 49 CFR 173, Subpart I, Class 7 Radioactive Materials (http://www.gpo.gov/fdsys/pkg/CFR-2010-title49-vol2/pdf/CFR-2010-title49-vol2-part173-subpartI.pdf).

4.6. Monitoring for Environmental Contamination

For all radionuclides, except ^{3}H, ^{14}C, and ^{35}S, a contamination survey, using a suitably sensitive survey meter for the isotope being monitored, must be performed and documented for each day of radioactive material use and weekly when radioactive material is not in use. Records of all surveys must be maintained to demonstrate radiation levels to RSC and RSO inspectors.

Each portable radiation survey instrument has different detection capabilities, as listed in Table 4-1. There are 3 common categories (G-M, scintillation, and ionization chambers), and selection is based on the type of radioactive material in use. Typically, research laboratories do not use an ionization chamber.

Table 4-1: Survey Requirements with Meter Options for Various Isotopes

Isotope	Daily-When Radioactive Material is Used	Weekly-Conducted Regardless of Work
	Probe Requirements (mrem/hr)	Counter/Meter
^{3}H	Use liquid scintillation counter (LSC) record results in disintegrations per minute	LSC
^{14}C	G-M detector	LSC
^{32}P, ^{33}P, ^{35}S, ^{51}Cr	G-M detector	LSC or G-M survey meter
Iodine-125 (^{125}I)	NaI scintillation detector	Low-energy gamma counter

Text description of this table is available on a separate page.

The following enclosures can be used to record survey results:

- Enclosure 10, Sample Inventory Record of Radioactive Material Form.
- Enclosure 11, Sample Monthly Research Laboratory Contamination Survey Form.

4.6.1. G-M Detectors

A G-M tube is the sensing element of a G-M detector (Figure 4-4). It is extremely sensitive, and can detect a single beta particle or photon of ionizing radiation. However, the *efficiency*, how well it responds to the radiation of various isotopes, varies widely depending on the energy of the incident radiation. In some instances, the efficiency may be so low as to render the instrument impractical for detection.

Figure 4-4: G-M Detectors with Different Probes
(Sources: Left: Aztec Research, 2011: http://www.aztecresearch.net/geiger.htm; Right: Radiation Answers, 2011: http://www.radiationanswers.org/radiation-introduction/detecting-esuring/geiger-mueller.html)

When using a hand-held survey meter, move the probe slowly and close to the surface without touching it. Even a tiny amount of contamination will take the probe out of service and may require replacement of the Mylar window. A count rate of more than two times the background typically indicates contamination.

4.6.2. Scintillation Detectors

Scintillation detectors absorb beta or gamma radiation and re-emit the energy as light. They are highly sensitive to the low-energy radiation emitted by some research isotopes. An LSC, (Figure 4-5), is used to detect ^{3}H, ^{14}C, ^{35}S, and ^{125}I and can be used to count contamination removed by wipe samples.

Figure 4-5: Liquid Scintillation Counter (Source: University of Michigan: http://www.lsa.umich.edu/psych/research/caf/equipment_available.html)

A scintillation probe is used on survey meters like the Ludlum 3 for low-energy photons associated with ^{125}I gamma photons.

4.7. Radiological Spill Response

Each local Radiation Safety Program is required to have a spill response procedure based on the type of isotope, energy level, and radiological hazard. When a spill occurs, the first step is to evacuate the area and contact the RSO. The RSO will determine the corrective actions to contain, clean-up/decontaminate, and dispose of the spilled material. Make sure you have the proper supplies and PPE and use a radiation survey meter appropriate for the type and energy of radiation to be surveyed. Follow-up procedures will include documentation of the incident and medical monitoring of potentially exposed workers.

4.8. Waste Disposal

Disposal of radioactive waste is a regulated activity and must comply with requirements in the local Radiation Safety Program.

As experiments are completed, solid and liquid [low-level radioactive waste (LLRW)] will be generated. This includes all contaminated materials (leftover bench solutions, expired stock vials, and disposable equipment). Decontaminate (render non-radioactive) discarded items, prior to disposal, whenever possible. Radioactive waste must be kept separate from non-radioactive waste and deposited in dedicated unbreakable waste containers with lids, which are labeled and have absorbent material to contain leaks. All radioactive waste must be secured at all times against unauthorized access. Radioactive waste from different sources (experiments) cannot be combined without the RSO's approval.

Waste disposal must be appropriately documented with fill logs and analysis forms completed by the authorized user and attached to each container. Prior to disposal, contamination survey of the exterior of the container must be performed, and the results reported to the RSO at the time of pick-up.

Several options for disposal are available, including decay in storage, discharge to sanitary sewer, or off-site disposal. The type of radioactive material determines the method of disposal used.

4.8.1. Decay-In-Storage

For certain isotopes with a half-life of 6 months or less, disposal by decay-in-storage may be an option. This requires approval by the RSC and will be overseen by the RSO. Although some decay occurs while waste is being accumulated in authorized use locations, the formal tracking, storage, monitoring, and final disposal of waste through the decay-in-storage process is usually performed in a separate, secure facility. Decayed waste can be disposed of as biomedical waste, but all radioactive labels must be obliterated prior to disposal.

Short-lived waste will normally be held for a decay period of 10 radioactive half-lives, after which less than 1/1000th of the original activity remains. If more than one isotope is mixed in the waste, it must be stored for a minimum of 10 half-lives of the slowest decaying component. Table 4-2 provides information regarding minimum decay-in-storage time for specific isotopes.

Table 4-2: Minimum Decay-In-Storage for Specific Isotopes

Isotope	Minimum Decay-In-Storage Time
^{32}P	6 months
^{51}Cr	1 year
^{125}I	2 years
^{35}S	3 years

Text description of this table is available on a separate page.

Additional requirements for decay-in-storage can be found in 10 CFR 35.92, Decay-In-Storage (http://www.gpo.gov/fdsys/pkg/CFR-2011-title10-vol1/pdf/CFR-2011-title10-vol1-sec35-92.pdf).

4.8.2. Sewer Disposal

Sanitary sewer limits can be locally established and more stringent than 10 CFR 20, NRC Standards for Protection Against Radiation. Sewer disposal involves the discharge of carefully measured and tracked quantities of radioactive liquids into the sanitary sewer system. It is the least expensive method for disposal, but *may only be performed in strict accordance with specific regulatory limits* on both the concentration of radioactivity in a liquid and the total amount of radioactivity that may be released on a monthly and annual basis. Sewer disposal requires approval of the RSC and will be overseen by the RSO.

4.8.3. Off-Site Disposal

Disposal of long half-life radioactive waste by off-site shipment is coordinated by the RSO working with the Green Environmental Management System (GEMS) Coordinator. Waste will be kept in a designated storage area. Contact the RSO to schedule waste pick-ups and prevent accumulation of full containers in work locations. It is extremely important that waste be labeled with the activity and isotope contained in the waste at all times. Every attempt should be made to limit such waste because shipments are expensive, strictly regulated, and must follow rigorous documentation requirements.

Non-compactable materials or items that cannot be incinerated (metal objects and lead shielding materials) should not be put into containers of long-lived dry waste unless absolutely necessary.

4.8.4. Special Cases

4.8.4.a. Mixed Waste

Mixed waste is any combination of hazardous and radioactive waste. The Environmental Protection Agency (EPA) defines hazardous waste as waste that poses a substantial or potential threat to public health or the environment and includes listed waste (lead, mercury, etc.) and categorical waste (ignitable, corrosive, toxic). Generation of mixed waste should be avoided if possible. The RSO and GEMS Coordinator must be involved in management of mixed waste.

4.8.4.b. Sealed Radioactive Sources

Sealed radioactive sources consist of radioactive material permanently bonded to a surface or sealed within a matrix in a manner that prevents the release or dispersal of the radioactive material under normal use conditions. Certain instruments and manufactured articles contain sealed radioactive sources, including smoke detectors, liquid scintillation counters, and standards used for calibration.

In general, sealed sources are very safe, but periodic leak testing of all sealed sources is required to ensure that the device remains intact. Though the packaging protects radioactive material from physical contact, it does not mean the source is shielded. Some sealed sources produce hazardous levels of radiation, and serious injury has been reported from individuals unknowingly placing them in their pockets. Contact the RSO for specific instructions regarding disposal of sealed sources or surplus equipment that contains radioactive material.

4.8.4.c. Lead Shielding Materials

Lead, often used for shielding materials, is toxic and requires special handling. Lead waste is considered hazardous waste; if disposal is required, lead shielding should be surveyed for contamination. Lead shielding must not be placed into a dry waste container because they cannot be compacted. Do not attempt to decontaminate lead by cutting, heating, or abrasive methods due to the risk of

inhalation and ingestion. Contact the RSO or GEMS Coordinator for specific information regarding disposal or decontamination.

4.9. Nonionizing Radiation

4.9.1. Overview

Nonionizing radiation is defined as electromagnetic waves that do not deposit enough energy to break chemical bonds or ionize atoms, such as radio waves [also called radio frequency (RF) radiation], microwaves, infrared (IR), visible, and UV radiation. Lasers that operate within these regions also are a form of nonionizing radiation. The primary effect of exposure to nonionizing radiation is heating within the exposed tissue. Organs with low blood flow (such as eyes and testes) are vulnerable to RF heating because they have a limited ability to dissipate heat.

4.9.2. Important Concepts and Standards

Electromagnetic radiation (EMR) is energy traveling through space with properties of both waves (oscillating electric and magnetic fields) and particles (discrete packets or photons of energy). Depending on the frequency/wavelength, duration of exposure, and intensity or strength of the radiation field, human health effects will vary from essentially none to potentially dangerous.

The Federal Communications Commission (FCC) authorizes and licenses all devices, transmitters, and facilities generating RF radiation and has set a maximum permissible exposure (MPE) guideline for human exposure to RF radiation, exclusive of IR, visible, or UV.

Two terms describe the transfer of energy and biological effects of nonionizing radiation:

- Power density: The power per unit area, expressed in milliWatts per square centimeter (mW/cm^2).
- Specific absorption rate (SAR): The rate energy is absorbed or transferred in tissue, expressed in watts per kilogram (W/kg) or milliWatts per kilogram (mW/kg).

The current exposure limits for RF radiation are established in 29 CFR 1910.97, Nonionizing Radiation (http://www.gpo.gov/fdsys/pkg/CFR-2011-title29-vol5/pdf/CFR-2011-title29-vol5-sec1910-97.pdf), is 10 mW/cm^2 power density (1 mW hour per cm^2 energy density). The FCC has established more stringent standards across that portion of the spectrum where human absorbance is greatest (30-300 MHz).

4.9.3. Biological Effects of Nonionizing Radiation

An SAR above 4 W/kg is generally considered harmful. Cell phones emit 0.2-1.4 W/kg, while some lasers may emit 1300 W/kg or more. The SAR is frequency-

dependent. The most restrictive exposure limits are between 30-300 MHz, the range where the human body absorbs RF energy efficiently.

At very high power densities (100 mW/cm^2 or more), tissue damage occurs when energy is transferred to tissue faster than the ability of the body to dissipate or remove the heat. Unshielded exposure to these levels is unlikely in research laboratories.

4.9.4. Microwave Radiation

Microwaves are part of the electromagnetic spectrum with an energy between radio signals and infrared radiation. Some common microwave applications are communication (such as cell phones), satellite transmissions, and food preparation. Research laboratory applications of microwave devices involve post-sectioning processes such as immunolabeling, immunohistochemistry, antigen retrieval, and cell staining. Microwave ovens used in research laboratories should be labeled “For lab use only-no food or drink.”

4.9.5. UV Radiation

Exposure to UV radiation may result in sunburns, corneal burns, fragility, and scarring. Long-term or repeated exposures may result in photoaging (wrinkles, sagging skin, loss of elasticity, and sun spots) or cause damage to DNA in skin cells, resulting in mutations that promote or cause cancer. Some individuals are at higher risk to exposure due to genetics, diet, medications, age, and overall health.

Eye injury is a significant concern because UV light exposure can damage the cornea. Cataracts are also a known health effect from prolonged UV radiation exposure.

UV radiation is used in some research laboratory procedures and is generally a low risk for personnel as long as safety precautions are followed. All equipment (such as transilluminators, UV crosslinkers, UV cabinets, etc.) must be appropriately shielded and should have functional lock-out switches to disable the UV light source and exposure. UV-blocking eye protection should also be used.

4.9.5.a. UV Safety

OSHA has adopted the 2003 guidelines established by the American Conference of Governmental Industrial Hygienists for occupational exposure to UV radiation. UV-generating equipment and the areas where they are used must be labeled (Figure 4-6) and should be designed to contain the hazardous energy. When exposure is possible, skin and eye protection is required. Gloves and long sleeve shirts may be sufficient for hands and arms. Eye protection must be designed to protect against the UV wavelengths produced by the equipment and include side shields.

Figure 4-6: Appropriate Signs for UV-Generating Equipment
(Sources: Left: University of Washington, 2011: http://www.ehs.washington.edu/rsononion/uvlight.shtm; Right: University of Farmington, Maine: http://students.umf.maine.edu/elizabeth.theriault/public.www/p2.html)

4.9.6. Lasers

A laser may be visible or invisible and produces an extremely intense stream of photons that can be focused precisely and loses little energy over significant distances. While useful for delicate medical applications, even momentary eye exposure to the beam without protection may cause blindness.

Any work involving lasers will require review and approval by the Laser Safety Committee or RSC. Laser safety requires comprehensive hazard management and specially-designed controls and protective equipment. Some lasers have high-voltage power sources with significant electrical shock hazards, while chemical lasers use mixtures of highly volatile and often toxic materials. Ventilation, beam control curtains, interlocks, and special protective equipment may be required based on the type and power level of the laser.

4.10. References and Resources

1. 10 CFR 19, Notices, Instructions and Reports to Workers: Inspection and Investigations: http://www.gpo.gov/fdsys/pkg/CFR-2011-title10-vol1/pdf/CFR-2011-title10-vol1-part19.pdf.

2. 10 CFR 20, NRC Standards for Protection Against Radiation: http://www.gpo.gov/fdsys/pkg/CFR-2011-title10-vol1/pdf/CFR-2011-title10-vol1-part20.pdf.

3. 10 CFR 35, Medical Use of Byproduct Material: http://www.nrc.gov/reading-rm/doc-collections/cfr/part035/.

4. 29 CFR 1910.97, Nonionizing Radiation: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9745.

5. 29 CFR 1910.1096, Ionizing Radiation: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10098.

6. Centers for Disease Control and Prevention, Workplace Safety & Health Topics, Electric and Magnetic Fields (EMF): http://www.cdc.gov/niosh/topics/emf/.

7. Frequently Asked Questions About Health Physics Based on 10 CFR 20: http://www.nrc.gov/about-nrc/radiation/protects-you/hppos/hppos-qa.html.

8. Memorandum of Understanding Between the U.S. Nuclear Regulatory Commission and the Occupational Safety and Health Administration 10/21/1988: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=MOU&p_id=233.

9. Health Physics Positions (HPPOS) Database: http://www.nrc.gov/about-nrc/radiation/protects-you/hppos/hppos.html.

10. NRC. 2009. NUREG-1556: http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1556/.

11. NRC Enforcement Manual: http://www.nrc.gov/about-nrc/regulatory/enforcement/guidance.html#manual.

12. NRC Inspection Manual: http://www.nrc.gov/reading-rm/doc-collections/insp-manual/.

13. NRC Key Guidance Documents: http://www.nrc.gov/reading-rm/basic-ref.html#key.

14. OSHA Letters of Interpretation:

    20097, Ionizing Radiation Hazards in the Workplace: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=20097.

    23451, Video Display Terminals (VDTs) and Radiation: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=23451.

24755, Workplace Exposure Limits for Ultra-Violet Radiation: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=24755.

15. OSHA Safety and Health Topics, Extremely Low Frequency (ELF) Radiation: https://www.osha.gov/SLTC/elfradiation/index.html.

16. VHA Directive 1105.01, Management of Radioactive Materials: http://www1.va.gov/vhapublications/ViewPublication.asp?pub_ID=2092.

4.11. Enclosures and Fact Sheets

Enclosure 1 Fact Sheet Listing

The following fact sheets contain quick-reference information relevant to this chapter:

4.1 Ionizing Radiation and Radioactive Isotope Safety
4.2 Nonionizing Radiation
4.3 Radioisotope Quick Reference, Carbon-14
4.4 Radioisotope Quick Reference, Iodine-125
4.5 Radioisotope Quick Reference, Iodine-131
4.6 Radioisotope Quick Reference, Phosphorus-32
4.7 Radioisotope Quick Reference, Phosphorus-33
4.8 Radioisotope Quick Reference, Tritium/Hydrogen-3
10.4 Storage of Radioactive Materials

Enclosure 9 Sample Isotope Use Record Form

Enclosure 10 Sample Inventory Record of Radioactive Material Form

Enclosure 11 Sample Monthly Research Laboratory Contamination Survey Form

Enclosures

Enclosure 1	Fact Sheet Listing
Enclosure 2	Sample Biological Spill Response Procedures
Enclosure 3	Sample Form for Declaration of Equipment as Free of All Hazards
Enclosure 4	Sample SOP: Glass Tubing
Enclosure 5	Sample SOP: Operating Compressed Gas Systems
Enclosure 6	Sample SOP: Safe Handling of Liquid Nitrogen
Enclosure 7	Sample SOP: Safe Operation of Centrifuges
Enclosure 8	Sample Centrifuge Log Sheet
Enclosure 9	Sample Isotope Use Record Form
Enclosure 10	Sample Inventory Record of Radioactive Material Form
Enclosure 11	Sample Monthly Research Laboratory Contamination Survey Form