CHEMICAL HYGIENE PLAN

Laboratory Safety Manual

RADFORD UNIVERSITY

ENVIRONMENTAL HEALTH & SAFETY

Environmental Health and Safety
501 Stockton Street
P.O. Box 6909
www.radford.edu/ehs
Phone: 540-831-7790 or Email: ehs@radford.edu

Revision Status

Implementation Date	Revision Number	Comments
July 2006	N/A	Initial Program Issued
June 2020	1	Program Overhaul; Incorporation of Laboratory Safety Manual; New Appendices; Incorporation of OSIG Recommendations from Chemical Inventory Audit

Emergency Telephone Numbers

On-Campus Emergencies - University Police Department

On-Campus Phone:	5500
Off Campus Phone:	540-831-5500

Campus Police should be used for all On-Campus Emergencies.

Off-Campus

Emergencies	911
Radford City Police (non-emergency number)	540-731-3624

Other Important Numbers
(During working hours from 8:00 am to 5:00 pm)

Environmental Health and Safety	540-831-7790
Office of Emergency Management	540-831-6696
Facilities Management	540-831-7800

Information to Provide for Emergency Calls
Your name
Type of Emergency (Fire, Injury, Chemical Spill, etc.)
Location of Emergency (Building, Room Number)
Extent of Emergency (Rooms or Number of People Involved)

When reporting an accident involving a hazardous substance the following information should be provided:

a. the identity of the hazardous substance(s) to which the employee may have been exposed, preferably in the form of a safety data sheet (SDS);
b. a description of the conditions under which the exposure occurred; and
c. a description of the signs and symptoms the employee is experiencing.

Safety Data Sheets (SDS) are available in the University's Chemical Inventory Management System, CHIMERA. All incidents involving students or employees should be reported to EHS.

STAY ON THE TELEPHONE UNTIL DISPATCHER HANGS UP FIRST!

Table of Contents

1. CHEMICAL HYGIENE PLAN – Laboratory Safety Manual

1.1 Purpose

Radford University is required under U.S. Code of Federal Regulations (CFR) Section 29, part 1910.1450 (Occupational Exposures to Hazardous Chemicals in Laboratories) to provide a chemical hygiene plan that establishes minimum safety standards for working with chemicals in the laboratory and outlines procedures that minimize both the risk of chemical exposure to laboratory personnel and the risk of chemical releases into the environment. 29 CFR 1910.1450, commonly known as the "Laboratory Standard," was developed in recognition of the differences between laboratories and industrial operations in their use and handling of hazardous chemicals. To adequately protect laboratory workers from exposure to hazardous chemicals, the Occupational Safety and Health Administration (OSHA) realized it was necessary to use a different regulatory approach from that applied to general industry.

The purpose of the Laboratory Standard is to protect the health of employees exposed to chemicals while working in a laboratory. It applies to all employers engaged in the laboratory use of hazardous chemicals.

The Virginia Occupational Safety and Health Standards for General Industry have adopted 29 CFR 1910.1450 and are responsible for the administration and enforcement of this standard. The Laboratory Standard became effective in Virginia on June 22, 1990. By January 31, 1991 employers were required to have developed and implemented a written program known as the Chemical Hygiene Plan (CHP). This Plan has been developed for laboratories at Radford University by the Office of Environmental Health and Safety (EHS) in compliance with this standard. This plan is to be used in conjunction with the Radford University's Hazard Communication Program (OSHA Hazard Communication, 29 CFR 1910.1200).

This *Laboratory Safety Manual* serves as the chemical hygiene plan for Radford University and provides guidance on the safe handling of hazardous substances, general laboratory safety practices, and procedures for proper acquisition, use, storage, transfer, and disposal of chemicals. Procedures for potential exposures from foreseeable emergencies are also included.

The recommendations and requirements provided in this manual are based on guidance from regulatory agencies and current professional standards. Radford University's Chemical Hygiene Officer oversees the development and implementation of Radford University's Chemical Hygiene Program.

1.2 Scope

Radford University's CHP applies to all university laboratory personnel and laboratories defined in this document. A laboratory is defined as, but not limited to, any location where research or teaching is conducted using hazardous chemicals, biohazardous/biological materials, radioactive materials, and/or radiation producing devices.

A location used for teaching or research that contains physical hazards may also be considered a laboratory, even if none of the materials listed above are routinely used in the area. Examples include electronics laboratories, fabrication laboratories, art studios, theater shops, laser laboratories, magnetics laboratories and clinical simulation laboratories.

A storage room containing the above materials is considered a laboratory if the materials are stored in support of both teaching and research laboratories.

1.3 Application

Chemical hygiene management is an ***ongoing*** program that requires responsible oversight and maintenance. This program is to be implemented on a departmental level by designated responsible persons, such as Department Chair, Laboratory Chemical Hygiene Officers (LCHO), Principal Investigators (PI), Laboratory Supervisors (LS), Instructors, Laboratory Personnel (Employees, Staff and Research Personnel), Safety Committees, or other designated persons.

All laboratories must follow the guidelines given in the University Chemical Hygiene Plan. In addition, these areas must develop a laboratory specific Chemical Hygiene Plan and/or Laboratory Safety Plan. A template for developing a Laboratory Chemical Hygiene Plan is available for use in Appendix E (Teaching Labs) and Appendix F (Research Labs).

2. INTRODUCTION

Instructional and research laboratories contain hazards that must be properly managed in order to minimize the risk they pose to health, safety, and the environment. These hazards include exposure to hazardous substances (e.g., chemicals, biological materials, and radioactive materials) and physical hazards associated with chemicals, equipment, and instruments used by laboratory personnel.

2.1 Hazardous Substance Definition

The term *hazardous substance*, as used in this manual, refers to any material that may present a danger to human health and welfare or the environment. This includes hazardous chemicals (e.g., laboratory chemicals, pesticides, and petroleum products), biohazardous/biological agents, and radioactive materials.

A *hazardous chemical*, as defined by the Occupational Safety and Health Administration (OSHA), is a chemical "which is classified as a physical hazard or a health hazard, a simple asphyxiate, combustible dust, pyrophoric gas, or hazard not otherwise classified." Most chemicals used in the laboratory are hazardous.

Particularly Hazardous Substances are a subset of hazardous chemicals that require special consideration and additional safety provisions, because of their toxic effects. Select carcinogens, reproductive toxins, and substances with a high degree of acute toxicity are particularly hazardous substances. More information about these substances is provided throughout this manual.

2.2 Regulations, Guidelines, and Permit Requirements

The following are some of the agencies that regulate laboratory activities and provide guidance and direction concerning the use of hazardous substances in the laboratory.

The Occupational Safety and Health Administration (OSHA) develops and enforces regulations based on federal statutes. OSHA regulates health and safety in the workplace, establishes chemical exposure limits, and sets minimum standards for work place health and safety (www.osha.gov).

The Environmental Protection Agency (EPA) develops and enforces environmental regulations to protect human health and the environment. The EPA regulates hazardous waste, machinery emissions, wastewater, storm water, and other hazardous materials in an effort to reduce their impact on the environment (www.epa.gov).

The National Institute for Occupational Safety and Health (NIOSH) is a research division of the Centers for Disease Control and Prevention (CDC) created by the Occupational Safety and Health Act of 1970. NIOSH conducts research, makes recommendations for the prevention of work related illness, and publishes sources of chemical toxicity information (www.cdc.gov/niosh).

The National Fire Protection Association (NFPA) provides codes and standards for fire safety, chemical storage, egress, and laboratory engineering controls for laboratories using chemicals (www.nfpa.org).

The United States Department of Transportation (DOT) regulates packaging, shipping, and documentation of hazardous materials during transportation and distribution including shipping and receiving (www.dot.gov).

The Virginia Department of Environmental Quality (DEQ) develops and enforces environmental regulations in the Commonwealth of Virginia. DEQ has the ability to enforce environmental regulations equivalent to or more stringent than those instituted by the federal government (www.deq.virginia.gov).

The Virginia Department of Health (VDH) Office of Radiological Health is responsible for protecting the public from unnecessary radiation exposure caused by a wide spectrum of applications used in the healing arts, research, educational institutions and industry. The office is responsible for: radioactive materials, X-ray machines, Emergency Preparedness and Response, Environmental Monitoring, and Radon. (www.vdh.virginia.gov/radiological-health/)

3. ROLES AND RESPONSIBILITIES

This Chemical Hygiene Plan applies to all work involving hazardous substances that is conducted in the laboratory. All individuals who plan to conduct instructional or research activities involving hazardous substances in a laboratory must undergo the chemical hygiene training.

3.1 Departments

Departments must designate responsible persons to coordinate the requirements of this program with employees/students and ensure that all persons working with hazardous products are trained and knowledgeable. Coordinators include Supervisors, Laboratory Chemical Hygiene Officers (LCHO), Principal Investigators (PI), Laboratory Supervisors (LS), Instructors, Laboratory Personnel (Employees, Staff and Research Personnel), Safety Committees, or other designated persons.

The Department Chair has the responsibility and the authority to see that the Chemical Hygiene Plan is written, updated, and implemented. The Department Chair has the final responsibility for the safety and health of the employees, visitors, students, and other personnel conducting work in the Department.

3.2 Laboratory Chemical Hygiene Officer

It is the responsibility of each department to appoint a Laboratory Chemical Hygiene Officer (LCHO). Chemical Hygiene Officers are responsible for evaluating and making recommendations on safety issues that concern their laboratories within the entire Department. Chemical Hygiene Officers also participate in periodic safety inspections of laboratories.

Chemical Hygiene Officers advise and assist their laboratory supervisors in training new personnel, disseminating safety information, conducting inspections of their group's laboratories, and inspecting and ensuring the maintenance of group safety equipment such as spill control kits, fire extinguishers, safety showers, and eyewash facilities. The Chemical Hygiene Officer's responsibilities include, but are not limited to, safety issues involving chemical hygiene. It is recommended that Chemical Hygiene Officer be the individual responsible for yearly review and updating of the Chemical Hygiene Plan, and keeping an accurate record of the amount of highly toxic substances being stored, used, dates of use, and names of persons using the substance. The Chemical Hygiene Officer is responsible for filing an accident/incident report form following a laboratory incident resulting in injury or illness, when a near miss incident that might have been more serious occurs, whenever an accident involving fire with flame occurs, and after all releases or spills of potentially hazardous substances. See Appendix A for a copy of the Accident/Incident Report Form.

3.3 Principal Investigators/Laboratory Supervisors/ Instructors

Principal Investigators (PI)/Laboratory Supervisors (LS)/Instructors are responsible for ensuring the policies and all employees, collaborating researchers, visitors, and students under their jurisdiction follow guidelines established in this manual. They are also responsible for ensuring individuals under their jurisdiction receive the appropriate training associated with the CHP.

They are charged with the development of specific standard operating procedures (SOPs) and polices that ensure that laboratory personnel are aware of (1) hazards that are present within their laboratory spaces, (2) engineering and administrative controls, (3) personal protective equipment (PPE), (4) location of Safety Data Sheets (SDS), and (5) the necessary steps to take in the event of an emergency. These SOPs should be incorporated into the Laboratory Chemical Hygiene Plan, found in Appendix E (Teaching Labs) and Appendix F (Research Labs). Any laboratory specific trainings associated with these SOPs must be documented within the Laboratory specific CHP.

3.4 Laboratory Personnel (Employees, Staff and Research Personnel)

Laboratory personnel are persons who conduct their work in a laboratory and are could have a potential exposure to hazardous chemical on a regular or periodic basis. This includes laboratory technicians, instructors, researchers, visiting researchers, administrative assistants, teaching assistants, student aides, student employees, and part-time and temporary employees.

All persons working in a laboratory must be familiar with the procedures and hazards associated with the particular laboratory they are working in.

- Attend and understand all trainings offered and ask questions as needed.
- Wear appropriate PPE, when needed.
- Demonstrate good laboratory safety habits.
- Immediately report any unsafe practices, conditions, or general hazards within their work area to their supervisor/Primary Investigator, and/or University Chemical Hygiene Officer.
- Familiarize themselves emergency procedures and steps needed in case of an emergency.
- Never work alone in the laboratory. This is especially important when conducting any work/research that is consider highly hazardous.

3.5 Students

Students are expected to observe all applicable safety practices and procedures within the Chemical Hygiene Plan, complete all designated training, and report any unsafe or hazardous conditions to the lab supervisor, PI, or University Chemical Hygiene Officer.

3.6 Visitors /Contractors/Vendors

Visitors /Contractors/Vendors are all persons entering a laboratory other than the PIs, laboratory staff, enrolled students, and authorized Radford University employees. All visitors must be under the supervision of the host laboratory. The host laboratory is responsible for laboratory security during the visit, notification and training of any potential hazards, and oversight of visitor compliance with applicable safety practices and procedures contained within the laboratory's CHP. Any necessary PPE is to be provided to all visitors by the laboratory or by contractor agreement.

3.7 Environmental Health and Safety

The Radford University Environmental Health and Safety (EHS) Office is responsible for the development of compliance assistance programs for the university based on all federal, state, and local rules and regulations. In particular EHS collaborates with the university community to promote health, safety, environmental protection, and compliance with applicable regulations, guidelines, and best practices in order to sustain a healthful and safe working and learning environment. This mission is accomplished by establishing policies and procedures, providing training and education, implementing preventive actions, and ensuring continuous improvement of Radford University's health and safety programs for employees, students, and visitors. The EHS Laboratory Safety Program provides services to assist laboratories in meeting regulatory requirements and minimizing the risks associated with laboratory hazards such as chemical substances, fire, electricity, explosion, high or low pressure systems and machinery.

EHS has the authority to stop any activity, which in their judgment is immediately dangerous to life and health.

3.8 Chemical Hygiene Officer

The institutional Chemical Hygiene Officer (CHO) is responsible for providing technical guidance for the development and implementation of the university's CHP. The University's CHO can be assigned duties such as acting as a point of contact with EHS, providing consultation and information on laboratory safety requirements, conducting laboratory safety audits/inspections, training, and conveying departmental information and concerns to EHS.

3.9 Student Health Services

Student Health Services can be reached at 540-831-5111 during school session and hours of operation are normally from 8 a.m. to 5 p.m., except for Fridays (opening at 9 a.m.), summer semesters (hours are Monday thru Thursday 10 a.m. to 2 p.m.), and breaks when there may not be hours of operation or they may vary from normal.

4. ASSESSMENT AND MANAGEMENT OF RISK

There are some general principles that should always be taken into account when individuals are working with chemical substances. Chemicals are an integral part of any laboratory. Safety must be incorporated into the laboratory environment. The following principles have been incorporated in Radford University's Chemical Hygiene Plan.

It is prudent to minimize all chemical exposure. There are few laboratory chemicals without hazards. Each specific chemical will not be addressed individually, however classes of chemicals will be identified. General precautions are provided for each class of laboratory chemicals. As a general rule, all skin contact with laboratory chemicals should be avoided. Additionally, instructors should use the most innocuous chemicals possible when designing labs.

It is critical that individuals working with chemicals never underestimate the risk. Even if a substance has no significant hazard, exposure should still be minimized. One should always assume that any mixture will be more toxic than its most toxic component. If a substance's toxicity is unknown, consider it toxic.

4.1 Risk Assessment

Exposure to hazardous substances can occur through inhalation, ingestion, contact with or absorption through skin, eyes or mucous membranes, or through injection (skin being punctured by a contaminated sharp object or uptake through an existing open wound) as illustrated in **Figure 4.1**. Damage may result from acute or chronic exposures and involve local tissue or internal organs. The extent of the injury depends on the dose administered, duration of the exposure, physical state, solubility, and interaction with other chemicals. Toxic chemicals include corrosives, systemic poisons, carcinogens, mutagens, and embryotoxins. When evaluating laboratory procedures, PI/LS/Instructors should consider likely routes of exposure for the hazardous substances used in the laboratory, engineering controls, safety precautions, and PPE that can be utilized to minimize the risk of exposure, and exposure response procedures to be implemented in the event of an exposure.

Dosage

The dose of a chemical is the most important factor that determines whether damage will result from exposure to the chemical. Chemicals vary tremendously in their toxicity. An excess of almost any chemical can be harmful and a sufficiently small amount of most chemicals will not cause injury. There is a threshold, or no effects level, that must be exceeded before toxic effects will be noticeable for most chemicals. Although the toxicity and chemical structure of a compound are generally related, each compound must be studied independently to determine its toxicity. In determining the toxicity of chemicals it is common to use standardized terms called the median lethal dose (LD50) or the median lethal concentration (LC50).

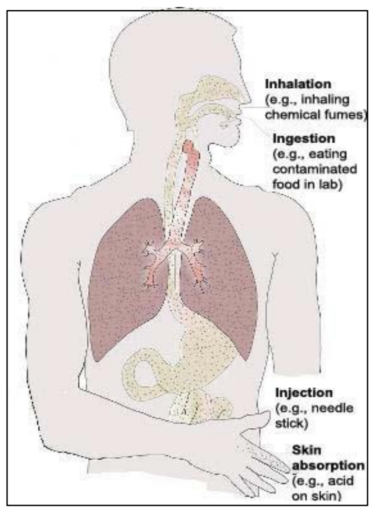


Figure 4.1 – Routes of Exposure

The LD50 is the dose of a chemical that will result in the death of 50% of a group of test animals when ingested or applied to the skin in a single dose. It is expressed in milligrams of the chemical per kilogram of body weight of the test animal. The LC50 refers to the concentration of a gas or vapor that will result in the death of 50% of the animals when inhaled and is expressed in parts per million (ppm).

A substance is considered toxic if the LD50 in test animals is between 50 mg/kg and 500 mg/kg when ingested, or between 200 mg/kg and 2000 mg/kg when in contact with the skin. The substance is also considered toxic if the LC50 is between 200 ppm and 20,000 ppm when inhaled. Examples of toxic chemicals include ammonia, bromine, sodium hydroxide, and methanol. A substance is considered highly toxic if it has an LD50 in test animals of less than 50 mg/kg by ingestion, less than 200 mg/kg by skin contact, or the LC50 is less than 200 ppm. Examples of highly toxic chemicals include chlorine, fluorine, and hydrogen sulfide.

Exposure

The toxicity of chemicals is also related to the duration of the exposure. Exposure to toxic chemicals is divided into two classes; acute toxicity and chronic toxicity.

Acute toxicity: An acutely toxic chemical causes damage in a relatively short time (within minutes or hours) after a single concentrated dose. Irritation, burns, illness, or death may result. Commonly used acutely toxic poisons include chlorine and ammonia. These substances may cause severe inflammation, shock, collapse or even sudden death when inhaled in high concentrations. Corrosive materials such as acids and bases may cause irritation, burns, and serious tissue damage if splashed onto the skin or eyes.

Chronic toxicity: A chemical that is a chronic toxin produces long term effects. Damage may result after repeated exposures to low doses over time, as from the slow accumulation of mercury or lead in the body, or after a long latency period from exposure to a carcinogen. Chronic exposure to solvents may also result in reproductive problems and behavioral changes. The symptoms from exposure to chronic toxins are usually different from those seen in acute poisoning from the same chemical. Since the level of contamination is low the worker may not be aware of the exposure to the toxin.

Chronic toxicity also includes exposure to embryotoxins, teratogenic agents, and mutagenic agents. Embryotoxins are substances that cause any adverse effects on the fetus (death, malformations, retarded growth, functional problems). Teratogenic compounds specifically cause malformation of the fetus. Examples of embryotoxic compounds include mercury and lead compounds. Mutagenic compounds can cause changes in the gene structure of the sex cells that can result in the occurrence of a mutation in a future generation. Approximately 90% of carcinogenic compounds are also mutagens.

Effects

Toxic effects are based on the site of action and are classified into local and systemic effects.

Local: The action of a toxin on the skin or mucous membrane at the point of contact is termed local toxicity or corrosivity. For example, acids have a local or direct irritating effect on the skin, eyes, nose, throat, and lungs. The skin may be severely burned or vision impaired. The lungs may be damaged because of inhaling toxic gases. Exposure may be through inhalation, ingestion, or direct contact with the skin or eyes.

Systemic: When a toxin is absorbed into the blood stream and distributed throughout the body systemic or indirect toxicity may occur. Absorption may take place through the lungs, skin, or gastrointestinal tract. Several sites may be damaged or the toxin may act on only one site. For example, arsenic may damage the blood, nervous system, liver, and kidneys. However, benzene acts on one site, the blood forming bone marrow. Pesticides are an example of systemic poisons commonly found in the work place.

Routes of Exposure

Toxic chemicals may enter the body through three routes: inhalation, ingestion, or contact with the skin and eyes.

Inhalation: Inhalation of toxic substances represents the most common means by which injurious substances enter the body. Air contaminants in the workplace present both acute and chronic dangers to health. Inhalation of toxic substances can cause serious local damage to the mucous membranes of the mouth, throat, and lungs; or pass through the lungs into the circulatory system producing systemic poisoning at sites remote from the point of entry.

Several thousand deaths per year are attributed to exposure to dust, fumes, gases, vapors, and mist in the work place. Exposure to organic dusts such as coal dust can cause asthma, chronic bronchitis, and emphysema. Mineral dusts such as asbestos can cause asbestosis, characterized by coughing and breathlessness, or mesothelioma, a cancer of the lung lining. Exposure to toxic chemical dusts may result in irritation, bronchitis, and cancer depending on the nature of the chemical. The poisoning effect may be fast or slow depending on the toxicity and concentration inhaled.

Breathing the fumes generated from the heating of heavy metals may result in metal fume fever characterized by irritation of the lungs, dry throat, chills, fever, and pain in the limbs. Cadmium fumes may cause emphysema. Exposure to hydrocarbons, chromium, beryllium, and arsenic fumes may cause lung cancer.

Exposure to acid and alkaline gases such as hydrochloric acid and ammonia will cause extreme local irritation to the lungs. Some gases such as carbon monoxide may pass into the blood stream and cause systemic injuries.

Vapors are the gaseous state of liquids. Inorganic vapors are generally harmless. Exposure to organic vapors, however, may cause nose and throat irritation, pulmonary edema or cancer.

Mists are fine suspensions of liquid in air and can cause chemical burns of the lungs, lung disease and cancer. Common mists include sulfuric acid and sodium hydroxide from oven cleaners.

Many gases can be detected by their odor or irritating effect which results in an immediate warning so that injury can be averted. Ammonia, for example, is highly irritating and has an offensive odor. Other toxic gases, such as carbon monoxide, however, may have no odor or irritating effects. Deadening of the sense of smell may occur with some gases, such as hydrogen sulfide, and prevent the detection of toxic quantities, or the pain may be delayed for several hours as from exposure to hydrogen fluoride. Although sensory warnings may give adequate warnings occasionally, it should not be relied on as a primary defense.

Ingestion: The ingestion of chemicals may cause severe local damage to the lining of the mouth, throat, and gastrointestinal tract. In addition, if the chemical is absorbed into the blood stream, systemic poisoning may result. Ingestion of chemicals may occur from eating contaminated food, smoking cigarettes contaminated with chemicals, or swallowing chemicals deposited in the throat through inhalation. Oral toxicity is generally lower than inhalation toxicity because of the relatively poor absorption of many chemicals from the intestines into the blood stream.

Skin contact: Chemical damage to the skin of the hands and arms is the most common occupational injury. Damage to the skin may include inflammation, burning, blistering, and complete destruction of the skin. The extent of the damage depends on the type of chemical, its concentration, and the duration of the contact. Chemicals that affect the skin are divided into two classes: irritants and sensitizers. Exposure to irritants can result in contact dermatitis, the most common occupational skin disease. Contact dermatitis is any local inflammation of the skin following exposure to damaging substances. Most organic and inorganic acids and bases are strong irritants. Exposure to these chemicals can result in serious local damage to the skin often requiring medical attention. Exposure to milder irritants such as detergents and solvents may cause redness, burning, and swelling. The irritation is usually confined to the area of skin that contacted the chemical and may heal in a few days.

Initial contact with a chemical sensitizer may produce no reaction. Once sensitized, however, subsequent exposures may result in an allergic-type of response called contact allergic dermatitis. Reactions usually develop several hours after re-exposure and may last for several days. Skin reactions may also appear at sites remote from the initial contact. Once a worker has become sensitized to a chemical, very small amounts of it may trigger a reaction. Typical sensitizers include arsenic, mercury, nickel compounds, petroleum distillates, detergents, and many pesticides.

Skin contact is also the primary route of entry into the body for many hazardous chemicals. Many pesticides, for example, may pass through the skin and cause serious or even fatal poisoning. The largest problem associated with skin absorption of chemicals, however, occurs with organic solvents. Solvents such as benzene, carbon tetrachloride, and methyl alcohol may be absorbed in sufficient quantities to cause systemic injury or even cancer at other organ sites. In addition, some solvents such as DMSO may act as vehicles that carry other chemicals through the skin.

Eye contact: The effects of accidentally splashing corrosive chemicals into the eye can range from minor irritation, to scarring of the cornea and loss of vision. Injury to the eye from bases is much more damaging than acid burns. Acids cause a protein barrier to form in the eye preventing further penetration of the acid. Bases, however, continue to soak into the eye and cause further damage. In addition, mists, vapors, and gases may produce varying degrees of damage to the eyes. Some chemicals may be absorbed by the eye and produce systemic poisoning.

Interactions

It is common for workers to be exposed to a wide range of chemicals. Consideration must be given to the possible interaction of these chemicals and how they may affect personnel. There is growing evidence that many chemicals may have a synergistic effect and produce toxic effects that are much greater in combination than would be predicted from their individual effects. Since standards for maximum permissible levels of chemicals are based on the effects of a chemical acting alone it is prudent to keep exposures to chemicals to the lowest possible level. Another possible hazard involves the interaction of chemicals with cigarettes. Cigarettes can convert chemicals in the atmosphere into more harmful forms. For example, chloroform can be converted by the heat from a cigarette into the highly toxic gas phosgene. Interactions may also occur inside the body of the worker, producing harmful substances.

Threshold Limit Values

Exposure limits to airborne concentrations of common chemicals are published yearly by the American Conference of Governmental Industrial Hygienists (ACGIH). These limits are recommendations, not legal standards, and represent conditions to which nearly all workers may be exposed without experiencing significant adverse effects. They are based on the best currently available data from industrial experiences, human population studies, and animal experiments. Three categories of Threshold Limit Values (TLV) are specified: Time Weighted Average (TWA), Short Term Exposure Limit (STEL), and Ceiling Value. TLV's are expressed in parts per million (ppm) or mg/cubic meter.

TWA: The TWA is the concentration of an airborne chemical averaged over an eight-hour workday that workers may be exposed to daily without sustaining injury. Exposure to concentrations above the limit is allowed as long as they are balanced by exposures below the limit and do not exceed the STEL or Ceiling Limit.

STEL: The STEL is the maximum concentration a worker can be exposed to for fifteen minutes without suffering from irritation, chronic or irreversible tissue damage, or narcosis of sufficient degree to cause impairment.

Ceiling limit: The Ceiling Limit is the concentration that should never be exceeded for any period of time.

PEL: The legal maximum levels of airborne chemicals are determined by OSHA and are called Permissible Exposure Levels (PEL). Most of the OSHA Permissible Exposure Levels are adopted from the ACGIH Threshold Limit Value list. OSHA values are not updated yearly as are the ACGIH Threshold Limit Values.

The TLV and PEL should only be used as guidelines for good practice and should not be used as fine lines between safe and unsafe concentrations. It is always prudent to keep exposures to airborne contaminants as low as possible.

PI/LS/Instructors should perform risk assessments that consider the types of hazards present in the laboratory, the risk of exposure to laboratory personnel, and the type of work to be performed. Complete a Laboratory Risk Assessment, found in Appendix L, when you are developing a new experiment, procedure, or project in the laboratory. Prudent planning is a critical component of risk assessment. The following factors should be considered when determining the risk associated with a particular project or procedure:

- Hazards associated with the procedure;
- Potential for a harmful personal exposure to occur;
- Potential for release of a hazardous substance to the environment;
- Level of training and experience of personnel;
- Use and condition of laboratory equipment;
- Availability of safety equipment such as chemical fume hoods and/or biosafety cabinets;
- Appropriate PPE;
- Type and volume of hazardous substances used and waste generated;
- Proper storage;
- Potential for production of harmful byproducts; and
- Appropriate response procedures in the event of an emergency.

Risk of injury due to physical hazards (e.g., thermal, electrical, mechanical) should also be evaluated. Attention should be given to the location of physical hazards and the availability of proper safeguards. In addition, good housekeeping practices and routine equipment maintenance should be implemented to prevent injuries resulting from trip hazards, frayed wires, malfunctioning equipment, or damaged instruments. EHS can assist PI/LS/Instructors in accurately assessing laboratory risks and in devising appropriate management strategies to minimize those risks.

4.2 Risk Management

Risk management involves the use of measures designed to eliminate or reduce potential exposure of laboratory personnel, the community, and the environment to hazards present in the laboratory. A comprehensive risk management program includes administrative, engineering, and physical controls that eliminate or reduce the duration, frequency, and severity of exposure to laboratory hazards. Controlling exposures to chemical hazards and toxic substances is the fundamental method of protecting workers. A hierarchy of controls is used as a means of determining how to implement feasible and effective controls, *see **Figure 4.2***.

Engineering controls include facility features such as laboratory design, ventilation systems, storage areas, and safety equipment. Administrative controls include written safety procedures and practices, training, documentation, access restrictions, and proper signage and labeling. Physical controls are provided by PPE and good chemical hygiene practices. Where possible, elimination or substitution is the most desirable followed by engineering controls.

Administrative or work practice controls may be appropriate in some cases where engineering controls cannot be implemented or when different procedures are needed after implementation of the new engineering controls.

Personal protection equipment is the least desirable but may still be effective.

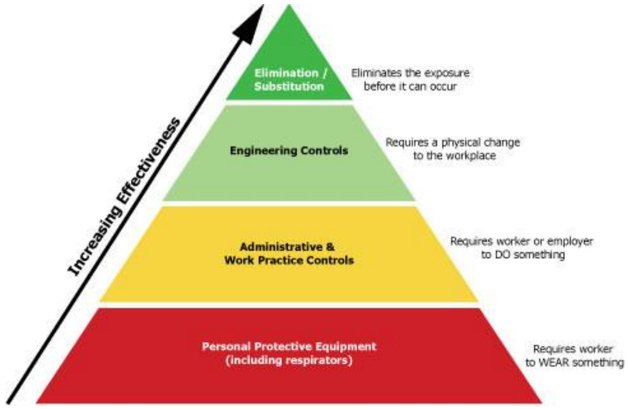


Figure 4.2 – Hierarchy of Controls

5.0 ENGINEERING CONTROLS

Engineering controls are facility features and equipment intended to reduce the likelihood or severity of an exposure. It requires a physical change to the workplace. This includes laboratory design, safety equipment, and safety guards on laboratory equipment. A fundamental and very common example is the laboratory fume hood which is very effective at containing chemical hazards and protecting users from inhalation hazards. Other examples of engineering controls include general room ventilation, flammable material storage units, and secondary containment. These controls offer the first line of protection and are highly effective in that they generally require minimal special procedures or actions on the part of the user except in emergency situations. Consult with EHS to select, acquire, and install appropriate engineering controls prior to the commencement of the work that requires these controls. This information should be considered when designing a new laboratory or renovating an existing laboratory facility.

5.1 Laboratory Design

Appropriate design and traffic flow is critical to the development of a safe work environment for laboratory personnel. In the following sections, several considerations for facility design discussed are useful for designing a new laboratory or renovating existing laboratory facilities. All OSHA regulated laboratories will have appropriate general ventilation available and adequate chemical storage areas. Hoods and sinks will be conveniently located and accessible in each lab and/or prep area. Each laboratory will have an emergency shower and eyewash station available.

5.2 Laboratory Safety Equipment

Each laboratory should contain or have easy access to the following safety equipment: emergency showers and eyewash stations, first aid supplies, spill supplies, fire suppression equipment, and chemical fume hoods. Additional safety equipment may be required depending on the substances or equipment used and procedures performed. In laboratories where biological or radioactive materials/equipment are used, the *Biosafety Manual*, the *Radioisotope*

Safety Manual, and the *Radiation Producing Machines Safety Manual* respectively, list additional safety equipment that may be required. PI/LS are responsible for working closely with EHS so that safety equipment is available to laboratory personnel, routinely inspected, and repaired or replaced as necessary.
New personnel must be instructed in the location of emergency showers and eyewash stations, first aid supplies, spill supplies, fire suppression equipment, chemical fume hoods and other safety equipment before they begin work in the laboratory. This training is considered part of the laboratory specific training that all employees must receive.


Figure 5.1 – Emergency Eyewash/Shower

5.2.1 Emergency Showers and Eyewash Stations

In areas where hazardous substances are used that may be harmful to the eyes or skin or that can be absorbed through the skin, an American National Standards Institute (ANSI) approved emergency shower and eyewash station (similar to **Figure 5.1**) must be available within a ten-second walk, be clearly labeled, and be easily accessible. Besides providing protection from chemical splashes, emergency showers can be used to extinguish clothing fires. Eyewash units and emergency showers should not be located near electrical apparatus, power outlets or water reactive chemicals. The area around the equipment must be kept clear to ensure immediate access. All laboratory personnel must know the location of the nearest shower and eyewash stations and must be trained in their use. If an emergency shower or eyewash station is not available, contact EHS.

Emergency showers are designed to provide immediate response to chemical exposures that cover a significant part of the body. Eyewash stations are designed to provide a soft stream of aerated water to rinse the eye.

Valve: The valve should be designed so that the water remains on without requiring the user to hold the valve open. Injured personnel must have the ability to hold both eyelids open or take their clothes off. The valve actuator should be large enough to be easily located and operated by the user. A self-closing valve on emergency showers may be used in low hazard areas if approved by EHS.

Pull devices: Overhead chains are most commonly used to activate showers. The chain should be at such a height that anyone working in the area could reach the chain. The chain should never be tied up out of the way. Rod-type pull activators are preferable to chains because they are easily accessible and cannot be tied out of the way.

Water flow: Eye-wash equipment should be capable of delivering to both eyes simultaneously at least 0.4 gallons of potable water per minute for 15 minutes without interruption. The velocity should be low enough so that it will not injure the user. Nozzles must be protected from airborne contaminants. The removal of the protective device should not require a separate motion by the user. Shower heads shall be between 82 and 96 inches from the floor. Emergency shower heads must be capable of delivering a minimum of 20 gallons of water per minute.

Signs: The location of eyewash units and emergency showers should be identified with a highly visible sign.

Back-up units: Small squeeze bottles of water or saline solutions are not acceptable as a primary eyewash unit because they do not supply the flow necessary for repeated washings and cannot flush both eyes simultaneously. Drench hoses are acceptable only as a back-up system because they cannot flush both eyes simultaneously and the user cannot hold both eyes open. In addition, hand-held drench hoses cannot provide the full flow associated with an emergency shower and can only be used to support an approved emergency shower. Small eye-wash units mounted on the ends of faucets are intended only to supplement, but not replace standard plumbed in eye-wash equipment. These units can be difficult to operate in an emergency.

Emergency showers and eyewash stations must be installed, maintained, flushed, and tested in accordance with the ANSI Standard for Emergency Eye Wash and Emergency Shower Equipment (Z358.1-2014). Emergency eyewash stations must be activated weekly by laboratory personnel to verify that they are operating properly and the effluent is clear. Routine flushing is managed by each department. Emergency shower/eyewash stations will be tested by EHS at least annually to confirm that water pressure and flow rate are within acceptable parameters. If an eyewash or safety shower needs repair, call Facilities Management and give the specific location of the defective equipment.

5.2.2 First Aid and Spill Kit Supplies

All laboratories and laboratory support rooms should be equipped with first aid supplies to assist laboratory personnel in responding to minor injuries and spill kit supplies relevant to the activities of the laboratory. The location of these supplies should be clearly marked and easily accessible. Phone numbers for emergency personnel should be posted in the same area. All laboratory personnel must know the location of these supplies. Supplies should be routinely inspected and re-supplied as necessary.

5.2.3 Fire Extinguishers

Portable fire extinguishers are the first line of defense against a fire. A fire extinguisher must be available near the laboratory exit or in the hallway and within 75 feet of the laboratory. Fire extinguishers should be readily accessible and the location of the extinguisher should be clearly identified. Access to the fire extinguisher should not be blocked. Fire extinguishers must be mounted off the floor and no higher than five feet. Extinguishers weighing over 40 lbs. should be mounted no higher than three 1/2 feet. It is generally recommended that laboratories working with combustible or flammable chemicals be equipped with multipurpose-type fire extinguishers. The fire extinguisher must be clearly labeled and readily accessible for use and inspection. Personnel should be familiar with the location, use and classification of the extinguishers in their laboratory.

All laboratories shall be equipped with an NFPA approved fire extinguisher. Every extinguisher should be labeled for the class of fire for which it is effective. Fires are classified as:

- Class A - involve burning paper, wood, rags and trash. Water extinguishers are most effective against this type of fire.
- Class B - involve burning liquids such as hydrocarbons. Carbon dioxide or dry powder extinguishers are used against this type of fire.

- Class C - involve live electrical equipment and are effectively extinguished using carbon dioxide or dry powder extinguishers.
- Class D - involve flammable metals such as alkali metals, metal hydrides and metal alkyls. Met-L-XR extinguishers or others that consist of special granular formulations are effective against metal fires.

Depending on laboratory operations, additional fire suppression equipment, such as a clean agent fire extinguisher or other specialized equipment may be required. EHS provides fire extinguishers to all Radford University buildings, advises PI/LS regarding appropriate fire suppression equipment for the laboratory, and provides fire safety training to personnel. Fire extinguishers should be maintained in operating condition, inspected monthly by EHS, checked against tampering, and recharged as required.

Training should be provided to laboratory personnel on the location, use, and limitations of the fire suppression equipment in their laboratory. EHS offers training on the proper use of fire extinguishers. In the event of a fire, laboratory personnel are not required to use fire extinguishers but are required to contact emergency services, pull the fire alarms and evacuate the building.

Any time a fire extinguisher is used, no matter for how brief a period, the Instructor, or most senior laboratory personnel present at the time of the incident, must immediately report the incident to EHS (540-831-7790) and RUPD (540-831-5500).

5.2.4 General Laboratory Ventilation

All laboratory rooms in which hazardous materials are used must have fresh air ventilation with 100% of the exhaust venting to the outside; laboratory rooms should not be part of recycled air systems. Laboratory ventilation systems are designed to be single-pass systems that support a negative pressure environment with respect to adjacent hallways and rooms. Building air intake and exhaust vents are situated to prevent recirculation of laboratory exhaust. General dilution ventilation is not sufficient to provide protection from chemical exposures; it is for this reason that work with hazardous substances should always be performed using engineering controls such as a chemical fume hood, biosafety cabinet, glove boxes, etc.

All modifications to laboratory heating, ventilation, and air conditioning systems must only be performed by Facilities Management. Once modifications have been made to laboratory systems, chemical fume hood evaluations must be conducted, and the room air changes per hour must be calculated and modified, as necessary, to meet ventilation standards.

Chemical fume hoods are the most commonly used local exhaust system on campus. Other types of ventilation equipment include vented enclosures for large pieces of equipment or chemical storage, and portable exhaust systems for capturing contaminants near the point of release. Other types of ventilation systems are equipped with air cleaning devices (HEPA filters or carbon absorbers). Laboratories where biohazardous material or sources of ionizing radiation are used or stored may require additional safety equipment. Please refer to the *Biosafety Manual*, the *Radioisotope Safety Manual*, and the *Radiation Producing Machines Safety Manual* for more information.

Additional engineering controls for minimizing exposures to hazardous chemicals may include:

- Substituting a less hazardous chemical (e.g., using isoflurane for animal anesthesia instead of ether, or using toluene instead of benzene).
- Isolating or enclosing an experiment within a closed system (i.e., glove box, sealed chamber).
- Micro scaling the size of the experiment to reduce the amount of chemical usage.

Fume Hoods, Biological Safety Cabinet (BCS), and Glove Box

Chemical fume hoods are sometimes mistakenly used as a BSC or glove box. The following chart and section provides guidance on which engineering control to use for various hazardous materials.

Fume Hood	**Glove Box/Isolator**	**BSC**
Volatile chemicals	Air reactive compounds	Biological aerosols including human blood
Flammable liquids	Highly toxic compounds	Biosafety Level 2 agents
Toxic materials	Controlled environment	Tissue culture
Hot processes		Sterile field
Open flames		Necropsy (Not Perfused)
Acids and bases		Non-volatile drugs
Gases		
Necropsy (Perfused)		

5.2.5 Chemical Fume Hoods

It is advisable to use a laboratory hood when working with all hazardous chemicals. In addition, a laboratory hood or other suitable containment device must be used for all work with "particularly hazardous substances." A chemical fume hood functions to capture, retain, and ultimately discharge out of the laboratory any noxious or hazardous vapors or fumes. Fume hoods are not designed for storage of hazardous chemicals, apparatus or other materials. Fume hoods are evaluated for operation and certified by EHS annually. These annual evaluations check the fume hood air flow velocity to ensure that the unit will contain hazardous vapors. Testing will follow Federal and State requirements for procedure and results. Data on annual fume hood monitoring will be maintained by EHS.

Figure 5.2 – Chemical Fume Hood

Laboratory fume hoods are one of the most important pieces of equipment used to protect laboratory and other workers from exposure to hazardous chemicals. Chemical fume hoods should be inspected upon installation, renovation, when a deficiency is reported, or a change has been made to the operating characteristics of the hood.

Anatomy and Functions of a Chemical Fume Hood

Know the important basic fume hood components and their functions. **Figure 5.3** displays the key components of a chemical fume hood.

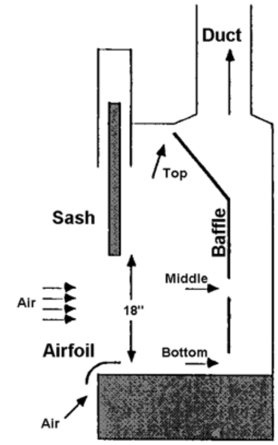


Figure 5.3 – Components of Chemical Fume Hood

- Hood Body - The visible part of the fume hood that serves to contain hazardous gases, vapors or fumes.
- Baffles - Moveable partitions used to create slotted openings along the back of the hood body. Baffles keep the airflow uniform across the hood opening, thus eliminating dead spots and optimizing capture efficiency. Storing things against the back lessons the efficacy of the hood for containing contaminants thus affecting the overall performance of the fume hood.
- Sash - By using the sash to adjust the front opening, air flow across the hood can be adjusted to the point where capture of contaminants is maximized. Each hood is marked with the optimum sash configuration. The sash should be held in this position when work involving the fume hood is being performed and closed completely when "hands-on" experiments are not in progress or hood is unattended. Fume hood sashes are made of fire and explosion resistant glass. The sash acts as a barrier and can protect the fume hood user from any splashes, flying glassware, and fires that can occur in the hood. The sash and hood are NOT explosion proof. If you will work with materials that pose an explosion hazard, contact EHS for guidance.
- Airfoil - Found along the bottom and side edges airfoils streamline air flow into the hood, preventing the creation of turbulent eddies that can carry vapors out of the hood. The space below the bottom airfoil provides source of room air for the hood to exhaust when the sash is fully closed. Cords, cables, tubing on the airfoil affect performance. Run electrical cords under the airfoil instead of on top of it.
- Work surface - Generally a laboratory bench top, but also the floor of a walk-in hood, this is the area under the hood where apparatus is placed for use.
- Exhaust plenum - An important engineering feature, the exhaust plenum helps to distribute air flow evenly across the hood face. Materials such as paper towels drawn into the plenum can create turbulence in this part of the hood, resulting in areas of poor air flow and uneven performance.
- Face - The imaginary plane running between the bottom of the sash and the work surface. Hood face velocity is measured across this plane in linear feet per minute (fpm).

The allowable face velocity for chemical fumes hoods at Radford University ranges from 80-120 feet per minute (fpm). During use, the sash should be opened to 18 inches or below the user's breathing zone; each chemical fume hood is labeled to indicate this position. In the event that the face velocity of a chemical fume hood is below 80 fpm or above 120 fpm or the hood is not operating properly, discontinue use and place a work order with Facilities Management to have the chemical fume hood repaired. All nonfunctioning fume hoods must be reported to EHS and labeled "Out of Order" until they are repaired and retested. **NOTE: Signs indicating a fume hood is inoperable may only be removed by EHS.**

An alarm or monitor must be present to show when hood velocity drops below the allowable level. The hood cannot be used without the alarm on and functioning. Don't rely solely on the monitor. Feel for air flow or use tissue to test (be careful not to allow tissues to flow into the exhaust intake). Listen for weird noises and call Facilities Management if something sounds wrong or different. Don't use a fume hood during a power outage or HVAC failure. In the event of ventilation hood alarm or failure, stop all experiments within the hood (if possible), lower the sash completely, until the alarm silences. In the event that it continues to alarm notify EHS and submit a work order with Facilities Management, if appropriate.

Figure 5.4 – Hood Flow Monitor

Types of Chemical Fume Hoods

Constant Air Volume (CAV) - These fume hoods exhaust the same amount of air all the time, regardless of sash position. As the sash is lowered and raised, the velocity at the face of the hood changes. This change in face velocity can result in less than optimal hood performance.

Variable Air Volume (VAV) - This fume hood, also known as a constant velocity hood, is a hood that has been fitted with a face velocity control, which varies the amount of air exhausted from the fume hood in response to the sash opening to maintain a constant face velocity. This allows for optimal hood performance regardless of the sash position. VAV hoods also provide significant energy savings by reducing the flow rate from the hood when the sash is closed.

A true VAV system ties the fume hood exhaust with the room's air supply and exhaust. The VAV system can then ensure that the required room air changes per hour are being met, that sufficient make-up air is provided to balance the air that's being exhausted, and that appropriate room temperatures are maintained.

A VAV system is often designed for a predicted fume hood usage that is less than all hoods being in use at the same time with their sashes open. This is frequently referred to as the "diversity factor" and allows for the VAV system to be downsized, e.g., the ductwork, pumps, and chillers. When a VAV system is designed using a "diversity factor" it relies on not having all the fume hoods in use at the same time. If all hoods are in use at the same time, i.e., their sashes are fully or partway open, some of the hoods will not perform properly because they won't be able to maintain an adequate face velocity. This can result in an unsafe condition for hood users. It is very important for VAV hood users to keep the sash closed as much as possible while working at the hood and to close the sash completely when the hood is not in use. This will ensure a safe work environment for all the hood users. Another very important characteristic and a benefit of keeping fume hood sashes closed, is that they are made of fire and explosion resistant glass. The sash acts as a barrier and can protect the fume hood user from any splashes, flying glassware, and fires that can occur in the hood.

It is important to know what type of fume hood you are using and how best to use it to minimize any risk of exposure.

Chemical Fume Hood Sashes

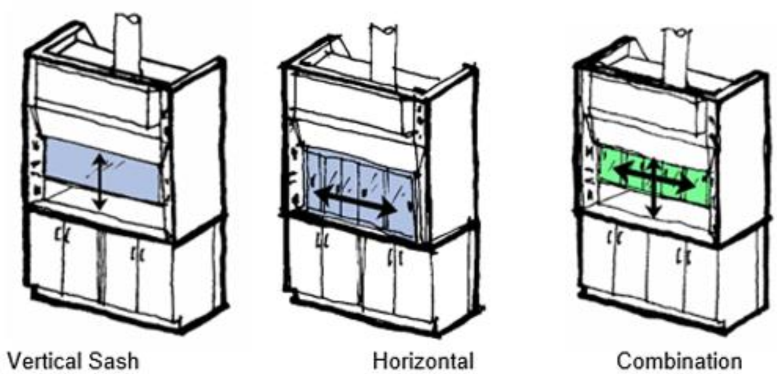


Figure 5.5 –
Types of Chemical Fume Hood Sashes

Hoods shall have transparent movable sashes constructed of shatter-resistance, flame resistant material and capable of closing the entire front face. The sash provides a physical barrier from chemical splashes and violent chemical reactions.

Vertical sashes are the most common. They provide the most access to the workstation because the window slides up and down.

Horizontal sashes slide from left to right, allowing a user to position themselves behind the sash for protection while enabling access through the sides. They provide the best access to the top interior of the hood but do not provide access to the entire width at the same time.

Combination sashes combine horizontal sash panes, in a vertical rising frame. They offer the advantages of both vertical and horizontal sashes.

Chemical Fume Hood Limitations

A chemical fume hood is not designed to contain particulate matter, explosions, infectious materials, or gas releases from pressurized systems. A chemical fume hood is not a pollution control device. All contaminants that are removed by the ventilating system are released directly into the atmosphere. Apparatus used in hoods should be fitted with condensers, traps, or scrubbers to contain and collect waste solvents or toxic vapors or dusts. A chemical fume hood should not be used for waste disposal by way of evaporation. It is a violation of environmental regulations to intentionally evaporate hazardous chemicals in the chemical fume hood. Chemical fume hoods are not designed to protect against aerosolized biohazardous material. Biosafety cabinets should be used for work involving these agents. More information about biosafety cabinets is provided in the *BioSafety Manual*. Ideally to comply with most licensing requirements when working with radioisotopes, a face velocity of 125 fpm is required. Refer to the Radioisotope Safety Manual for more information.

Using Chemical Fume Hoods

Good laboratory practices must be employed while performing work in a chemical fume hood to facilitate adequate protection. A list of recommended practices follows:

- Before working with chemicals, you should become familiar with the hazards of the materials
- When possible, substitute less hazardous materials (less toxic, less flammable, less reactive, avoid strong oxidizers, pyrophorics, etc.).
- Train all new employees about the hazards of the chemicals in the lab. They should review the label and Safety Data Sheets (SDS) for materials they will work with.
- Know the signs and symptoms of exposure to these chemicals.
- Understand the physical hazards (flammable, conditions of violent or explosive reaction) and communicate this to new staff.
- Conduct a risk assessment (a what-if checklist) of your experiments/processes to discern possible failure points.
- Use a chemical fume hood or other local ventilation device when working with volatile substances with a threshold limit value (TLV) less than 50 parts per million (ppm).
- Design experiments in consideration of chemical fume hood space and air flow.
- Before beginning work, verify that the type of chemical fume hood to be used and the face velocity are appropriate for the chemicals involved and the procedure to be performed.
- The hood is not a substitute for personal protective equipment. Wear gloves, safety glasses, lab coat, long pants/skirt, and shoes that fully cover your feet. If working with extremely flammable materials, ensure the lab coat is flame resistant and properly launder to avoid damaging these properties.
- Do not use perchloric acid in a conventional chemical fume hood. Perchloric acid vapors accumulate in ductwork and form perchlorate crystals that have the potential to explode, causing serious injury to personnel and damage to property. Contact EHS prior to any laboratory activities that require the use of perchloric acid.

Figure 5.6 – Types of PPE

- Check areas around the chemical fume hood for sources of cross drafts that may cause turbulence and result in leaks from the hood into the laboratory. Other personnel working in the laboratory should avoid walking behind individuals conducting work at the fume hood to reduce negative turbulence. Doors should remain closed reduce to maintain negative pressure in the laboratory relative to the hallway.
- Each chemical fume hood must be inspected/certified annually. Each chemical fume hood should be labeled with an inspection sticker that displays the date that the hood was inspected/certified, the measured face velocity, and the name of the inspector who conducted the test. Chemical fume hoods that fail inspection must be labeled “Out of Order” and cannot be used until they are repaired and retested.
- Verify that the reading from the continuous airflow monitoring device is no less than 80 fpm, no greater than 120 fpm, and within 15% of the face velocity value listed on the inspection sticker. If the reading differs significantly from that on the sticker, the chemical fume hood may not be operating properly. Routine maintenance and repairs of fume hoods are coordinated by Facilities Management. Hood users may route requests for hood repair directly to Facilities Management.

- Visually inspect the baffles (openings at the top and rear of the hood) to be sure that the slots are open, unobstructed, and set to the proper configuration based on the chemicals and equipment used.
- Conduct all experiments at least six inches from the front of the chemical fume hood. The air foil located at the front of the fume hood beneath the sash minimizes turbulence and creates smooth air flow for air entering the hood. For this reason all apparatus and equipment should be located at least six inches away from the hood face.
- Provide secondary containment for containers that could break or spill.
- If large equipment must be placed in the chemical fume hood, elevate it approximately two inches above the surface so that air may pass beneath it.
- Ensure that all electrical devices are connected outside the chemical fume hood to avoid an electrical arc that can ignite a flammable or reactive chemical.
- Clean all chemical residues from the chemical fume hood chamber after each use.
- ***Keep the sash completely lowered when the chemical fume hood is not in use or when an experiment in the hood is left unattended***. Closing of chemical fume hood sashes when not in use reduces energy cost, helps to maintain comfortable conditions in the laboratory, and extends the functional life of the fume hood.
- Chemicals and equipment should not be stored in the chemical fume hood. Chemicals should alternatively be placed in appropriate chemical storage cabinets.

<u>5.2.6 Other Laboratory Ventilation Systems</u>

Snorkel and Canopy Hoods

Many laboratories use equipment that can generate airborne contaminants, but cannot be used within a chemical fume hood. Examples include gas chromatographs, ovens, and vacuum pumps. Other types of local exhaust ventilation may be required to control contaminants generated by these operations. Such ventilation must have a separate exhaust duct and must not be installed without approval from EHS. For best performance, a snorkel hood should be placed within six inches of the item needing ventilation. Snorkel hoods should only be used to exhaust heat and nuisance odors. They should never be used with highly toxic or flammable chemicals. Consult EHS before installing, modifying, or purchasing laboratory ventilation equipment to verify that it conforms to all relevant safety, building, and fire code regulations.

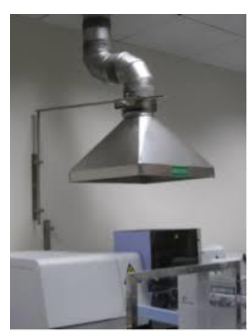


Figure 5.7 –
Examples of Snorkels and Canopy Hoods

Biological Safety Cabinets or Biosafety Cabinets (BSCs)

BSCs provide containment for biohazardous materials or recombinant DNA materials and are not intended for use as a chemical fume hood. When used and maintained correctly, Class II biosafety cabinets protect the user from exposure to harmful biological agents and also protect the product from contamination by filtering the air inside the cabinet through High Efficiency Particulate Air (HEPA) filters. Before using a biological safety cabinet, laboratory personnel should be thoroughly trained on how to properly use and maintain the BSC.

Follow these instructions for safe use of a biological safety cabinet:

a. Only biosafety cabinets that are certified according to National Sanitation Foundation (NSF) Standard # 49 may be used with pathogenic or recombinant DNA materials. BSCs must be certified upon installation, upon being moved, after major repair, and at least annually.
    i. BSC and laminar flow hoods are managed by EHS. Contact EHS for more information.
    ii. BSCs that are not certified annually or that fail certification will be tagged "Not Safe For Use With Pathogens"
b. Locate biosafety cabinets away from doorways and high traffic areas. As with chemical fume hoods, rapid movement in or near the cabinet can create turbulence, causing contaminants to be drawn out of the cabinet and into the general laboratory area.
c. Restrict entry into the laboratory when work is being conducted in the BSC.
d. Turn off UV light before beginning work in a BSC.
e. Disinfect the biosafety cabinet prior to beginning and after completing work in the cabinet.
f. Allow cabinet to operate without activity at least 15-20 minutes before and after use. This will allow all the air in the cabinet to circulate through the HEPA filters, removing any contaminants that may be present.
g. Keep the BSC clear of clutter and loose paper. Only place items that are needed in the cabinet.
h. Keep clean items and dirty items segregated in the BSC.
i. Provide a waste container inside of the cabinet and keep it covered.
j. Always wear appropriate personal protective equipment.
k. Keep face away from the BSC opening.
l. Never use a Bunsen burner in a biosafety cabinet. Dangerous levels of gas can build up in the cabinet. Also, heat from the open flame can damage the HEPA filters.
m. Clean up spills in the BSC immediately.

Glove Boxes

Glove boxes are designed to be leak-tight and can be used with highly toxic or air-reactive chemicals and materials. Some glove boxes may also be appropriate for use with some radioactive materials. The leak-tight design provides a controlled atmosphere, protecting both the product and the worker by preventing vapors/moisture, gases, and particulates from entering or leaving the box.

Laminar Flow Hoods

Also known as clean benches, laminar flow hoods provide a continuous flow of HEPA filtered air across the work surface. This design helps prevent contamination of the product, but does not offer any protection to the worker. Laminar flow hoods should only be used with non-hazardous materials. Laminar flow hoods may be certified at the user's discretion. Contact EHS for more information.

5.3 Physical Hazards

There are a variety of physical hazards that can be found in a laboratory environment. Many of these hazards are similar to those found in every home, and if common sense is applied, risks are fairly easy to minimize. This section will focus on common physical hazards and how to reduce the risk associated with them.

5.3.1 Fire Safety

All laboratories should meet the requirements of NFPA-45 *Standard on Fire Protection for Laboratories Using Chemicals*. These requirements include the following:

a. Passageways and aisles must be a minimum of 36 inches wide and must remain unobstructed.
b. Statewide Fire Prevention Code (SFPC) requires a clearance of 18 inches between the ceiling and any materials in the room to allow proper operation of the fire suppression system.
c. The location of emergency exits for each laboratory and laboratory support room must be clearly marked. If possible, there should be two exits for each laboratory area.
d. Exits, stairs, and passageways should be permanently illuminated to facilitate evacuation in the event of an emergency. Emergency exits must be clearly marked.
e. Many areas of the buildings may contain critical fire doors as part of the building design. These doors are an important element of the fire containment system and should remain closed and unobstructed unless they are on a magnetic self-closing or other automated self-closing system.
f. Flammable chemicals should be stored within flammable cabinets.

5.3.2 Electrical Safety

Electrical safety is an important component of laboratory safety. When using electrical equipment in a laboratory, the guidelines below should be followed:

a. Check electrical cords and switches for damage prior to using equipment or appliances. Damaged cords (cords with frayed or exposed wires or with damaged or missing plug prongs) should be repaired promptly or the equipment should be locked/tagged out until the cord can be repaired.
b. Use extension cords only on a temporary basis (less than eight hours). Do not use extension cords as a substitute for permanent wiring. Contact Facilities to request new outlets if your work requires equipment in an area without an outlet.
c. Do not run electrical cords above ceiling tiles, through walls or across thresholds.

d. Keep electrical cords away from areas where they may be pinched and areas where they may pose a tripping or fire hazard (e.g., doorways, walkways, under carpet, etc.).
e. Avoid plugging more than one appliance in each outlet. If multiple appliances are necessary, use a single approved power strip with surge protection and a circuit breaker. Do not overload the circuit breaker.
f. Avoid “daisy-chaining” or “bird-nesting.” Connecting power strips and/or extension cords in a series or cluster is against fire and electrical codes.
g. Large equipment must be plugged directly into the wall outlet.
h. Use ground fault circuit interrupters when using electrical equipment near water sources.
i. Only equipment with three-prong plugs should be used in the laboratory. The third prong provides a path to ground for internal electrical short circuits, thereby protecting the user from a potential electrical shock.
j. Any modifications to existing equipment or electrical service in a laboratory or building must be approved through a work order and completed by Radford University Facilities Management.
k. Keep access to electrical panels clear of obstructions.

5.3.3 Machine Guarding

All mechanical equipment shall be adequately furnished with guards that prevent access to electrical connections or moving parts, i.e. belts and pulleys. All laboratory employees shall inspect equipment prior to using it to ensure that the guards are in place and functioning.

- Power tools, such as drill presses and saws, must meet and be used in accordance 29 CFR 1910 Subpart O.
- Safety shielding should be used for any operation having the potential for explosion.
- Centrifuges that are not fitted with an interlocking lid shall not be used.
- Gas hose connectors are allowed to be used for laboratory equipment, such as Bunsen burners, provided the following items are met:
- A shut off valve is installed where the connector is attached. The connector shall not exceed 6 feet. The connector shall not be concealed nor shall it pass from room to room or through walls, ceilings or floors.
- Guards on fan blades shall have openings no larger than one-half inch.
- Only listed gas hose connectors shall be used. According to the National Fuel Gas Code, latex tubing is not allowed to be used as a connector between a gas source and a Bunsen burner.

5.3.4 Glass & Metal Sharps

Accidents involving glassware are a leading cause of laboratory injuries. Careful handling and disposal of metal and glass sharps can minimize the risk of cuts and puncture wounds, not only for laboratory personnel, but for other university employees as well.

Laboratory Glassware

Follow these practices for using laboratory glassware safely:

a. Prevent damage to glassware during handling and storage.
b. Inspect glassware before and after each use. Discard or repair any chipped, cracked, broken, or damaged glassware.
c. Thoroughly clean and decontaminate glassware after each use. Use a standard laboratory detergent to clean glassware.
d. When handling cool flasks, grasp the neck with one hand and support the bottom with the other hand.
e. Lift cool beakers by grasping the sides just below the rim. For large beakers, use two hands: one on the side and one supporting the bottom.
f. Never carry bottles by their necks.
g. When inserting glass tubing into rubber stoppers, corks, or tubing, follow these guidelines:
    i. Use adequate hand protection, such as a glass tubing insertion tool.
    ii. Lubricate the tubing with water or glycerin.
    iii. Hold hands close together to minimize movement if the glass breaks.
h. When possible, use plastic or metal connectors instead of glass connectors.
i. Heat and cool large glass containers slowly to reduce the risk of thermal shock.
j. Use Pyrex or heat-treated glass for heating operations.
k. Handle hot glassware with heat resistant gloves or proper size and type of tongs.
l. Use a cart or specially designed secondary container to transport large and/or heavy bottles.
m. Never use laboratory glassware to serve food or drinks or wash laboratory glassware in the same sink in which food and beverage utensils are washed.
n. Use thick-walled and/or round-bottomed glassware for vacuum operation. Flat-bottomed glassware is not as strong as round-bottomed glassware.
o. Use a mesh glass sleeve around glassware or tape glassware that is under pressure. This will contain the glass in one place should it break.
p. Do not pick up broken glass with bare or unprotected hands. Use a wet paper towel or brush and dust pan to clean up broken glass. Remove broken glass in sinks by using tongs for large pieces and cotton held by tongs for small pieces and slivers.

IMPORTANT: Do not use chromic acid to clean glassware. Use a standard laboratory detergent. Chromic acid is extremely corrosive and expensive to dispose of. Chromic acid must not be disposed in the sanitary sewer system.

Metal Sharps

Metal sharps should be carefully stored and handled properly. Follow these guidelines:

a. Do not uncap a needle by placing the cap in your mouth.
b. Never re-cap a used syringe needle by hand or mouth, and never manipulate (bend, break, shear, remove from syringe, etc.) a needle. Immediately place used/contaminated sharps in a sharps disposal container.
c. Do not leave sharps, including razor and scalpel blades, lying unprotected on bench tops. Place in a secondary container when not in use or when being transported.
d. If a needle/syringe must be reused, use self-sheathing syringes or other safety devices for re-capping sharps whenever possible. The one-handed scoop method may be used as a last resort.
e. Place the uncapped syringe/needle in cork or foam, or place it in a tray or other type of secondary container when not in use and when being transported.

5.3.5 Aerosol Production

Liquid or solid particles suspended in air are referred to as "aerosols." Aerosols containing infectious agents and hazardous materials can pose a serious health risk. If inhaled, small aerosol particles can readily penetrate and remain deep in the respiratory tract. Also, aerosol particles can easily contaminate equipment, ventilation systems, and human skin. Because they may remain suspended in the air for long periods of time after they are initially discharged, steps should be taken to minimize the production of and exposure to aerosols.

The following may produce aerosols:

a. Centrifuge
b. Blender
c. Shaker
d. Magnetic stirrer
e. Sonicator
f. Pipette
g. Vortex mixer
h. Syringe and needle
i. Vacuum-sealed ampoule
j. Grinder, mortar, and pestle
k. Test tubes and culture tubes
l. Heated inoculating loop
m. Separatory funnel
n. Animals
o. Hot plate (if chemicals are spilled onto the hot surface)
p. Chemical or biological spills

Follow these guidelines to eliminate or reduce the hazards associated with aerosols:

a. Conduct procedures that may produce aerosols in a certified biological safety cabinet or a chemical fume hood.
b. Keep tubes closed when vortexing or centrifuging.
c. Allow aerosols to settle for five to ten minutes before opening a centrifuge, blender, or tube.
d. Place a cloth soaked with disinfectant over the work surface to kill any biohazardous agents.
e. Slowly reconstitute or dilute the contents of an ampoule.
f. When combining liquids, discharge the secondary material down the side of the container or as close to the surface of the primary liquid as possible to avoid splattering the material.
g. Avoid splattering by allowing inoculating loops or needles to cool before touching biological specimens.
h. Use a mechanical pipetting device.

5.4 Equipment Safety

5.4.1 Compressed Gases

Compressed gases in the laboratory present chemical and physical hazards. The gases may be toxic, corrosive, flammable, or explosive (reactive). If compressed gases are accidentally released, they may cause the following:

- Depleted oxygen atmosphere, potentially resulting in asphyxiation (includes inert gases)
- Fire or explosion
- Adverse health effects from chemical exposure
- Physical damage to facilities or injuries to personnel as a result of the sudden release of potential energy
- Cylinders that fall or are knocked over or dropped can be very dangerous and can cause serious injuries. If a valve is knocked off a compressed gas cylinder, the cylinder can become a high speed, potentially lethal projectile.

IMPORTANT: Cylinders can travel through walls much like a torpedo travels through water. They can cause structural damage, severe injury, and even death.

Guidelines to ensure safe storage of gas cylinders:

a. Store cylinders in an upright position with caps on.
b. Secure all cylinders to a wall or bench using brackets or clamping devices designed for such. Cylinders may also be stored in gas cylinder racks or floor stands. (A cylinder dolly should not be used for storage.)
    i. Fasten cylinders individually (not ganged or grouped).
    ii. Fasten cylinders with a sturdy chain or strap; bungee cords and rope are not acceptable as a means of securing compressed gas cylinders.
c. Store cylinders in a well ventilated area that is cool and dry. Ignition sources such as heat, sparks, flames, and electrical circuits should be kept away from gas cylinders. No part of a cylinder shall be subjected to temperatures higher than 125 degrees Fahrenheit.
d. When not in use (i.e., the regulator has been removed), gas cylinders should be stored with the safety cap on.
e. The quantity of compressed and liquefied gases in Class A, Class B, and Class C laboratory units shall be in accordance with the amounts listed in Table 6.3.1 of NFPA 55. The quantity of compressed and liquefied gases in instructional and educational laboratory work areas shall be in accordance with the amounts listed in NFPA 45. Minimize the number of hazardous gas cylinders in a laboratory. Do not exceed the following:
    i. Three 10" x 50" flammable gas and/or oxygen cylinders, and
    ii. Two 9" x 30" liquefied flammable gas cylinders, and
    iii. Three 4" x 15" cylinders of severely toxic gases (e.g., arsine, chlorine, diborane, fluorine, hydrogen cyanide, methyl bromide, nitric oxide, phosgene).
f. Store cylinders of flammables and oxidizing agents at least 20 feet apart, or separate these items with a fire wall.
g. Do not store cylinders with corrosive materials.
h. Do not store cylinders on the tops of shelves or cabinets.
i. Keep flammable gases away from doorways or exit routes.
j. Separate full cylinders from empty cylinders. Label empty cylinders “Empty.”
k. Do not store gas cylinders in hallways or public areas. Cylinders should be stored in a secure area.

l. Close valves, and release pressure on the regulators when cylinders are not in use.
m. Dispose of old lecture bottles. Return lecture bottles to the supplier or dispose of them as hazardous waste.

Handling and working with compressed gas cylinders:

a. Cylinders shall be handled and connected to gas delivery systems designed by trained personnel.
b. Never move a gas cylinder unless the cylinder safety cap is in place.
c. When working with particularly hazardous gases use special procedures and work in approved gas storage cabinets.
d. The gas cylinder should be chained or otherwise secured to an approved cylinder cart or dolly when being transported. Do not move a cylinder by rolling it on its base.
e. Cylinders shall be attached to an instrument for use by means of a regulator.
f. Only use regulators approved for the type of gas in the cylinder. Do not use adapters to interchange regulators. Also, never try to repair or modify a gas regulator or its pressure gauges.
g. Do not use Teflon tape when attaching the regulator.
h. When opening a cylinder valve, follow these guidelines:
    i. Direct the cylinder opening away from people.
    ii. Open the valve slowly. Never open a cylinder valve without a regulator.
i. For a leaking cylinder:
    i. Close the valve if it is open and contact the supplier to pick it up.
    ii. If the valve is already closed, leave the laboratory and shut the door behind you. Contact EHS immediately.
j. Do not use oil or other lubricant on valves and fittings.
k. Do not use oxygen as a substitute for compressed air.
l. Do not lift cylinders by the safety cap.
m. Do not tamper with the safety devices on a cylinder. Have the manufacturer or supplier handle cylinder repairs.
n. Do not change a cylinder's label or color. Do not refill cylinders yourself.
o. Do not heat cylinders to raise internal pressure.
p. Do not use compressed gas to clean your skin or clothing.
q. Do not completely empty cylinders. Maintain at least 30 psi pressure.
r. Do not use copper (>65% copper) connectors or tubing with acetylene. Acetylene can form explosive compounds with silver, copper, and mercury.
s. Bond and ground all cylinders, lines and equipment used with flammable gases.
t. Toxic, flammable and corrosive gases should be handled in a hood.
u. Always wear impact resistant glasses or goggles when working with compressed gases.
v. Do not subject compressed gas cylinders to cryogenic temperatures.
w. Cylinders not “in use” shall not be stored in the laboratory unit.
x. An emergency gas shutoff device in an accessible location near one of the egress doors from the laboratory work area shall be provided in addition to the manual point-of-use valve in each educational and instructional laboratory space that has a piped gas dispensing valve.

5.4.2 Cryogenic Liquids

Cryogenic fluids are extremely cold liquefied gases, such as liquid nitrogen or liquid oxygen, and are used to obtain extremely cold temperatures. Most cryogenic liquids are odorless, colorless, and tasteless. When cryogenic liquids are exposed to the atmosphere, however, they create a highly visible and dense fog.

Cryogens pose numerous hazards. A person who is exposed to cryogens can have significant health consequences. All cryogens, with the exception of oxygen, can displace breathable air and can cause asphyxiation. Cryogens can also cause frostbite on exposed skin and eye tissue.

IMPORTANT: Be aware of the tremendous expansion and threat of asphyxiation when a cryogenic liquid vaporizes at room temperature.

There is also an increased risk of fire in areas where liquid cryogens are stored and used. For example, cryogenic vapors from liquid oxygen, liquid hydrogen or other flammable cryogens may cause a fire or explosion if ignited. Materials that are normally noncombustible (e.g., carbon steel) may ignite if coated with an oxygen-rich condensate. Liquefied inert gases, such as liquid nitrogen or liquid helium, are capable of condensing atmospheric oxygen and causing oxygen entrapment or enrichment in unsuspected areas. Extremely cold metal surfaces are also capable of entrapping atmospheric oxygen. Because the low temperatures of cryogenic liquids may affect physical properties of materials such as stainless steel or aluminum, take care to select equipment materials accordingly.

Follow these guidelines when working with cryogenic liquids:

a. Before working with cryogenic liquids, acquire a thorough knowledge of cryogenic procedures, equipment operation, safety devices, and material properties. Cryogenic training should be documented.
b. Reject delivery of unsafe cylinders.
c. Keep equipment and systems extremely clean.
d. Avoid skin and eye contact with cryogenic liquids. Wear appropriate personal protective equipment, such as a laboratory coat, temperature resistant gloves, chemical splash goggles and face shield. Also, do not inhale cryogenic vapors.
e. Pre-cool receiving vessels to avoid thermal shock and splashing.
f. Use tongs to place and remove items in cryogenic liquid.
g. When discharging cryogenic liquids, purge the line slowly. Only use transfer lines specifically designed for cryogenic liquids.
h. Rubber and plastic may become very brittle in extreme cold. Handle these items carefully when removing them from cryogenic liquid.
i. Store cryogenic liquids in double-walled, insulated containers (e.g., Dewar flasks) which are designed for this use.
j. Tape exposed glass on cryogenic containers. In the event the container breaks or implodes, the tape will reduce fragmentation and violent dispersal of glass shards.
k. Do not store cylinders of cryogenic liquids in hallways or other public areas.

5.4.3 Vacuum Systems

All vacuum equipment is subject to possible implosion which includes the potential of abruptly releasing glass shrapnel and the contents of the container. Take precautions to minimize damage and injuries that can result from an implosion. When using a vacuum system, follow these guidelines and requirements to ensure system safety:

a. Ensure that pumps have belt guards in place during operation.
b. Ensure that service cords and switches are free from defects.
c. Always use a trap on vacuum lines to prevent liquids from being drawn into the pump, vacuum line, or water drain. An in-line High Efficiency Particulate Air (HEPA) filter is required whenever biohazardous or recombinant DNA materials are used in a vacuum system.
d. Replace and properly dispose of vacuum pump oil that is contaminated with condensate. Used pump oil must be disposed of as hazardous waste.
e. Place a pan under oil-based pumps to catch oil drips.
f. Do not operate pumps near containers of flammable chemicals.
g. Do not place pumps in an enclosed, unventilated cabinet. Dangerous carbon monoxide gas and heat can build up in enclosed spaces.
h. Conduct all vacuum operations behind a table shield or in a fume hood. Also, glassware may be wrapped with tape to minimize the effects of an implosion.
i. Use only heavy-walled round-bottomed glassware for vacuum operations. The only exception to this rule is glassware specifically designed for vacuum operations, such as an Erlenmeyer filtration flask.
j. Wrap exposed glass with tape to prevent flying glass if an implosion occurs.
k. Carefully inspect vacuum glassware before and after each use. Discard any glass that is chipped, scratched, broken, or otherwise stressed.
l. Wear appropriate PPE, including safety glasses or goggles and a face shield when approaching a system under pressure.
m. Use steam or heating mantles to heat flasks.

Desiccators

Glass desiccators often have a slight vacuum due to contents cooling. When possible, use molded plastic desiccators with high tensile strength. For glass desiccators, use a perforated metal desiccator guard. Utmost caution is to be employed when evacuating desiccators. Inspect for defects/cracks and discard if any are found. Implosion protection must be provided without impairing visual inspection. This is often accomplished by wrapping with tape in a grid pattern that leaves the contents visible while guarding against flying glass should the vessel implode. Handle cautiously.

Flasks

Relieve vacuum slowly avowing sudden pressure changes which could cause breakage or spattering of contents. Do no relieve vacuum until flask has cooled. Never evacuate ordinary non-vacuum flasks, especially those with flat surfaces. Erlenmeyer flasks under vacuum pose a significant implosion hazard and should never be used on a rotovap or for evaporating chromatographic fractions.

Rotovaps

a. Implosion Protected

The body of a rotary evaporator needs to be implosion protected, without loss of visibility. This can be accomplished by using a plastic encased flask, by wrapping with electrical tape in a grid pattern or by wrapping it with protective webbing designed for that purpose.

b. Evaporation Containers
A one-liter flask is the largest that can be used effectively with most rotary evaporators. Flasks larger than one-liter pose safety risks due to possible breakage of the neck of the flask, increased bumping of liquids, and the risk of spilling large quantities of chemicals due to the possibility of a poor vacuum.

Water Aspirators

Glassware evacuated using water aspirators poses a significant implosion hazard. Aspirators are a good vacuum source (achieving 30-40 mm Hg of vacuum) relative to atmospheric pressure (~760 mm Hg). Therefore, care should be taken when evacuating glassware using water aspirators.

CAUTION: Do not underestimate the pressure differential across the walls of glassware that can be created by a water aspirator.

<u>5.4.4 Distillation Apparatus</u>

a. Distillations shall be conducted in equipment designed and fabricated for this use and shall be assembled with consideration being given to fire hazards from vent gases and possible equipment breakage or failure.
b. Care shall be taken to avoid the presence of unstable components (e.g., peroxides) in the still pot and to avoid overheating still contents.
c. Glass equipment used for distillations shall be inspected for cracks, scratches, and other defects prior to each use.
d. Faulty glass equipment shall be discarded or repaired.
e. Secure glass joints with wire or clamps to prevent vapor leakage.
f. Make sure system is vented and watch for plugging the condenser.
g. Use boiling chips or stirring to prevent bumping.
h. Use heating mantle where possible.
i. Avoid overheating still bottoms at end of distillation.
j. Do not distill ethers until peroxides have been removed.

<u>5.4.5 Centrifuges</u>

A centrifuge is a common piece of laboratory equipment, and using a centrifuge properly is essential to preventing accidents which could result in serious injury or destruction of the equipment. The hazards associated with centrifuges can be related to the equipment itself, the materials used in the centrifuge, or improper use of the centrifuge. It is vital that the centrifuge operator has been thoroughly trained on how to safely use the centrifuge and on how to properly maintain it.

The following safe operating guidelines should be followed for proper centrifuge operation:

a. Centrifuge operators must be trained in the proper use, handling, storage, and maintenance of the equipment.
b. Use a centrifuge only if it has a disconnect switch that deactivates the rotor when the lid is open. Replace older models that do not have this safety feature.
c. Always keep the lid closed and locked during operation and shut down. Do not open the lid until the rotor is completely stopped or attempt to break the head rotation by hand; IMPORTANT: Attempting to defeat safety mechanisms and/or to brake the rotor by hand could result in severe injury!
d. Use the centrifuge in a well ventilated area.
e. Inspect the inside of each tube cavity or bucket prior to using the centrifuge. The rotor and tubes should be clean and dry. Remove any glass or other debris from the rubber cushion.
f. Before loading the rotor, examine the tubes for signs of stress, and discard any tubes that are damaged.
g. Ensure that centrifuge tubes are not filled more than three-fourths full. Overfilling can result in leaks or spills. Also, do not fill tubes to the point where the rim, cap, or cotton plug becomes wet.
h. When balancing the rotors, match the tubes, buckets, adapters, and inserts against each other, and consider any added solution. Tubes, etc. should be spaced or distributed evenly around the rotor, and the density of the contents of the tubes should also be similar.
i. Do not use aluminum foil to cap a centrifuge tube. Foil may rupture or detach.
j. Ensure that the centrifuge has adequate shielding to guard against accidental ejection.
k. Stop the rotor and discontinue operation if you notice anything abnormal such as a noise or vibration.
l. Low-speed and small portable centrifuges that do not have aerosol-tight chambers may allow aerosols to escape. Use a safety bucket to prevent aerosols from escaping or use the centrifuge in a biological safety cabinet or fume hood.

Centrifuging Risk Group 2 or higher materials

Centrifuges create aerosols every time they are used. Potentially hazardous aerosols must always be properly contained. Special considerations must be made when centrifuging Risk Group 2 (RG2) or higher agents.

a. Safety cups or sealed rotors must be used in order to centrifuge RG2 or higher agents. Safety cups and sealed rotors have O-rings or other compressible gaskets in the lid that form a tight seal when the lid is properly closed.
b. Gaskets must be inspected before every use. Ensure broken or cracked gaskets are replaced before using.
c. Lightly lubricate gaskets regularly to prolong their life and create a better seal.
d. Load and unload rotors only inside the BSC. Sealed containers can only protect you from aerosols if you contain them while they’re opened.
e. Transport rotors to and from centrifuges on carts to prevent dropping.
f. Thoroughly decontaminate tubes as they are removed from the rotor. Thoroughly decontaminate the rotor before it is removed from the BSC.

5.4.6 High Speed Centrifuges

High-speed centrifuges pose additional hazards due to the higher stress and force applied to their rotors and tubes. It is necessary to understand the basic mechanics of the equipment and to know how to maintain it properly to ensure overall safety and reduce risk. In addition to the safety guidelines outlined above, follow these guidelines for high-speed centrifuges:

a. Be sure the centrifuge rotor and tubes are clean and dry prior to use.
b. The centrifuge should be cleaned periodically to help prevent corrosion or other damage. Routinely wash rotors with a mild dish soap to prolong rotor life. Rinse and let air dry.
c. Clean any spills in the centrifuge immediately, especially if the materials are corrosive.
d. Frequently inspect the rotor and other parts for corrosion, wear, or other damage; turn the spindle by hand. Rotors or parts exhibiting corrosion or other damage should be removed from use and evaluated by a service technician.
e. Check the expiration date of both the rotor and centrifuge. Always follow the manufacturer’s retirement date for rotors and other centrifuge parts.
f. Do not exceed manufacturer recommendations for safe operating speeds.
g. Keep a record of rotor usage and follow the manufacturer’s recommendations on when to replace the rotor.
h. For centrifuges that have been refrigerated, wipe away any excess moisture and allow the open unit to dry.
i. Filter the air exhausted from the vacuum lines.

5.4.7 Electrophoresis

Electrophoresis equipment may be a major source of electrical hazard in the laboratory. The presence of high voltage and conductive fluid in this apparatus presents a potentially lethal combination.

Many people are unaware of the hazards associated with this apparatus; even a standard electrophoresis operating at 100 volts can deliver a lethal shock at 25 milliamps. In addition, even a slight leak in the device tank can result in a serious shock.

Protect yourself from the hazards of electrophoresis and electrical shock by taking these precautions:

a. Use physical barriers to prevent inadvertent contact with the apparatus.
b. Use electrical interlocks.
c. Frequently check the physical integrity of the electrophoresis equipment.
d. Use warning signs to alert others of the potential electrical hazard.
e. Use only insulated lead connectors.
f. Turn the power off before connecting the electrical leads.
g. Connect one lead at a time using one hand only.
h. Ensure that your hands are dry when connecting the leads.
i. Keep the apparatus away from water and water sources.
j. Turn the power off before opening the lid or reaching into the chamber.
k. Do not disable safety devices.
l. Follow the equipment operating instructions.

5.4.8 Heating Systems

Common hazards associated with laboratory heating devices include electrical hazards, fire hazards, and hot surfaces. Devices that supply heat for reactions or separations include the following:

a. Open flame burners
b. Hot plates
c. Heating mantles
d. Oil and air baths
e. Hot air guns
f. Ovens
g. Furnaces
h. Ashing systems

Open Flame Operations

Laboratory operations using open flames shall be performed in accordance with the following requirements:

a. Whenever possible, alternative methods to the use of open flames, such as heating mantels, hot plates, glass bead sterilizers, or infrared loop sterilizers, shall be used.
b. Never leave an open flame unattended.
c. Never use an open flame in the vicinity of flammable liquids.
d. Hoses/tubing connecting a gas supply to a torch or Bunsen burner shall be in good condition, compatible with the gas being used, and rated at least 150 percent of working pressure.
e. Open flame equipment with a small gas cylinder attached shall be handheld, clamped, or weighted to prevent equipment from falling over.
f. If open flame operations are performed outside a hood, operations shall not be conducted under shelves, cabinets, or other overhanging equipment.

Biological operations using open flames and flammable liquids shall be performed in accordance with the following requirements:

a. Gas lines and open flames should not be used in recirculating BSCs.
b. The volume of flammable liquid in use in an open container shall be limited to 50 ml or less. The container of flammable liquid shall be glass or metal and shall have a tight fitting, slip-on lid to seal the container when not in use or if the flammable liquid catches on fire.
c. The container of flammable liquid shall be kept as far as possible from the open flame but not less than 0.305 m (12 in.).
d. Flammable liquids and other hazardous materials that are not used for open flame operations shall be placed in storage.
e. Combustible materials shall be kept at least 0.610 m (2 ft) away from the open flame and the container of flammable liquid. Absorbent paper shall not be used under the open flame operation.

Refer to Appendix M – Alternatives for Laboratory Work with Open Flames, for alternatives to open flame work.

Follow these guidelines when using heating devices:

a. Before using any electrical heating device:

    i. Ensure all unattended electrical heating equipment is equipped with a manual reset over-temperature shutoff switch, in addition to normal temperature controls, if overheating could result in a fire or explosion.
    ii. Ensure that heating devices and all connecting components are in good working condition, e.g., heating equipment with circulation fans or water cooling shall be equipped with an interlock arranged to disconnect current to the heating elements if the fan fails or the water supply is interrupted.
    iii. Burners, induction heaters, ovens, furnaces, and other heat-producing equipment shall be located a safe distance from areas where temperature-sensitive and flammable materials and compressed gases are handled.

b. Use caution when heating chemicals, as heated chemicals can cause more damage more quickly than would the same chemicals at a lower temperature. RULE OF THUMB: Generally, reaction rates double for each 10°C increase in temperature.
c. Use a chemical fume hood when heating flammable or combustible solvents. Arrange the equipment so that escaping vapors do not contact heated or sparking surfaces.
d. Use non-asbestos thermal-heat resistant gloves to handle heated materials and equipment.
e. All soldering, brazing or welding and all open flame glass blowing/glass manipulation is done either in an EHS /Facilities Management approved area or under an individually granted hot work permit.
f. Use of Perchloric acid must be approved by EHS prior to purchase.

5.4.9 Refrigerators/Freezers

Using a household refrigerator to store laboratory chemicals is extremely hazardous for several reasons. Many flammables solvents are still volatile at refrigerator temperatures. Refrigerator temperatures are typically higher than the flashpoint of most flammable liquids. In addition, the storage compartment of a household refrigerator contains numerous ignition sources including thermostats, light switches, heater strips, and light bulbs that could spark and trigger an ignition. Furthermore, the compressor and electrical circuits, located at the bottom of the unit where chemical vapors are likely to accumulate, are not sealed.

Laboratory-safe and explosion-proof refrigerators typically provide adequate protection for chemical storage in the laboratory. Laboratory-safe refrigerators, for example, are specifically designed for use with flammables since the sparking components are located on the exterior of the refrigerator. These units should be labeled with a rating from Underwriters Laboratory or other certifying organization. Explosion-proof refrigerators are required in areas that may contain high levels of flammable vapors (e.g., chemical storage rooms with large quantities of flammables). These units must be permanently wired to the electrical system.

Follow these rules for using refrigerators and freezers in the laboratory:

a. Never store flammable chemicals in a household refrigerator.

b. Do not store food or drink in a laboratory refrigerator/freezer.
c. Ensure that all refrigerators are clearly labeled to indicate suitable usage.
    i. Laboratory-safe and explosion-proof refrigerators should be identified by a manufacturer label.
    ii. Each refrigerator, freezer, or cooler shall be prominently marked to indicate whether it meets the requirements for safe storage of flammable liquids. "Not Safe for Flammable Storage" labels are available from the Environmental Health & Safety Department and must be applied to any household style refrigerator or freezer used in a laboratory.
    iii. Refrigerators used to hold food should be labeled "For Food Only" and should be located outside of the laboratory.

5.4.10 Storage Containers and Cabinets

Certain chemicals, particularly flammable liquids and acids, must be stored in special containers and/or cabinets in order to minimize their hazards. Storage of hazardous chemicals must be in accordance with provisions of the Virginia Statewide Fire Prevention Code (SFPC) and OSHA.

5.4.11 Safety Cans

Portable approved safety cans are used to safety store, carry, and pour flammable and combustible liquids. The main purpose of the safety can is to prevent an explosion of the container when it is heated. Safety cans are constructed of terne plate steel, stainless steel, or high density polyethylene. The type of can purchased is determined by the chemical properties of the flammable liquid and how it will be used. Terne-plate steel cans are designed to store petroleum solvents if the purity and color of the solvent are not critical. Some solvents may also dissolve the paint from the outside of these cans. Stainless steel cans are recommended when high purity solvents are needed. High density polyethylene cans are resistant to many solvents but may cause discoloration of the solvent.

Approval: Safety cans must be UL listed and FM approved, and properly labeled to identify contents.

Construction: All approved cans must have a lid that is spring loaded to close automatically after filling or pouring. The lid also acts as a relief valve when pressure builds up in the can. A flame arrestor screen must be inside the cap spout to prevent fire flashback into the can.

Flammable liquids in quantities greater than 1 gallon (3.8 liters) should be kept in metal safety cans designed for such storage. The cans shall be used according to the manufacturer's instructions and the following safety practices:

- Keep the can closed except when adding or removing liquid.
- Always keep the flame-arrestor screen in place; replace if punctured or damaged.
- Never disable the spring-loaded enclosure.

5.4.12 Flammable Storage Cabinets

Quantities of flammable liquids greater than 10 gallons must be stored in flammable storage cabinets, approved safety cans, or a properly designed flammable storage room. Approved storage cabinets are designed to protect flammable liquids from involvement in an external fire for 10 minutes. This is the time it would normally take for an area to become seriously involved in a fire.

Approval: All cabinets must comply with OSHA and NFPA requirements. Cabinets can be made of metal or wood if properly constructed.

Storage limits: Maximum storage limits for flammable liquids in approved storage cabinets are 120 gallons. Of this total, only 60 gallons of Class I and Class II liquids are allowed. No more than three such cabinets may be stored in a fire area.

Venting: Storage cabinets are not required to be vented. Venting a cabinet may defeat the cabinet's purpose of protecting the contents from involvement in a fire for 10 minutes.

The cabinets shall be used according to the manufacturer's instructions and the following safety practices:

- Store only flammable liquids in the cabinet.
- Do not store paper, cardboard or other combustible material in the cabinet.
- Do not overload the cabinet; the manufacturer establishes maximum quantity limits for each cabinet.
- Cabinet should be labeled to identify the hazard of the contents.

5.4.13 Acid Storage Cabinets

Acids should be kept in cabinets specially designed to hold them. Wooden or metal cabinets treated with a corrosion-resistant coating are recommended. The cabinets shall be used according to the manufacturer's instructions and the following safety practices.

- Store only acids in the cabinet.
- Store organic and inorganic acids separately, preferably in different storage cabinets; however they can be stored in the same cabinet if they are separated by distance and a barrier such as secondary containment.
- Store nitric acid away from all other acids unless you're cabinet has a separate compartment for nitric acid.
- Cabinet should be labeled to identify the hazard of the contents.

5.4.14 Secondary containment

Secondary containment must be provided for corrosive and reactive chemicals and is recommended for all other hazardous chemicals. Secondary containment must also be used for chemical containers on the floor and in hazardous waste accumulation areas. Secondary containment should be made of chemically resistant materials and must be compatible with its contents. The container should be sufficient to hold the volume of at least the largest single bottle stored in the container.

5.4.15 Sinks

Laboratories that use hazardous substances must contain a fully functional sink with a drain and pressurized water. Sink drains should be made of nonporous material and easily disinfected. The area in and around laboratory sinks should be kept clean and uncluttered so that the sink may be used for hand washing to remove any final residual contamination. Hand washing is recommended whenever a staff member who has been working with hazardous materials plans to exit the laboratory or work on a project that does not involve hazardous materials.

5.4.16 Autoclaves

The use of an autoclave is a very effective way to sterilize labware and decontaminate biological waste. Autoclaves work by killing microbes with superheated steam. Before autoclaving, evaluate the waste to verify that the heat and pressure of autoclaving do not create unsafe conditions. Minimal parameters are 121°C at 15 psi for 15 minutes. Time may need to be increased for larger loads, larger volumes of liquid or the type of item that is being autoclaved.

The following are recommended guidelines when using an autoclave:

- Before autoclaving, evaluate the waste to verify that the heat and pressure of autoclaving do not create unsafe conditions. Autoclaving waste containing flammable liquids may result in a fire or explosion. Note also that steam sterilization of waste that contains bleach may harm an autoclave. Do not autoclave these types of waste streams.
- Do not put sharp or pointed contaminated objects into an autoclave bag. Place them in an appropriate rigid sharps disposal container. Use caution when handling an infectious waste autoclave bag, in case sharp objects were inadvertently placed in the bag. Never lift a bag from the bottom to load it into the chamber. Handle the bag from the top.
- Do not fill autoclaves and other pressure-reaction vessels more than half full to ensure that space remains for expansion of the liquid when it is heated. Always use secondary containment when autoclaving.
- Do not make leak corrections or adjustments to the apparatus while it is pressurized; rather, depressurize the system before mechanical adjustments are made.
- Do not overfill an autoclave bag. Steam and heat cannot penetrate as easily to the interior of a densely packed autoclave bag. Frequently the outer contents of the bag will be treated but the innermost part will be unaffected.
- Do not overload an autoclave. Items should be loaded in manner that ensures that steam can penetrate packages. An overpacked autoclave chamber does not allow efficient steam distribution. Considerably longer sterilization times may be required to achieve decontamination if an autoclave is tightly packed.
- Annual calibration and maintenance should be performed by an outside service vendor.

- Conduct autoclave sterility testing on a regular basis using appropriate biological indicators (Bacillus stearothermophilus) to monitor efficacy. Autoclave indicator tape should be clearly visible on each item placed in the autoclave.
- Do not mix contaminated and clean items together during the same autoclave cycle. Clean items generally require shorter decontamination times (15-20 minutes) while a bag of infectious waste (24" x 36") typically requires 45 minutes to an hour to be effectively decontaminated throughout.
- Always wear personal protective equipment, including heat-resistant gloves, safety glasses and a lab coat when operating an autoclave. Use caution when opening the autoclave door. Allow superheated steam to exit before attempting to remove autoclave contents.
- Be on the alert when handling pressurized containers. Superheated liquids may spurt from closed containers. Always loosen the lid of the container before autoclaving. Never seal a liquid container with a cork or stopper. This could cause an explosion inside the autoclave.
- Agar plates will melt and the agar will become liquefied when autoclaved. Avoid contact with molten agar. Use a secondary tray to catch any potential leakage from an autoclave bag rather than allowing it to leak onto the floor of the autoclave chamber.
- If there is a spill inside the autoclave chamber, allow the unit to cool before attempting to clean up the spill. If glass breaks in the autoclave, use tongs, forceps or other mechanical glassware.
- Do not to leave an autoclave operating unattended for a long period of time. Always be sure someone is in the vicinity while an autoclave is cycling in case there is a problem.
- Recordkeeping – There should be a log or notebook adjacent to the autoclave to indicate the date, time, username, cycle type used (liquid, gravity, and vacuum), items autoclaved (media, waste, etc.), and verification performance checks.
- Autoclaves should be placed under preventive maintenance contracts to ensure they are operating properly.

5.5 Biological and Animal Safety

Many laboratories on campus use biological materials, including biological pathogens, toxins and allergens derived from biological agents, and recombinant DNA materials. Some laboratories work with animals in their research. In these laboratories, Biological and/or Animal Safety is integral to overall laboratory safety.

For research involving biological materials or animals, oversight by the Research Compliance Office (RCO) may be required. Two committees within the RCO oversee and grant approval for conducting such research.

- The Institutional Review Board (IRB) manages research involving human subjects.
- The Institutional Animal Care and Use Committee (IACUC) oversees any research involving the use of animals.
- The Institutional Biosafety Committee (IBC) is a third committee between the RCO and EHS which manages research involving agents such as
  a. Microorganisms or agents potentially pathogenic to humans, animals, or plants;

b. Materials potentially containing human pathogens (including human blood or other body fluids, tissues, organs, and cell lines; non-human primate blood, tissue, and cell lines);
c. Recombinant or synthetic nucleic acid molecules (r/sNA) (regardless of origin) and r/sNA-containing organisms or cell cultures including creation or use of transgenic plants and animals (see https://osp.od.nih.gov/wpcontent/uploads/NIH_Guidelines.pdf);
d. Select agents and toxins (see http://www.selectagents.gov/) including strains and amounts exempted from the select agent regulations; or
e. Any material requiring a CDC import license or a USDA permit;
f. Animals for which a reasonable potential for transmission of naturally infected zoonotic agents exists, e.g., wild-trapped animals, necropsy, etc.;
g. Nanomaterials

Specific information on BioSafety may be obtained from EHS or from reviewing the Bisoafety Manual.

5.6 Radiological and Laser Safety

Radioactive materials and lasers pose unique hazards, and their use is regulated by the State of Virginia. Refer to the Radioisotope Safety Manual or Laser Safety Program for more information.

5.7 X-ray Safety

X-ray machines are used on campus in many different locations for research and diagnosis. It is very important that users of X-ray machines become familiar with their operating procedures and potential hazards before using the machines. It is especially important to avoid any exposure to the main beam of the X-ray machine.

X-Ray Machines Description

An X-ray machine produces a beam of ionizing radiation when operating. These machines present no hazard when the power is off. All X-ray machines have a light that indicates when the X-ray is ON.

Signage

X-ray machines and signs should be posted with a sign or label indicating the presence of X-ray beams. These signs should also include lab contact information and contact information for emergency response personnel, should an emergency arise.

Safety Devices

Analytical X-ray machines used for research are surrounded by an enclosure to prevent personnel exposure and unauthorized entry. Areas around enclosed X-ray devices may be accessed safely. Most X-ray machines have an interlocking device that prevents entry of limbs, fingers, hands, etc. into the primary beam path or causes the beam to be shut off upon entry into its path. Operators must perform and document monthly checks of these interlocks. If you must enter an X-ray room and an operator is not present, stay outside of the X-ray enclosure. Do not disturb any settings on the X-ray machine.

Refer to the Radiation Producing Machines Safety Manual for additional details and information regarding Radiation Producing Devices.

Controlled Substances

The purchase, storage, and use of many drugs are regulated under Title 21 CFR Part 1300-1399 as controlled substances. Every person who engages in research with controlled substances must acquire the appropriate license through the Drug Enforcement Agency (DEA) to distribute, store, and administer controlled substances for research purposes at the University. The research use of these controlled substances can be hazardous based on the specific chemical properties and planned use. Health, safety, security, and licensing concerns must be addressed prior to doing this work.

Anesthetic Gases

Anesthetic gases, used during research involving animals, must be properly controlled to avoid overexposure of the researcher to the chemical. Workers acutely exposed to excess amounts of anesthetic gas can experience symptoms of drowsiness, headache, nausea, poor judgment and loss of coordination. Chronic symptoms of over-exposure can include liver, kidney and reproductive effects. Anesthetics of concern include ether, nitrous oxide, and halogenated agents including: chloroform, enflurane, halothane, isoflurane, methoxyflurane and trichloroethylene. Use of anesthetic gases requires engineering controls (typically ventilation) to remove chemicals from the workplace and prevent overexposure. See the Anesthetic Gas SOP for additional information.

Nanomaterials

A nanoparticle is a collection of atoms with one dimension less than 100 nanometers. Nanoparticles that are naturally occurring (e.g., volcanic ash) or incidental byproducts of combustion processes (e.g., welding, diesel engines) are often termed ultrafine particles. Engineered nanoparticles are intentionally produced and designed with very specific properties related to shape, size, surface properties and chemistry. They may be bought from commercial vendors or generated via experimental procedures by researchers in the laboratory. Examples of engineered nanomaterials include: fullerenes, carbon nanotubes, metal oxide nanoparticles, and quantum dots, among many others. The health effects of exposures to nanomaterials are not fully understood at this time. Until more definitive findings are made regarding the potential health risks of handling nanomaterials, researchers planning to work with nanomaterials must implement a combination of engineering controls, work practices, and personal protective equipment to minimize potential exposures.

6.0 ADMINISTRATIVE CONTROLS

Administrative controls (or work practice controls) are changes in work procedures such as written safety policies, rules, supervision, schedules, signage and labeling, record keeping, medical surveillance and training with the goal of reducing the duration, frequency, and severity of exposure to hazardous substances or situations. Essentially, they require the worker or employer to DO something. Administrative controls should be established prior to beginning a laboratory project or protocol.

PRUDENT LABORATORY PRACTICES

It is prudent to minimize all exposures to hazardous substances. Few laboratories are without hazards, and general precautions for handling all hazardous substances should be adopted, in addition to specific guidelines for particular materials. Exposure should be minimized even for substances of no known significant hazard, and special precautions should be taken for work with substances that present special hazards. One should assume that any mixture will be more toxic than its most toxic component and that all substances of unknown toxicity are toxic.

The type of work performed in laboratories is wide-ranging. Hazards found in laboratories can vary depending on the nature of the work performed. Laboratory safety may include one or more areas of safety: chemical safety, fire safety, electrical safety, radiation safety, physical/equipment safety, laser safety and biological safety, etc. Avoid inadvertent exposures to hazardous materials by developing and encouraging safe habits and thereby promoting a strong safety culture.

6.1 Safe Laboratory Practices

a. Know the hazards associated with the materials (chemical, biological, electrical, physical, etc.) and equipment in your laboratory. Refer to the appropriate safety information, such as Safety Data Sheets (SDSs), Standard Operating Procedures (SOPs), and equipment operating instructions, and follow the recommended safe practices. Consider what training, knowledge, safety equipment, etc. are required to do the procedure safely. Seek information and advice about hazards, plan appropriate protective procedures, and plan positioning of equipment before beginning any new operation.
b. Know the locations of safety equipment and emergency exits.
c. Be alert to unsafe conditions and ensure that they are corrected when detected. Develop a plan of action for how to respond to emergencies in your laboratory. Review this plan often so that you will be ready to respond as needed.
d. Use appropriate engineering controls to minimize exposure to hazardous substances. Verify that safety equipment is working properly prior to use.
e. Follow proper operating procedures when using a chemical fume hood. Keep the hood sash at a comfortable working height (less than 18”), and close the sash completely when the hood is unattended.
f. Do not engage in distracting behavior such as practical joke playing in the laboratory. This type of conduct may confuse, startle, or distract another person.
g. While in the laboratory, researchers must be fully aware of their surroundings and the events taking place around them. Be aware of the hazards posed by the work of others in the laboratory and any additional hazards that may result from contact between materials and chemicals from different work areas. Laboratory personnel actively working with

hazardous materials, operations, or equipment must be especially cautious and make sure they are not distracted while working with the hazard or unable to hear warnings from those around them. Inadequate situational awareness has been identified as one of the primary factors in accidents attributed to human error. Thus, electronic devices that impede awareness of laboratory activities or emergency situations are prohibited for those actively working with hazardous materials, operations, or equipment. This rule applies to the use of electronic devices with earbuds or headphones like MP3 players and cell phones.

6.2 Housekeeping

Maintaining a neat and clean laboratory work area is instrumental to minimizing accidents in the laboratory. The following steps should be taken:

a. Keep work areas neat, clean and uncluttered.
b. Counters and lab benchtops will be cleaned after each use by laboratory students, staff or faculty. Facilities Housekeeping personnel should not clean countertops and benchtops in laboratories.
c. Keep stairwells, hallways, corridors, aisles and areas of egress free from obstruction or clutter.
d. Facilities Housekeeping personnel are not permitted to clean up any type of spill. If laboratory staff are not available, contact RUPD at 540-831-5500 or EHS at 540-831-7790.

6.3 Safety Equipment Maintenance

Emergency showers and eyewash stations must be installed, maintained, flushed, and tested in accordance with the ANSI *Standard for Emergency Eye Wash and Emergency Shower Equipment* (Z358.1-2014). Emergency showers and eyewash stations shall be tested, at least, annually by EHS. All tests shall be documented. The following information should be included: location; date of inspection; type of inspection; type of equipment; deficiencies in operation; corrective action taken. Weekly activations of eyewash stations should be performed and documented by laboratory staff.

Fire extinguishers shall be inspected annually by the fire equipment service company that is on university contract. EHS personnel will conduct monthly fire extinguisher checks. A copy of any safety related work orders shall be sent to the Fire Safety officer (540-831-7792).

First aid and Spill kit supplies depending on the hazards should be located in laboratories and laboratory support rooms to assist personnel in responding to minor injuries and activities in the laboratory. The location of these supplies should be clearly marked and easily accessible. All laboratory personnel must know the location of these supplies. Supplies should be routinely inspected and replaced as necessary.

Laboratory ventilation systems (chemical fume hoods, biosafety cabinets, laminar flow hoods, snorkels and canopy hoods) shall be evaluated for operation and certified by EHS annually. Testing will follow Federal and State requirements for procedure and results. Data on annual fume hood monitoring will be maintained by EHS.

6.4 Food/Drink

a. Do not eat or drink in a laboratory or any other space in which hazardous substances are stored or handled.
b. Do not use tobacco products, chew gum, apply cosmetics or handle contact lenses in areas where hazardous substances are present.
c. Do not store personal food and drink products in laboratories or in laboratory refrigerators or freezers. Do not prepare food in the laboratory or wash utensils used for food and drink in laboratory sinks. Food and drink products purchased for research and/or instructional purposes only and stored in laboratories or in laboratory refrigerators/freezers must be labeled accordingly. Similarly, refrigerators/freezers should be labeled "No Food or Drink." Refrigerators/freezers used for the storage of personal food and beverages should be kept in a separate room (break area) with a door separating the laboratory from the break area. Label these units "Food Use Only."
d. Other laboratory equipment that could be used for the preparation of food or beverages (such as microwave ovens or ice machines) should be dedicated exclusively for laboratory use. Clearly label such equipment to indicate "Lab Use Only," "No Food or Drink," and/or "Not for Human Consumption."

6.5 Working Alone

Every person who works in a laboratory, whether an employee or a student, is responsible for being aware of the hazards in that laboratory and for working in a safe manner. Work with hazardous substances or physical hazards (e.g. high voltage, mechanical hazards not known to be intrinsically safe) or any other work that might prove immediately dangerous to life and health (IDLH) shall not be conducted alone in any Radford University laboratory. It is recommended that all laboratory work be conducted with a partner or co-worker, or in proximity to others, in case of emergency. If procedures require a person to work at a time when others may not be present (such as after hours or on weekends) and when hazardous conditions exist, the person shall

a. Knowing where emergency contact information is posted and ensure that a means to contact emergency response personnel is available when working alone in the laboratory;
h. Knowing and following emergency response procedures (including spill response, first aid response, locations of safety equipment, evacuation routes, etc.);
b. Ensuring they have received proper safety training before working with hazardous materials or equipment;
c. Wearing appropriate Personal Protective Equipment;
d. Make arrangements for someone to check on them at regular intervals; and
e. Be alert to unsafe conditions and ensure that they are corrected when detected or report unsafe conditions to their supervisor and/or to EHS.
f. Personnel working late at night are discouraged from working alone and are strongly advised to keep their work area locked. Utilize caution on admitting anyone into your work area if alone or when in transit between destinations. Escort services are available. Contact RUPD for further information.

NOTE: According to the National Safety Council, the term alone means that a person is beyond the visual or auditory range of any other individual for more than a few minutes at a time.

6.6 Unattended Activities

Do not leave reactions or other potentially hazardous procedures unattended. Protect operations from utility failures and other potential problems that could lead to overheating or other hazardous events. If there is the need for a laboratory procedure or research activity to be left unattended, the individual responsible must notify the appropriate parties and an appropriate sign will be posted on the area within the laboratory or the door. The individual responsible for the unattended activity will need to provide for containment of the chemicals involved in the event of an unforeseen accident. Avoid unattended operations, if at all possible. Unattended operations require prior approval from the Department Head/Chair.

6.7 Laboratory Security and Access

Laboratory security is vital to ensuring safety on campus. Not only should you protect your work area from theft and mischievous activities, but you should also keep unauthorized or unsuspecting persons from potentially becoming exposed to hazardous conditions. Laboratories contain hazardous substances that can pose a serious danger to public health if handled by untrained personnel or removed from the laboratory. In addition, laboratories contain expensive instruments and equipment that must be protected from unauthorized use, vandalism, and theft. Therefore, it is imperative that appropriate security precautions are implemented to prevent unauthorized individuals from gaining access to laboratory materials and equipment.

Recently regulatory agencies have been implementing rules to ensure chemical security. While many of these rules are for large manufacturing facilities, it is critical that chemicals be secured to prevent theft from campus laboratories. Numerous federal agencies are involved in the maintenance of laboratory security, including the Drug Enforcement Agency, Federal Bureau of Investigations, and Department of Homeland Security.

It is each Department's responsibility to prevent and report any theft of chemicals from their laboratory. Follow these steps to secure your laboratory:

a. Keep laboratory doors closed and locked when the laboratory is unoccupied.
b. Never prop open a laboratory door, except for a brief time to move items in and out.
c. Limit unauthorized entry into laboratories, especially when hazardous procedures are being conducted.
d. Secure stocks of organisms and hazardous chemicals, especially when the laboratory is unoccupied.
e. Lock refrigerators, freezers, and chemical storage cabinets that are located in areas open to public access.
f. Keep an accurate record of chemicals, stocks, cultures, etc. and any items or equipment that support project activities.
g. Notify the Radford University Police Department (RUPD) if materials are damaged or missing from laboratories or if unauthorized entry into a laboratory has been attempted.
h. Inspect all packages arriving into the laboratory. Do not accept suspicious or unexpected packages.
i. At the end of the day, ensure that all hazardous materials, whether chemical or biological have been properly stored and secured.

j. Escort visitors to and from the laboratory. If unexpected, greet all visitors to the laboratory immediately, and determine their reason for entering your laboratory. Ask them to exit the room if they are not authorized to be there.
k. Implement other security requirements as necessary for your work.
l. Post current Emergency Contact Information on all laboratory door signs.
m. Train laboratory personnel to implement security procedures.

6.8 Restricted Access for Visitors

Visitors should not be allowed to enter laboratories unattended and should be escorted to and from the laboratory by Radford University personnel. Prior to allowing visitors to tour or observe in a laboratory, the supervising employee must conduct a basic safety orientation, including both general safety information and any hazards particular to the lab in question.

6.9 Restricted Access for Support Services Staff

All support services staff (e.g., housekeeping, facilities management, police, etc.) must receive appropriate training prior to entering laboratories or laboratory support rooms. Once trained, support services staff may enter laboratories and laboratory support rooms with the exception of specific rooms designated as restricted areas.

Restricted areas include laboratories that house animals, chemical storage rooms, BSL laboratories, radioactive materials, and other areas with unique hazards. Support services staff are not permitted to enter restricted areas unless requested by PI/LS or EHS. In this situation, the person requesting the service must submit a work order and arrange for access. EHS maintains a current list of restricted areas.

For non-restricted laboratories and laboratory support rooms, support services staff must notify the unit of non-routine services (e.g., mopping and waxing floors, light bulb replacement, and equipment inventory) at least 10 university working days in advance of when the work is to occur. PI/LS may request that services be scheduled at a time that does not interfere with ongoing laboratory operations or critical experiments.

Support services staff have been instructed that they need not perform any services which make them uncomfortable or of which they are unsure. Specifically, housekeeping staff has been instructed that they should not clean pools of liquid on laboratory floors.

6.10 Door Signage

Laminated lab door signs are required for all laboratories and areas that contain hazardous materials. The signage complies with applicable regulations and provides a consistent look for all campus locations where hazardous materials are in use. Information on the sign can inform staff and emergency responders about the types of hazards that are in the lab and if any precautions are required. The sign also provides contact information of who to notify in case of an emergency in the room or area. Additionally, information concerning the correct personal protective equipment can be accessed prior to entering the lab. Refer to Appendix H for the Laboratory Door Sign Worksheet and instructions. If information contained on the lab sign requires updating (such as adding or deleting hazardous materials, change of emergency contacts, etc.) it is the responsibility of the laboratory personnel to contact EHS so an updated sign can be created.

Depending upon the hazards located in the laboratory, such as biological or radiological, additional signage may be required. This information is critical for emergency personnel responding to an incident in the laboratory. Consult CHIMERA, the appropriate section(s) within Safety Data Sheets, or authority for more information on signage requirements.

Laboratories containing equipment that may pose a potential health risk (such as those with magnetic fields) must have warning signs posted at the entrance to the laboratory and at a safe distance from the entrance. These warning signs must indicate the type of hazard present and identify any particular risks associated with this hazard.

6.11 Labels

Labels should be affixed to the container or as close as possible to the container using string, wire, adhesive, or any other method that prevents their loss or unintentional removal. The following items within a laboratory must be identified with labels or signage. Templates for different labels can be accessed under the Laboratory Quick Links on the EHS website.

a. Emergency shower;
b. Emergency eyewash station;
c. Fire extinguisher;
d. First aid kit;
e. Spill kit;
f. Refrigerator/Freezer;
g. Microwave;
h. Ice machine;
i. Cabinet where hazardous chemicals are stored;
j. Equipment where biohazardous agents are used and/or stored;
k. Satellite accumulation area;
l. Chemical storage area;
m. Electromagnetic equipment;
n. Radioactive Material;
o. Laser;
p. Thermal hazard;
q. Electrical hazard;
r. Mechanical hazard; and
s. Unique hazard.

6.12 Laboratory Equipment (Damaged/Inoperable and Repair/Surplus/Disposal)

Equipment that is damaged and/or not operational must be taken out of service and labeled to prevent further use by laboratory personnel. Notify EHS immediately of broken or malfunctioning safety equipment (e.g., chemical fume hoods, biosafety cabinets, emergency shower/eyewash stations, fire extinguishers, etc.).

Finally, before any equipment used with a hazardous chemical, biohazardous material, or radioactive material can be sent for repair, surplus, or disposal, it must be decontaminated and labeled with a *Decontamination Certificate* (see Appendix N).

6.13 Chemical Management

Accidents associated with the handling of chemicals can occur during, storage, use, and disposal. Personnel may be exposed to hazardous chemicals that present health hazards, such as toxins and corrosives, and physical hazards that may result in fires and explosions. These risks can be minimized by following the general precautions recommended below.

Chemical Purchasing

The procurement of chemicals or chemical products is one of the first opportunities to facilitate chemical safety in the lab. The following considerations are recommended:

a. When purchasing new chemicals for use in the lab, always order the smallest amount needed to complete a project and to reduce disposal costs.
b. When possible, purchase the lowest concentration of a chemical.
c. Review the Safety Data Sheet sent with the shipment or within CHIMERA and identify whether a less hazardous substitute could be purchased. Consider ordering less hazardous materials if the same research objectives can be achieved.
d. Contact other laboratories through the CHIMERA and inquire whether another department may have excess amounts of the same chemical available for use.
e. Prior to ordering, determine its hazards and assure the space is approved for the chemical hazard and anticipated quantities as well as ensuring adequate storage space exists for the chemical and any generated waste.

Chemical Storage and Handling

a. Do not smell or taste chemicals.
b. Never use mouth suction for pipetting or starting a siphon.
c. Prior to any new laboratory procedure review the SDS to become aware of any hazards, ways to protect against the hazards, and disposal considerations.
d. Personnel should receive adequate training in handling the material.
e. Use only those chemicals for which the quality of the available engineering control is appropriate.
f. Vent apparatus which may discharge toxic chemicals (vacuum pumps, distillation columns, etc.) into local exhaust devices.
g. In accordance with Globally Harmonized System of Classification and Labeling of Chemicals (GHS), and in compliance with OSHA 1910.1200; Labels on incoming chemicals must contain the name of the product or chemical, identify hazardous ingredients or components, display the appropriate signal word, appropriate physical, health, environmental hazard statements, supplemental information, precautionary measures & pictograms, first aid statements, and the name and address of the manufacturer. Unlabeled chemicals must not be accepted. Properly label and store all chemicals. Use secondary containment at all times.
h. All departments must maintain an inventory of incoming hazardous chemicals.

i. Do not dispose of any hazardous substances through drain disposal. Requests for sanitary sewer disposal for any waste streams not already authorized can be made by contacting EHS. Those with waste streams that have been authorized should receive a copy of their permit(s).

j. Deposit chemical waste in appropriately labeled receptacles and follow all other waste disposal procedures of the Chemical Hygiene Plan and the Hazardous Waste Management Program Guidebook.

k. In the case of an accident or spill, refer to the emergency response procedures for the specific material. These procedures should be readily available to all personnel. Information on minor chemical spill mitigation may also be referenced in Appendix D. For general guidance, the following situations should be addressed:

   Eye Contact: Promptly flush eyes with water for a prolonged period (15 minutes) and seek medical attention.

   Skin Contact: Promptly flush the affected area with water and remove any contaminated clothing. If symptoms persist after washing, seek medical attention.
   Clean-up:

   For spills:

Figure 6.1 –
Simple* Spill Cleanup

6.14 Equipment Storage and Handling:

a. Use equipment only for its designed purpose.
b. Do not use damaged glassware or other equipment, under any circumstances.

c. Store laboratory glassware with care to avoid damage. Use extra care with Dewar flasks and other evacuated glass apparatus; shield or wrap them to contain chemicals and fragments should implosion occur.
d. Use certified fume hoods, biosafety cabinets, or other ventilation devices for operations which might result in release of toxic chemical vapors or dust. Preventing the escape of these types of materials into the working atmosphere is one of the best ways to prevent exposure.
e. Do not use uncertified or inoperable ventilation systems for hazardous substance handling.
f. Keep hood closed when you are not working in the hood.
g. Leave the fume hood "on" even when it is not in active use if toxic substances are in the fume hood or if it is uncertain whether adequate general laboratory ventilation will be maintained when it is "off".
h. Avoid storing materials in fume hoods.
i. The chemical fume hood should not be used for storage of chemicals, waste, equipment, or other materials. Stored material in the hood interferes with airflow and may contribute to fueling a fire or block air flow. Only the containers, materials, and equipment you are actually using should be in the chemical fume hood.
j. Do not store, handle, or consume food or beverages in storage areas, refrigerators, freezers, glassware or utensils which are also used for laboratory operations.
k. Handle all sharps, including needles, scalpels, pipets and broken glassware with caution to prevent injury to personnel.
    i. Do no recap, bend, or break needles. Place used needles in a puncture-resistant sharps container. Sharps containers should be placed within arm's reach of your work area.
    ii. Do not pick up broken glass with your hands. Use a broom and dustpan or forceps and dispose of glass in a sturdy cardboard box.
l. Disinfect work surfaces and equipment regularly. Keep work surfaces clear and tidy so routine decontamination is easy.
m. Decontaminate all cultures, plates, and supplies that have come into contact with biohazards. This can be done by adding appropriate chemicals to liquid cultures or by autoclaving wastes using a validated and regularly verified autoclave cycle.
n. Use of sealed rotors or safety cups when centrifuging biohazardous materials.
o. Vacuum lines must be protected with HEPA filters.
p. UV lamps in biosafety cabinets (BSC) are not recommended for disinfection, but if there is one in your BSC, make sure it is turned off when people are in the lab. It is best to leave the blower fan running at all times. If your BSC is not already running when you need to use it, allow it to run for ten minutes to establish proper airflow before working.
q. Disinfect the interior surfaces of the BSC using an appropriate disinfectant. Don't forget to wipe the interior walls of the BSC including the inside of the sash. If your disinfectant is corrosive (e.g. bleach, Wescodyne), make sure to rinse it thoroughly or the stainless steel will rust.
r. Never use a Bunsen burner inside a BSC. Properly used, BSCs provide semi-sterile environments that do not require the use of a flame to maintain. If you need to heat-sterilize equipment within the BSC, contact Biosafety for information about alternative devices such as Bacticinerators or Touch-o-matic burners.

6.15 Equipment Maintenance

All laboratory equipment will be continually evaluated and periodic calibration of equipment will be performed. Equipment checks will be the responsibility of the affected department. The specialist will keep a record of all maintenance, deficiencies and corrective actions. Facilities Management will be responsible for maintenance, repair and general cleaning of the lab and prep rooms. ***Facilities Housekeeping personnel are not responsible for cleaning countertops and upper laboratory surfaces.*** All required repairs should be documented by a written work order.

6.16 Standard Operating Procedures (SOPs)

Standard Operating Procedures (SOPs) relevant to safety and health considerations must be developed and followed when laboratory work involves the use of hazardous chemicals. SOPs are written instructions that detail the steps that will be performed during a given experimental procedure and include information about potential hazards and how these hazards will be mitigated. SOPs should be laboratory specific and written by laboratory personnel who are most knowledgeable and involved with the experimental process. These safety procedures should be communicated via lab specific trainings and properly documented. The development and implementation of SOPs is a core component of promoting a strong safety culture in the laboratory and helps ensure a safe work environment.

While general guidance regarding laboratory work with hazardous materials is contained in this plan. Laboratory Instructors/PIs are required to develop and implement laboratory-specific SOPs for hazardous materials that are used in their laboratories. The Instructors/PIs and all personnel responsible for performing the procedures detailed in the SOP shall sign the SOP acknowledging the contents, requirements and responsibilities outlined in the SOP. The SOPs shall be reviewed by qualified personnel and shall be amended and subject to additional review and approval by the Instructors/PIs where changes or variations in conditions, methodologies, equipment, or use of the hazardous substance occurs. For certain hazardous chemicals, PHS, or specialized practices, consideration must be given to whether additional consultation with safety professionals is warranted or required.

When drafting a SOP, consider the type and quantity of the hazardous substance being used, along with the frequency of use. The Safety Data Sheet (SDS) for each hazardous substance that will be addressed in the SOP should be referenced during SOP development. The SDS lists important information that will need to be considered, such as hazard(s) identification, first-aid measures, handling and storage, exposure controls/personal protection, symptoms of exposure, stability and reactivity, toxicological information, and disposal considerations. If a new chemical will be produced during the experiment, an SDS will not necessarily be available. In these cases, the toxicity is unknown and it must be assumed that the substance is particularly hazardous, as a mixture of chemicals will generally be more toxic than its most toxic component.

See Appendix I for a SOP Template.

6.17 Training

Effective training is critical to facilitate a safe and healthy work environment, to mitigate employee exposures, to prevent laboratory accidents, and to ensure laboratory security.

Department Heads must ensure that all their employees have appropriate safety training before working in a laboratory. PIs/Instructors must ensure that all students have appropriate safety training before beginning any laboratory experiment.

Radford University laboratory personnel, students, support services staff, and visitors entering laboratories or laboratory support rooms are required to receive safety training commensurate with their level of participation in laboratory activities and the duties they are to perform. EHS provides training including, but not limited to, laboratory safety, chemical safety, bloodborne pathogens, and biosafety in accordance with relevant guidance and regulatory requirements.

All laboratory personnel must complete general safety training before:

a. Beginning work in the laboratory;
b. Prior to new exposure situations; and
c. As work conditions change.

Annual refresher training is also required for all laboratory personnel. EHS can offer general classroom training, plus resource materials to assist laboratories in implementing laboratory-specific training.

6.17.1 Laboratory Safety Awareness

Laboratory Safety Awareness training offers non-laboratory personnel a fundamental overview of laboratory hazards, hazard identification, and emergency response. Specific *Laboratory Safety Awareness* training is offered to Facilities Management and University Police. Each training course focuses on the specific duties and safety concerns of the trainees.

6.17.2 Laboratory Safety Orientation

All personnel working in Radford University laboratories are required to attend *Laboratory Safety Orientation*.

Laboratory Safety Orientation will serve as the foundation for all participants who are new to Radford University instructional or research laboratories. This course will instruct participants on Radford University-specific laboratory safety policies and procedures; risk assessment and management to include recognition of laboratory hazards and the use of engineering controls, administrative controls and PPE to mitigate the hazards; review of reference materials (e.g., SDS) on hazards, handling, storage and disposal of hazardous chemicals; waste management guidelines, and fire safety and emergency response information. This course will also introduce participants to best practices for chemical and noninfectious biological material work within the laboratory, as well as services available to laboratory personnel through EHS.

This training must be renewed annually. Once you have taken this training course, you may substitute Laboratory Safety Refresher training to meet the annual requirement.

6.17.3 Bloodborne Pathogens

In accordance with the OSHA Bloodborne Pathogen (BBP) Standard, training on risks associated with bloodborne pathogens, safe laboratory practices, medical waste management, and emergency procedures is provided annually to all individuals at occupational risk for exposure to bloodborne pathogens. Individuals working in or frequenting laboratories or clinical settings where bloodborne pathogens or other potentially infectious materials are present must receive bloodborne pathogens training before beginning work. BBP training is also required for those working with sharps and biohazardous agents. Training must be renewed annually.

6.17.4 Biological Safety

Many laboratories on campus use biological materials, including biological pathogens, toxins and allergens derived from biological agents, and recombinant DNA materials. In these laboratories, Biological Safety is integral to overall laboratory safety.

All individuals working in or frequenting laboratories where biohazardous agents are used or stored must receive Biological Safety training before beginning work with biohazardous materials. This training reviews the principles of biosafety including risk assessment and management strategies, risk groups and biosafety levels safe laboratory practices, methods of disinfection and decontamination, waste management, and spill and exposure response. Additionally, this training will instruct participants on Radford University-specific laboratory safety policies and procedures, chemical safety and hygiene, risk assessment and management, waste management guidelines, and emergency response information. Biological Safety training must be renewed annually.

The Institutional Biosafety Committee (IBC) manages research involving biohazardous agents. Specific information on Biological Safety may be obtained from EHS.

6.17.5 Radiological and X-ray Safety

EHS provides radiation safety training to all individuals working in or routinely entering laboratories where radioactive material or instruments that produce ionizing radiation are used. Training is also required for individuals who receive radioactive materials packages. X-ray safety training is provided to personnel who use x-ray producing devices. Additional training opportunities are discussed in the Radiation Safety Program.

6.17.6 Laser Safety

The Laser Safety Officer provides laser safety training in accordance with ANSI Standard z136.1. Information about laser safety training is available in the Laser Safety Program.

6.17.7 Respiratory Protection and Hearing Conservation Programs

OSHA requires that all individuals who are issued respiratory protection or hearing protection devices be enrolled in the Radford University Respiratory Protection Program and Hearing Conservation Program, respectively. These programs are administered by EHS, and annual training is required as part of these programs. Personnel whose work requires the use of respiratory protection [e.g., half face, full face, powered air purifying respirator (PAPR), particulate mask (including N95 or N99 filtering face piece)] or hearing protection devices (e.g., ear muffs, ear plugs) must contact EHS prior to beginning work.

6.17.8 Laboratory-Specific Training

In addition to training provided by EHS, laboratory personnel must receive training specific to the laboratory in which they work. This training is provided by the PI/LS/Instructor, should be based on the Department CHP and/or Supplemental Laboratory Safety Plan, and must include such topics as risks associated with the hazardous substances in the laboratory, physical hazards present in the laboratory, proper use of instruments and safety equipment, and laboratory procedures and protocols. To verify receipt of laboratory-specific training, laboratory personnel must sign the Laboratory Training Signature Page kept in the CHP or Laboratory Safety Plan. Please refer to the department specific CHP for this page or consult with EHS.

6.17.9 Instructional Laboratory-specific training

Laboratory safety training for students enrolled in instructional laboratories is provided by the PI or Instructor. Training must include a discussion of the risks associated with the substances used and procedures to be performed, proper techniques for handling and disposing of hazardous substances, safety precautions to be used to prevent exposure or release into the environment, PPE usage, location of emergency equipment, and emergency and spill procedures. EHS is available to assist course instructors in developing this training, and will provide additional laboratory safety training in instructional courses upon request.

Training must be documented. EHS can provide additional assistance in planning laboratory-specific training upon request.

6.17.10 Animal and Vivarium Safety

Some laboratories work with animals in their research or instructional settings. In these laboratories, Biological and/or Animal Safety is integral to overall laboratory safety.

For research and instructional laboratory activities involving animals, oversight by the Research Compliance Office (RCO) may be required. Committees within the RCO oversee and grant approval for conducting such research.

- The Institutional Review Board (IRB) manages research involving human subjects.
- The Institutional Animal Care and Use Committee (IACUC) oversees any research involving the use of animals.

6.17.11 Documentation of Training

Accurate recordkeeping is a critical component of health and safety training. Per OSHA regulations, departments or laboratories are responsible for documenting health and safety training, including safety meetings, one-on-one training, and classroom and online training. Documentation should be maintained in the laboratory safety manual. Additional information on recordkeeping can be found in Section 6.18.5.

6.18 Prior Approval

In order to comply with government regulations regarding hazards in research and instructional laboratories and to provide a safe and healthful work place, Radford University requires that some aspects of research and instructional projects undergo review prior to the project start. Prior approval must be obtained for the use of hazardous substances, animal subjects, and human subjects.

6.18.1 Review of Projects Involving Biological Materials or Ionizing Radiation

To initiate review of projects involving biological materials or sources of ionizing radiation, PI/LS please consult the Biosafety Manual, Radioisotope Safety Manual, and the Radiation Producing Machines Safety Manual for guidance on how to proceed. Instructions can be found within these forms and/or by contacting EHS.

Submitted forms will be reviewed by EHS, and must receive approval prior to work beginning on the project. EHS will evaluate the proposed project to evaluate the safety precautions to be employed and compliance with relevant regulatory requirements. Depending on the nature of the project and materials used, EHS may request revisions to the project design before approving the project.

In addition to EHS approval, the use of select agents and toxins must be registered with the United States Department of Health and Human Services and/or the United States Department of Agriculture. EHS serves as point of contact for these federal entities and administers the university's Select Agent Program. Therefore, PI/LS considering work with select agents and toxins must first contact EHS to initiate the approval process. Contact EHS for more information regarding work with select agents and toxins.

Approval for all projects expires 36 months after the date of approval. EHS will contact PI/LS several months before the expiration of their registration to facilitate the renewal process. Registrations should be updated as frequently as necessary to reflect changes in experimental protocols, the types or amount of material used, laboratory personnel, or location. Significant procedural changes such as modifications in laboratory procedures, project design, the types or amounts of materials used, or laboratory location may require safety committee review before the changes can be implemented. More information about project review is available on the EHS website.

6.18.2 Review of Projects Involving Animal or Human Subjects

The RCO, along with IACUC and the IRB, oversees the review of projects involving animal or human subjects. See the RCO website for more information.

6.18.3 Review of Projects Involving Particularly Hazardous Substances

PI/LS must review and approve new laboratory projects, tests, or procedures before they are initiated by laboratory personnel. Special consideration should be given to projects that involve particularly hazardous substances. Review of projects involving these substances should be done in cooperation with the Chemical Hygiene Officer; and should examine the manner in which the chemicals are to be used, stored, and discarded. Appropriate safety measures should also be considered. Standard operating procedures (SOP) for projects involving particularly hazardous substances should be kept with the Department CHP and/or Supplemental Laboratory Safety Plan. Projects should be reevaluated for safety if any of the following conditions arise:

a. A new laboratory test or procedure is to be conducted.
b. Potential exists for chemical exposure above the permissible exposure limit (PEL) or TLV, whichever is lower.
c. A significant change occurs in project procedures, project design, or the types of chemicals used.
d. A significant change (approximately 10%) is to be made in the amount of hazardous chemicals used.
e. An experiment or project will be run unattended on a frequent basis.
f. The project will be managed by one person and they are the sole occupant of the laboratory.
g. A significant spill or accident occurs.
h. Someone is injured or exposed while working.
i. An emergency occurs while conducting routine laboratory activities.
j. EHS is available to assist PI/LS in reviewing procedures and in developing appropriate SOP.

6.18 Required Records

PI/LS/Instructors are required to maintain records regarding laboratory safety and compliance. Records should be kept in a central location where they are available to laboratory personnel and inspectors. Safety and compliance records may be kept in each laboratory where safety manuals and SDS are kept.

6.18.1 Laboratory Safety Manual

To comply with 29 CFR 1910.1450, a copy of the Laboratory Safety Manual (which serves as Radford University's chemical hygiene plan) must be available in each laboratory and laboratory personnel must be familiar with the manual.

6.18.2 Chemical Inventory

Each research and instructional laboratory is required to maintain a chemical inventory that includes all of the chemicals stored in the laboratory. Chemical inventories are maintained through the CHIMERA database. PI/LS, or their designee, are responsible for updating the database at the beginning of each semester and maintaining current chemical inventory records. To request access to CHIMERA, please complete the request form located at: https://chimeracloud.org/chimera/register.php?c=radford. An updated Chemical Inventory Report should be kept in the laboratory in the SDS binder.

6.18.4 Safety Data Sheet (SDS)

A SDS contains product information regarding hazards associated with the substances the product contains. Chemical manufacturers must provide a SDS for each chemical they produce.

Many manufacturers provide SDS online and may not include paper copies with each chemical delivery. Electronic copies of the SDS can be found in CHIMERA. Maintaining a notebook of SDSs in each laboratory provides laboratory personnel the information necessary to safely manage chemicals, identify potential hazards, and design laboratory projects with consideration to chemical hazards. The SDS also serves to inform laboratory and emergency personnel of the correct actions to take in the event of an emergency and how to effectively respond to a chemical spill. Each SDS contains the following information:

Identification;
Hazard(s) identification;
Composition/information on ingredients;
First-aid measures;
Fire-fighting measures;
Accidental release measures;
Handling and storage;
Exposure controls/personal protection;
Physical and chemical properties;
Stability and reactivity;
Toxicological information;
Ecological information;
Disposal considerations;
Transport information;
Regulatory information; and
Other information.

It is the responsibility of the PI/LS/Instructor to provide and maintain the notebook with SDSs in a conspicuous location in their laboratory and update it regularly to reflect the inventory of the laboratory. All laboratory personnel must be trained in how to look up and retrieve SDS.

6.18.5 Training Records

Record Keeping Requirements

Accurate recordkeeping demonstrates a commitment to the safety and health of the Radford University community, as well as the protection of the environment. EHS is responsible for maintaining records of inspections, accident investigations, and training conducted by EHS staff. Per OSHA regulations, departments or laboratories must document health and safety training, including safety meetings, one-on-one training, and classroom and online training. Additionally, the following records must be retained in accordance with the requirements of state and federal regulations:

Accident records;
Measurements taken to monitor employee exposures;
Inventory and usage records for high-risk substances should be kept;

Medical records must be retained in accordance with the requirements of state and federal regulations.

PI/LS are responsible for providing laboratory-specific training and verifying that laboratory personnel complete the Laboratory Training Signature Page. EHS maintains records of training provided by EHS.

6.18.6 Additional Records for Biological Laboratories

Additional records required for laboratories using biological materials include:

Biosafety Manual;
SDS for biohazardous materials used or stored in the laboratory (when available); and
Copies of biological project approvals.

See the Biosafety Manual for more information.

6.18.7 Additional Records for Radiation and X-ray Laboratories

Additional records required for laboratories using sources of ionizing radiation include:

Radiation Protection Plan;
Radiation Inventory Use and Disposal Log for all open sources of radioactive material; and
Monthly and/or post-experiment wipe tests and monitoring records (if applicable).

See the Radioisotope Safety Manual and Radiation Producing Machines Safety Manual for more information.

6.18.8 Additional Records for Animal Laboratories

Consult with the RCO for information on required records for Animal Laboratories.

6.18.9 Additional Records for Laser Laboratories

Consult the Laser Safety Program for information on required records for Laser Laboratories.

6.19 Inspections

Radford University is periodically inspected by federal, state, and local agencies. These regulatory agencies may visit Radford University at any time, with or without prior notification, to assess safety and compliance at the university. During these visits, inspectors may ask to examine laboratories and laboratory support rooms, question laboratory personnel, and examine laboratory records.

EHS has the ability to assist laboratories and other university departments that use, handle or store hazardous materials to maintain a safe work environment. This program helps to ensure compliance with regulations and to fulfill Radford University's commitment to protecting the health and safety of the campus community.

As part of this chemical safety program, EHS conducts semi-annual inspections of laboratories and other areas with hazardous materials to ensure the laboratory is operating in a safe manner and to ensure compliance with all federal, state and university safety requirements. The primary goal of inspection is to identify both existing and potential accident-causing hazards, actions, faulty operations and procedures that can be corrected before an accident occurs. IACUC conducts facility inspections twice a year to evaluate the effectiveness of control measures in place to reduce the risk of injury and illness of personnel working with or near laboratory or research animals.

EHS inspections examine laboratory entrance and egress, documentation, housekeeping and facility design, emergency equipment/supplies, PPE, fume hoods, chemical safety, biological safety, radiation safety, laboratory waste, as well as electrical and mechanical safety. A list of the laboratory safety inspection categories is available on the EHS website.

PI/LS are encouraged to participate in EHS inspections. Following an inspection, PI/LS will receive a Laboratory Inspection Report via email from EHS that identifies safety issues and corresponding corrective actions. The report identifies deficiencies in the laboratory, both serious and non-serious. Serious deficiencies are those that have the potential to lead to serious injuries or be of critical importance in the event of an emergency. These deficiencies must be immediately corrected. Non-serious deficiencies must be corrected within 60 days of receipt of the original report.

EHS has the authority to close laboratories or discontinue certain activities when there is an immediate or imminent threat to human health, property, or the environment. Additionally, laboratories that persistently fail to comply with safety regulations and Radford University safety standards may be closed until necessary modifications, improvements, or corrective actions are completed. EHS will assist all laboratories in meeting regulatory compliance and safety standards.

PI/LS may request that EHS perform an informal inspection of their laboratory to identify safety concerns and to assist them in meeting government regulations. PI/LS interested in scheduling an inspection should contact EHS.

Additionally, PI/LS can conduct their own self-inspection of laboratory spaces utilizing the forms found in Appendix J and Appendix K.

6.20 Chemical Monitoring

Regular monitoring of airborne concentrations is not usually justified, but shall be instituted in select cases when deemed necessary by responsible faculty and implemented by the CHO:

- There is any reason to believe that exposure levels routinely exceed the TLV, PEL or STEL values.
- There is a redesign of ventilation or hoods.
- A highly toxic substance is used regularly in the lab.
- Personal exposure has occurred.
- Formaldehyde is used (initial monitoring is required).
- Anesthetic gases are used (initial monitoring is required).
- Monitoring reveals an exposure level above what is allowed.

The CHO will notify the department head in writing of the monitoring results. The department head will then notify the affected employees of the results.

6.21 Exposure Monitoring

Exposure monitoring is be conducted when there is reason to believe that exposure levels for a chemical may exceed the regulated limits. Exposure monitoring may be required when modifications to laboratory ventilation equipment are made or when particularly hazardous substances are used regularly.

After an exposure, EHS and PI/LS will review the operations of the laboratory and implement corrective actions [changes in administrative controls, engineering controls (e.g., modifications to procedures or chemical substitutions) or PPE] designed to reduce or eliminate exposure to hazardous substances.

6.22 Medical Surveillance

Radford University is required by OSHA in 29 CFR and Virginia Administrative Code (16 VAC 25-90) to ensure that employees exposed to health hazards at work are included in a medical surveillance program. Medical surveillance is a series of medical services provided by Physician or Other Licensed Healthcare Professional (PLHCP) for the primary prevention of occupational injuries and illnesses, including a review of occupational and medical history, physical exams, diagnostic and performance testing, and vaccinations. Radford University's Medical Surveillance Plan complies with applicable regulations and guidelines and establishes minimum medical surveillance requirements to prevent occupational injuries and illnesses for Radford University employees whose job duties place them at risk of exposure to occupational hazards. The Medical Surveillance Plan is available on the EHS website.

Among the services offered through EHS are medical screening and health assessments, immunizations, consultation regarding health risks, and exposure incident monitoring. These services are provided at no cost to employees. In addition, an employee has the right to seek medical care pursuant to 29 CFR 1910.1450 (g), should any of the following occur:

a. The employee experiences signs or symptoms associated with chemical exposure.
b. A spill, leak, explosion, or other occurrence results in the likelihood of an exposure.
c. Exposure monitoring reveals an exposure level above the PEL.
d. The employee routinely (e.g., three times a week) uses chemicals with high chronic toxicity.

Under these conditions, medical care must be performed without the loss of pay at a reasonable time and place. Laboratory personnel who are not Radford University employees (e.g., unpaid visiting faculty, volunteers, graduate students, and undergraduate students) are not covered under the Medical Surveillance Plan. These individuals should discuss the nature of their laboratory work with their healthcare provider and should have personal health coverage. EHS maintains medical surveillance records (employee name, employee ID number, PLHCP written opinion) for a period of 30 years after termination of employment.

6.23 Reproductive Health and Pregnancy Safety - See email regarding RU language

Please be aware that risks and hazards may be present within Radford University facilities and that you are a critical component in safeguarding your reproductive health, which applies to both men and women. In addition, laboratory workers who are pregnant or attempting to become pregnant need to take extra precautions to promote the best possible outcome of the pregnancy. The following guidelines are highly recommended to protect you and the developing embryo or fetus:

a. Consult with your personal physician about your work conditions and activities in order to plan a safe course of action pre-conception, during pregnancy and post-partum. Any restrictions placed by the physician should be brought to the attention of the principal investigator or laboratory supervisor and EHS immediately.
b. Clear communication and cooperation among the laboratory worker, the principal investigator or laboratory supervisor, and EHS are necessary to conduct a thorough hazard assessment of laboratory operations and conditions, which may put the developing embryo or fetus at risk. In cases where a pregnancy is planned, the laboratory worker should initiate the hazard assessment prior to conception because certain chemical exposures may affect fertility success or critical fetal development in the earliest stages.
c. In addition, this same group (worker, supervisor and safety personnel) needs to work together in developing a plan and finding creative solutions to ensure a safe work environment during the pregnancy. In some cases, work activities and conditions may need to be modified - such as working in a separate laboratory, substituting extremely hazardous reagents with less harmful ones, or focusing on a different aspect of research.
d. For the health of the developing embryo or fetus, the pregnant individual and laboratory coworkers must strictly adhere to the safety guidelines in this Chemical Hygiene Plan. Give special attention to section F, “Carcinogens, Reproductive Toxins and Acutely Toxic Chemicals.”

Individuals with specific questions should address them to sources including, but not limited to, their health care provider, their Laboratory Supervisor or Principal Investigator, Safety Data Sheets (SDS), and the Radford University Environmental Health and Safety office. Talk to these sources about any specific concerns or question you may have. Always follow all safety procedures to minimize exposure.

6.24 Biological and Animal Laboratories

The National Research Council and NIH have developed industry standards and guidelines that require specific actions to be completed prior to the handling of laboratory and research animals. The Biosafety Manual provides guidance on protecting personnel from hazards specific to the care and use of laboratory and research animals, and outlines occupational hazards, risk assessment, hazard assessments, injury and illness reporting, and training requirements for personnel.

7.0 PERSONAL PROTECTIVE EQUIPMENT (PPE)

Personal protective equipment (PPE) serves as a person's last line of defense against exposures to hazardous substances and is required by everyone entering a laboratory containing hazardous substances.

The most fundamental piece of personal protective equipment is normal clothing worn by the laboratory employee. The Personal Protective Equipment Program outlines the basic PPE requirements which include but are not limited to:

- Gloves
- Eye/Face protection (safety glasses, goggles, face shields)
- Protective apparel (full length clothing, lab coats, aprons, coveralls, etc.)
- Low-heeled shoes with fully covered "uppers", i.e., close-toed shoes; boots, shoe coverings
- Respiratory protection

Personal protective equipment needed while working in the laboratory shall be identified in the laboratory SOPs and supplied by the Principal Investigator. It is the responsibility of each employee to be certain that the appropriate personal protective equipment is worn as necessary. Ensure that appropriate PPE is worn by all persons, including visitors, where chemicals are stored or handled.

The primary goal of basic PPE is to mitigate, at a minimum, the hazard associated with exposure to hazardous substances. In some cases, additional or more protective equipment must be used. Gloves should only be used under the specific condition for which they are designed, as no glove is impervious to all chemicals. It is also important to note that gloves degrade over time, so they should be replaced as necessary to ensure adequate protection. If a project involves a chemical splash hazard, chemical goggles are required; face shields may also be required when working with chemicals that may cause immediate skin damage. Safety goggles differ from safety glasses in that they form a seal with the face, which completely isolates the eyes from the hazard. If a significant splash hazard exists, heavy gloves, protective aprons and sleeves may also be needed. If engineering controls are not feasible, employers must provide respirators and employees must wear them when necessary to protect their health. Remove PPE and wash hands before leaving the laboratory.

7.1 Protective Gloves

Hands are vulnerable to cuts, punctures, burns, bruises, electrical shock, and amputation. Forms of hand protection available to employees include but are not limited to:

- Disposable exam gloves (nitrile, latex, vinyl, etc.)
- Chemical resistant gloves (rubber, nitrile, neoprene, etc.)
- Cut-resistant gloves for handling sharp items, such as metal and glass
- Cryo-gloves for handling cryogenic liquids
- Heat resistant gloves for handling hot objects
- Rodent handling gloves for protection from teeth and claws when handling small animals

Appropriate protective gloves shall also be worn whenever the potential exists for contact with corrosive, contact-hazard or toxic materials, materials of unknown toxicity or biohazardous agents. There is no universal glove that protects you from all hazards.

While wearing gloves, be careful not to handle anything but the materials involved in the procedure. Touching equipment, phones, wastebaskets or other surfaces may cause contamination. Be aware of touching the face, hair, and clothing as well.

Disposable Gloves should be selected on the basis of their compatibility with the chemicals used, the particular hazard involved, and their suitability for the operation being conducted. Before use, gloves should be inspected for signs of wear or penetration, and replace them often. Disposable gloves shall not be reused. When removing gloves, be careful to avoid touching the outside of the gloves with your bare hands. Always remove gloves before leaving lab.

To choose the correct glove, go to a Glove Reference Chart such as can be found utilizing the links below. Chlorinated solvents are carcinogenic and are particularly challenging to find appropriate gloves for.

All gloves are permeable, only the permeation rate varies, depending on the chemical, the glove material and thickness, temperature, concentration gradient, etc. However, once a material begins to permeate the glove, it will continue until an equilibrium is reached. You must, therefore, decide when it is appropriate to discard dirty gloves.

Disposable gloves provide minimal protection and should be used accordingly. If using concentrated solvents, corrosives or toxics, more heavy-duty gloves should be worn. These provide more protection, but have the drawback of being more cumbersome. Note also that about 15% of the population is allergic to latex to some degree.

Gloves for Handling Pyrophorics: These chemicals spontaneously ignite in air, but are only found in a few departments. Having the proper glove is important to avoid injury from a burning/melting glove. Per a legal Agreement between UC and Cal-OSHA, all lab workers who handle pyrophorics outside of an inert gas glove box, must use special non-combustible gloves for handling pyrophorics.

Glove Reference Charts (No guarantees are made regarding the accuracy of these charts. Recommend cross-checking at least two sites for consistency.)

Ansell Chemical Resistance Guide

Microflex Chemical Resistant Guide

Safety Glove Chemical Compatibility Database

Before removing them, wash the outside of the glove. To avoid accidental skin exposure, remove the first glove by grasping the cuff and peeling the glove off the hand so that the glove is inside out. Repeat this process with the second hand, touching the inside of the glove cuff, rather than the outside. Wash hands immediately with soap and water. Follow the manufacturer's instructions for washing and caring for reusable gloves.

PROPER GLOVE REMOVAL

Gloves should be removed avoiding skin contact with the exterior of the glove and possible contamination. Disposable gloves should be removed as follows:

- Grasp the exterior of one glove with your other gloved hand.
- Carefully pull the glove off your hand, turning it inside-out. The contamination is now on the inside.
- Ball the glove up and hold in your other gloved hand.
- Slide your ungloved finger into the opening of the other glove. Avoid touching the exterior.
- Carefully pull the glove off your hand, turning it inside out again. All contamination is contained.
- Discard appropriately.

Figure 7.1 –
Proper Removal of Gloves

Latex Gloves and Related Allergies

Allergic reactions to natural rubber latex have been increasing since 1987, when the Centers for Disease Control recommended the use of universal precautions to protect against potentially infectious materials, bloodborne pathogens and HIV. Increased glove demand also resulted in higher levels of allergens due to changes in the manufacturing process. In addition to skin contact with the latex allergens, inhalation is another potential route of exposure. Latex proteins may be released into the air along with the powders used to lubricate the interior of the glove.

In June, 1997, the National Institute of Occupational Safety and Health (NIOSH) issued an alert Preventing Allergic Reactions to Latex in the Workplace (publication number DHHS (NIOSH) 97-135).

Latex exposure symptoms include skin rash and inflammation, respiratory irritation, asthma and shock. The amount of exposure needed to sensitize an individual to natural rubber latex is not known, but when exposures are reduced, sensitization decreases.

NIOSH recommends the following actions to reduce exposure to latex:

- Whenever possible, substitute another glove material.
- If latex gloves must be used, choose reduced-protein, powder-free latex gloves.
- Wash hands with mild soap and water after removing latex gloves.

7.2 Eye and Face Protection

Appropriate protective eyewear shall be worn in all locations where chemicals are handled or stored. The use of eye protection is especially important for contact lens wearers, because of the difficulty in removing the lens following a chemical splash. Avoid use of contact lenses in the laboratory unless necessary; if they are used, inform supervisor so special precautions can be taken.

Goggles or other safety protection should be worn over prescription safety glasses. Based on the chemical and/or physical hazards present in the laboratory, the following types of eye protection may be used:

- Safety Glasses - Shall only be used when working with solid materials, even if equipped with side shields. Although side shields offer some protection from objects that approach from the side, they do not provide adequate protection from splashes. Safety glasses shall not be used when working with liquid chemicals.
- Goggles - Form a liquid-proof seal around the eyes necessary when working with liquid chemicals. Splash goggles with splash-proof sides should be used for protection from harmful liquid chemicals, particularly corrosive chemicals. Direct ventilation goggles are ideal for protecting from impact hazards and airborne dust and debris. Indirect ventilation goggles are suited for handling chemicals.
- Face Shields - Protect the face and throat from flying particles and splashed liquid. Consider for use when handling: hazardous liquids with splash hazards; pyrophorics, water reactive or potentially explosive chemicals; cryogenic liquids and high pressure or vacuum systems. Goggles or safety glasses with side shields must be worn under a face shield. The goggles protect the eyes in case a splash is from the side or beneath the shield.
- Specialized Eye Protection - Some protective eyewear protects against specific chemical vapors, fumes and dusts, while others protect against intense light sources (e.g., lasers, ultraviolet light (UV), welding).

7.3 Protective Apparel

Wear closed-toe shoes and full length clothing at all times when in the laboratory. Additional protective apparel is required for most laboratory work and includes lab coats, aprons and coveralls. Protective apparel protects underlying clothing and skin from minor chemical splashes, and gives the wearer time before skin contact occurs.

Lab coats are required when handling chemical, biological or radiological materials. The requirement also applies to working at a lab bench or with equipment where such materials are handled or working adjacent to areas with such work. The coats must be maintained in good condition and reasonably clean so as to not create a hazard.

Proper fit of the lab coat is also important. The coats should cover the user's legs to the knees and arms to the wrist.

Persons working with pyrophoric liquids are also required to wear 100% cotton clothing underneath the FR lab coat on days that they handle these materials in the lab.

Lab coats and gloves are not to be worn in offices, lunch rooms, break rooms, rest rooms, conference rooms, meeting rooms or other public access areas. Whenever possible, lab coats are to be hung in the lab before exiting.

Lab coats which are grossly contaminated by over use or because of a spill (on to the lab coat) should be disposed of as hazardous waste or autoclaved if biologically contaminated.

Lab coats are made of various fabrics and blends. The fabric material shall be selected primarily based on the hazards present. See the table below for selection information.

Fabric	**Hazards**	**Notes**
20%-60% cotton - polyester blends	Appropriate for biological materials, powders, and small volume liquid chemical manipulation.	Burns more readily than 100% cotton or FR. Not appropriate for use with flammable liquids, pyrophoric materials, or near open flame.
100% cotton	Appropriate for hazards above plus light flammable liquids use and can be used around open flames (such as alcohol burners).	Burns less readily than polyester blends. Not appropriate for use with pyrophoric materials.
Flame Resistant (FR) materials	Appropriate for hazards above. Flame resistant (FR) material is required for handling pyrophoric materials and for heavy use of flammable liquids.	FR fabrics can be made of Nomex, FR treated cotton or Tecasafe Plus. Some of these materials have special washing instructions.

Flame resistant laboratory coats for high hazard materials, pyrophorics, and flammables. Protective apparel should meet performance requirements for strength, chemical and thermal resistance, flexibility and ease of cleaning. Remove laboratory coats or gloves immediately on significant contamination, as well as before leaving the laboratory.

7.4 Respiratory Protection

RU is required to minimize employee exposure to airborne contaminants through the use of engineering and/or administrative controls; however, if such controls are not feasible or not sufficient to keep contaminant concentrations below regulatory limits, employees shall be provided respirators in accordance with the VOSH Respiratory Protection Standard 1910.134. Radford University's Respiratory Protection Program is managed by EHS. An employee must contact EHS prior to the use of any respiratory device so that you can be enrolled in the EHS respiratory protection program. This program meets OSHA regulations that require that all users are provided with a specialized physical, if necessary; a respirator fit test, and training before using a respirator. An employee must receive an authorization from EHS prior to wearing a respirator (which includes N95's).

7.5 How to Use and Maintain PPE

Personal protective equipment should be kept clean and stored in an area where it will not become contaminated. Personal protective equipment should be inspected prior to use to ensure it is in good condition. It should fit properly and be worn properly. If it becomes contaminated or damaged, it should be cleaned or repaired when possible, or discarded and replaced.

7.6 Contaminated Clothing/PPE

In cases where spills or splashes of hazardous substances on clothing or PPE occur, the clothing/PPE should immediately be removed and placed in a closed container that prevents release of the material. Heavily contaminated clothing/PPE resulting from an accidental spill should be disposed of as hazardous waste or biohazard waste depending on the source of contamination. Non-heavily contaminated laboratory coats should be cleaned and properly laundered, as appropriate.Laboratory personnel should **never** take contaminated items home for cleaning or laundering. Persons or companies hired to clean contaminated items must be informed of potentially harmful effects of exposure to hazardous chemicals and must be provided with information to protect themselves.

8.0 CHEMICAL HAZARD COMMUNICATION

Regulatory Requirements

Radford University has an established Hazard Communication Program that complies with 29 CFR 1910.1200, the Federal Hazard Communication Standard. The purpose of Radford University's Hazard Communication Program is to ensure that all employees have the right to receive information regarding the hazardous substances to which they may have been exposed at work. Radford University is responsible for providing information about the hazardous substances in our workplace, the associated hazards, and the control of these hazards, through a comprehensive hazard communication program that is summarized briefly below (see Radford University's *Hazard Communications Program* for more details). The requirements of the Hazard Communication Program apply to laboratory environments at Radford University due to the potential for large scale experiments and for activities that may occur outside of areas where engineering controls are available.

8.1 Safety Data Sheets (SDS)

Safety Data Sheets (SDS) are documents that summarize the hazards associated with a chemical product and precautions. SDSs are important for first responders, such as firefighters, responding to a hazardous materials incident. OSHA regulations all employees "who might handle, work with or be exposed to hazardous materials must have access to the Safety Data Sheets". SDSs have replaced Material Safety Data Sheets (MSDSs), since OSHA have adopted new Hazardous Communication Standards as of June 1, 2015. SDSs are required to be follow a uniform format and include section numbers. The sections and associate information covered by each section are:

Section 1, Identification includes product identifier; manufacturer or distributor name, address, phone number; emergency phone number; recommended use; restrictions on use.
Section 2, Hazard(s) identification includes all hazards regarding the chemical; required label elements.
Section 3, Composition/information on ingredients includes information on chemical ingredients; trade secret claims.
Section 4, First-aid measures includes important symptoms/effects, acute, delayed; required treatment.
Section 5, Fire-fighting measures lists suitable extinguishing techniques, equipment; chemical hazards from fire.
Section 6, Accidental release measures lists emergency procedures; protective equipment; proper methods of containment and cleanup.
Section 7, Handling and storage lists precautions for safe handling and storage, including incompatibilities.
Section 8, Exposure controls/personal protection lists OSHA's Permissible Exposure Limits (PELs); ACGIH Threshold Limit Values (TLVs); and any other exposure limit used or recommended by the chemical manufacturer, importer, or employer preparing the SDS where available as well as appropriate engineering controls; personal protective equipment (PPE).
Section 9, Physical and chemical properties lists the chemical's characteristics.
Section 10, Stability and reactivity lists chemical stability and possibility of hazardous reactions.

Section 11, Toxicological information includes routes of exposure; related symptoms, acute and chronic effects; numerical measures of toxicity.
Section 12, Ecological information*
Section 13, Disposal considerations*
Section 14, Transport information*
Section 15, Regulatory information*
Section 16, Other information, includes the date of preparation or last revision.

CHIMERA is the platform for maintaining chemical inventories at Radford University. While electronic SDSs are available in CHIMERA, hard copies of SDSs must be kept in a binder or folder in the laboratory. Hard copies allow for rapid access to hazard information in the event of an emergency including power outages, equipment failures, online access delays, etc. When a laboratory orders a new reagent, the SDS must be added to the notebook. SDS must be readily accessible to all personnel to all laboratory personnel. The location of the SDS notebook must be clearly identified in the laboratory.

8.2 Labels and Other Forms of Warning

Labeling requirements for all hazardous substances are summarized as follows:

- All containers of hazardous materials must be labeled with the identity of the hazardous substance.
- The label must contain all applicable hazard warning statements.
- The name and address of the chemical manufacturer or other responsible party must be present.
- Manufacturer's product labels must remain on all containers, and must not be defaced in any way.
- Labels must be legible, in English, and prominently displayed.
- Secondary containers (such as spray bottles) must be labeled with the identity of the substance and appropriate hazard warnings.
- Newly synthesized compounds must be labeled with the appropriate hazard warnings based on the knowledge of the chemical and physical properties of that substance.

Additional information on container labeling is provided in Appendix B.

<u>GLOBAL HARMONIZATION SYSTEM (HAZARD COMMUNICATION STANDARD PICTOGRAMS)</u>

Health Hazard	Flame	Exclamation Mark
		
Carcinogen Mutagenicity Reproductive Toxicity Respiratory Sensitizer Target Organ Toxicity Aspiration Toxicity	Flammables Pyrophorics Self-Heating Emits Flammable Gas Self-Reactives Organic Peroxides	Irritant (skin and eye) Skin Sensitizer Acute Toxicity Narcotic Effects Respiratory Tract Irritant

Gas Cylinder  Gases Under Pressure	Flame Over Circle  Oxidizers	Skull and Crossbones  Acute Toxicity (fatal or toxic)
Corrosion  Skin Corrosion/Burns Eye Damage Corrosive to Metals	Environment (Non-Mandatory)  Aquatic Toxicity	Exploding Bomb  Explosives Self-Reactives Organic Peroxides

8.3 Employee Information and Training

Employee training on specific workplace hazards must be provided at the time of initial assignment. Additional employee training is required whenever a new hazard is introduced into the work environment, and must be provided within 30 days of receiving the SDS or other safety information. All training must be in the appropriate language, educational level, and vocabulary for laboratory personnel. Employees must be given the opportunity to ask questions. Each Department is responsible for training its own personnel. EHS can provide assistance with this training. At a minimum all employees who work in laboratories or with chemicals must be trained in the following:

a. Contents of this Chemical Hygiene Plan;
b. Potential hazards of common chemicals in the lab including signs and symptoms of an overexposure;
c. Methods and observations to detect the presence of hazardous chemicals in the work place.
d. How to protect yourself from these hazards, covering topics such as safe work practices, proper PPE, first aid procedures, spill procedures, emergency procedures, etc.;
e. How to locate, read and understand a safety data sheet (SDS);
f. Personal Protective Equipment (PPE) - selection, location and care of same;
g. Laboratory Safety- "do's and don'ts" in the laboratory, and
h. Spill Control- see Section 9 below.

9. CLASSES OF HAZARDOUS CHEMICALS

Identification & Classification of Hazardous Chemicals

Lung irritants: Lung irritants are chemicals that irritate or damage pulmonary tissue. Chemical irritants are classified as primary or secondary. Primary irritants exert their effect locally, for example, acid fumes burning the lungs. Secondary irritants, such as mercury vapors, may exhibit some local irritation but the main hazard is from systemic effects resulting from absorption of the chemical.

Irritation of the lungs may produce acute pulmonary edema (fluid in the lungs). Symptoms include shortness of breath and coughing that produces large amounts of mucous. Reactions to some chemicals may produce an allergic sensitization that causes asthmatic-type symptoms following additional exposures. Short term exposure to irritants is usually reversible with no permanent damage, however, systemic poisoning may persist and cause permanent damage.

The solubility of an irritant gas influences the part of the respiratory tract that is affected. For example, soluble gases such as ammonia, hydrogen chloride, and sulfur dioxide mainly irritate the upper respiratory tract. Insoluble gases such as carbon monoxide and phosgene travel deeply into the lungs and cause irritation of the bronchi and air sacs. These gases are then absorbed into the blood stream and damage various organ sites. Some gases such as chlorine and hydrogen sulfide may affect the entire respiratory tract.

Skin irritants: Although not as destructive as corrosive chemicals, skin irritants can cause severe rashes and dermatitis to the hands upon significant and repeated contact. Many common solvents, such as toluene and xylene, are irritants.

Asphyxiants: Chemical asphyxiants prevent or interfere with the uptake and transformation of oxygen. Examples include carbon monoxide, which prevents oxygen transportation, and hydrogen cyanide which inhibits enzyme systems and interferes with the transportation of oxygen to the tissues. At sufficiently high concentrations, both chemicals can result in immediate collapse and death.

Narcotics: Narcotics affect the central nervous system causing symptoms that range from mild anesthesia reactions to loss of consciousness and death at high doses. Examples include acetone, toluene, xylene, and chloroform.

Chemicals can be divided into several different hazard classes. The hazard class will determine how these materials should be stored and handled and what special equipment and procedures are needed to use them safely. Each chemical container, whether supplied by a vendor or produced in the laboratory, must include labels that clearly identify the hazards associated with that chemical. In addition to specific chemical labels, hazard information for specific chemicals can be found by referencing the Safety Data Sheet (SDS) for that chemical. Note that products regulated under the Food and Drug Administration are not covered under the Hazard Communication Standard. This includes pharmaceuticals and drugs in solid form.

9.1 Fire Hazards

Flammable liquids are among the most common occupational hazards found in the work place. Flammable liquids can easily vaporize and form flammable and explosive mixtures in air. The degree of hazard is determined by the flash point of the liquid, the concentration of the air-fuel mixture, and the availability of ignition sources. In addition, many flammable chemicals react violently with oxidizing compounds and may start a fire. The flammability properties of a chemical should be checked before a flammable liquid is used. The danger of fire and explosions can be eliminated or reduced by strict handling, dispensing, and storage procedures.

Definitions

Flash point: The fire hazard associated with a flammable liquid is usually based on its flash point. The flash point is the lowest temperature at which a liquid in an open vessel will give off sufficient concentration of vapors to form an ignitable mixture with air. Many common solvents have flash points below room temperature. Acetone, for example, has a flash point of 15 F.

Flammable or explosive range: An important factor in determining the fire hazard of a flammable liquid is its flammable or explosive range. Once the flash point has been reached, flammable vapors will be given off that can mix with air to form a flammable or explosive mixture. Every flammable liquid has an upper and lower limit that defines the range of concentrations of the liquid in air that will ignite and propagate a flame. The lower flammability limit is the minimum concentration of the vapor in air that will sustain the spread of a flame; below this concentration, the mixture is too lean to burn. The upper flammability limit is the maximum concentration of vapors in air that will propagate a flame. Above this concentration, the mixture is too rich to burn. The range is usually expressed as a percentage by volume of vapor in air. Ethyl ether, for example, has a wide flammability range extending from a minimum of 2% by volume in air to an upper limit of 48%. If the lower limit is small it only takes a small amount of vapors in the air to form an ignitable mixture. Flammable liquids with a lower flammability limit of less than 10% are considered especially hazardous.

Ignition temperature: Once the flammability range has been reached, the vapors will ignite at the proper ignition temperature. The ignition temperature of a substance is the lowest temperature necessary to cause the vapor-air mixture over the liquid to ignite and continue to burn without the heat source. If the vapor-air mixture is confined and there is an ignition source, an explosion will result. The ignition temperature is often misleading because it is a relatively large number, often in the hundreds of degrees. However, it only takes a short duration of contact with a potential ignition source to reach this temperature and ignite a flammable vapor. For example, a spark contacting a few molecules of a flammable vapor can raise the temperature above the ignition point in only a few thousandths of a second. A hot light bulb can ignite some chemicals.

Sources of ignition: Three conditions must exist before a fire can occur: fuel concentration that is within the flammability range for the substance, air, and a source of ignition. To prevent fires, it is necessary to remove one of these conditions. The easiest way to prevent fires is usually to separate the flammable vapors from an ignition source. Many sources such as sparking electrical equipment, open flames, static electricity, and hot surfaces can ignite flammable vapors. Close attention must be given to all sources of ignition when using flammable liquids, especially those at a lower level than the liquid. The vapors of most flammable liquids are heavier than air and can travel considerable distances.

Spontaneous ignition: Spontaneous ignition takes place when a substance generates heat faster than it can be dissipated and reaches its ignition temperature independent of an ignition source. Materials susceptible to spontaneous ignition include oil or paint soaked rags, organic materials mixed with strong oxidizing agents, alkali metals, phosphorus, and finely divided pyrophoric metals.

Classes

Flammable and combustible liquids are divided into the following classes; based on flash points and boiling points. Flammable liquids are defined as those with flash points below 100 F and combustible liquids have flash points at or above 100 F. Flammable and combustible liquids are further subdivided into the following classes:

Class IA: Flash point below 73 F. Boiling point below 100 F. Examples include ethyl ether, and gasoline.

Class IB: Flash point below 73 F. Boiling point at or above 100 F. Examples include acetone, benzene, ethyl alcohol, isopropyl alcohol, methyl alcohol, toluene, and petroleum ether.

Class IC: Flash point at or above 73 F and below 100 F. Examples include xylene and turpentine.

Class II: Flash point at or above 100 F and below 140 F. Examples include kerosene, mineral spirits, and diesel fuel.

Class IIIA: Flash point at or above 140 F and below 200 F. Examples include pine tar oil, fuel oil no. 6, and phenol.

Class IIIB: Flash point at or above 200 F. Examples include mineral, motor, and tung oil.

Safety Procedures

Ventilation: Ventilation is essential to prevent the buildup of vapors that could lead to flammable liquid fires and vapor-air explosions. Vapors must be controlled by confinement, local exhaust, or general room ventilation. Ventilation systems should be designed to keep the vapor concentration below 25% of the lower flammability level. Room ventilation should be adequate to prevent the accumulation of dangerous concentrations of vapors if only very small quantities are released.

Ignition sources: Flammable liquids should never be heated with an open flame. Steam baths, water baths, oil baths, heating mantles, and hot air baths should be used. Containers should always be kept closed to reduce the possibility of flammable vapors contacting an ignition source. When flammable liquids are used, all unnecessary ignition sources should be removed. Ignition sources include open flames, non-explosion proof electrical equipment, hot surfaces, and static sparks.

Smoking: Smoking is prohibited in areas where flammable liquids are used or stored.

Fire extinguishers: Appropriate fire extinguishers must be located in work areas using flammable liquids.

Warning signs: "No Smoking" and "Flammable Liquids" signs shall be prominently posted in areas where flammable liquids are used or stored.

General storage: Flammable liquids should not be stored near heat, ignition sources, powerful oxidizing agents, or other reactive chemicals. Flammable liquids should not be stored near an exit, stairway, or any area normally used for the safe egress of people. Storage in glass bottles should be avoided if possible. If glass must be used, the bottle should be protected against breakage. The quantity of flammable liquids should be limited to what is immediately needed. As much as possible of working quantities should be stored in safety cans. Flammable liquids should not be stored above eye level.

Refrigerators/Freezers: Flammable solvents must not be stored in standard refrigerators/freezers; explosions may result from the ignition of confined flammable vapors by sparking electrical contacts. Only explosion-proof or explosion-safe refrigerators/freezers may be used.

Container size: Flammable and combustible liquids must be stored in appropriate containers according to their classification. See Chapter 4 for proper container sizes.

Storage limits: The maximum amount that may be stored within a fire area outside approved safety cans, storage cabinets, or flammable storage rooms is 10 gallons. Approved flammable storage cabinets may contain a maximum of 60 gallons of Class I or II liquids, or 120 gallons of Class I, II, and III liquids combined. Only three cabinets are allowed in a fire area.

Inside storage rooms: Bulk quantities of flammable liquids, such as 30 or 55 gallon drums, must be stored in properly designed indoor storage rooms or outside storage areas. Indoor storage rooms containing flammable and combustible liquids must meet the requirements of OSHA Standard 1910-106(d). These standards include spill control measures, spark-proof electrical fixtures, fire suppression equipment, and ventilation requirements.

Electrical grounding: Transferring liquids from one metal container to another may produce static electricity sparks capable of igniting the flammable vapors. To discharge the static electricity, dispensing drums should be adequately grounded and bonded to the receiving container before pouring. Bonding between containers may be made by means of a conductive hose or by placing the nozzle of the dispensing container in contact with the mouth of the receiving container. If the container cannot be grounded, then the liquid should be poured slowly to allow the charge time to disperse.

PPE: Flame-resistant laboratory coats must be worn when working with flammable materials and/or with procedures where a significant fire risk is present (e.g., when working with open flame, etc.). These materials can constitute a significant immediate threat and should be treated with particular care, even though the use of these materials is fairly common in the laboratory setting.

Spills: Appropriate spill kits should be available in work areas using flammable liquids. Materials should absorb the solvent and reduce the vapor pressure so that ignition is impossible.

Transportation: Flammable solvents should be transported in metal or other protective containers.

9.2 Reactive Chemicals

Reactive and explosive substances are materials that decompose under conditions of mechanical shock, elevated temperature, or chemical action, and release of large volumes of light, gases and heat. Some materials, such as peroxide formers, may not be explosive, but may form explosive substances over time. These substances pose an immediate potential hazard and procedures which use them must be carefully reviewed. These materials must also be stored in a separate flame-resistant storage cabinet or, in many cases, in laboratory grade refrigerator or freezer that are designed for flammable and reactive chemicals (unless they are peroxide formers). Reactive chemicals must be handled with extreme care. Even milligram quantities of some chemicals can result in explosions. Pyrophoric chemicals are a special classification of reactive materials that spontaneously combust when in contact with air and require laboratory-specific training. Flame-resistant laboratory coats must always be worn when working with pyrophoric chemicals.

Classes

Reactive chemicals are classified as explosives, strong oxidizing agents, acid sensitives, water reactives, air reactives, and special organic compounds.

Explosives: Explosives are substances that can detonate or decompose rapidly and violently at room temperatures and pressure with an essentially instantaneous release of large quantities of gases and heat. Gentle heat, light, mild shock, and chemical action can initiate these explosive reactions. Many of these compounds become more sensitive as they age or dry out. Examples include peroxides, nitroglycerin, and TNT.
Peroxide formers: Materials that react with oxygen to form peroxides, which can explode on impact, heat or friction. Peroxide-forming compounds can be divided into three categories:

Solvents and Recommended Storage Time Limits Table
Category I Materials-recommended 3 month shelf life for both inhibited and uninhibited

Chemical	Synonyms
Isopropyl Ether	Diisopropyl Ether, Diisopropyl Oxide
Diethyl Ketene	2-Ethyl-1-butene-1-one
Divinyl Ether	Vinyl Ether, Divinyl Oxide
Potassium Metal	Potassium

Potassium Amide	
Sodium Amide	Sodamide
Sodium Ethoxyacetylide	
Vinylidene Chloride	1,1-Dichloroethylene, 1,1-Dichloroethane

Category II Materials-12 Month Shelf Life for Inhibited, 3 Month for Uninhibited

p-Dioxane	1,4-Dioxane, Diethylene Dioxide
Ethyl Ether	Ether, Diethyl Ether, Ethoxyethane
Tetrahydrofuran	Butylene Oxide, Diethylene Oxide
Acetal	1,1-Diethoxyethane, Diethyl Acetal
Acetaldehyde	Ethanal, Ethyl Aldehyde
Cumene	Isopropyl Benzene
Cyclohexene	1,2,3,4-Tetrahydrobenzene
Cyclopentene	
Diacetylene	Beacetylene
Ethylene Glycol Dimethyl Ether	1,2-Dimethoxy Ethane, Glyme, Monoglyme
Furan	Divinylene Oxide
Methyl Acetylene	Allylene, Propyne
Methyl Cyclopentane	
Tetrahydronapthalene	Tetraline
Vinyl Ethers	Ethyl Vinyl Ether, Methyl Vinyl Ether
Diethylene Glycol Dimethyl Ether	Diglyne

Category III Materials- 12 Month Shelf Life for Inhibited, 3 Month for Uninhibited
These are hazardous due to peroxide polymerization when stored as a liquid. The peroxide forming potential increases and should be considered a peroxide hazard on storage.

Chemical	**Synonyms**
Chlorobutadiene	Chloroprene
Vinyl Acetate	
Vinyl Acetylene	Buten-3-yne
Vinyl Chloride	Chloroethylene, Ethylene Monochloride
Vinyl Pyridine	
Styrene	

Precautions: All peroxidizables shall be dated upon receipt and opening. **Do not open any container that has crystal formation around the lid.**

Strong oxidizing agents: Many strong oxidizing agents are capable of detonation or explosive decomposition under conditions of strong heat, confinement, or a strong shock. Violent reactions can occur when strong oxidizers are mixed with combustibles such as wood or paper. Strong oxidizing agents that can cause explosions include perchlorates, inorganic nitrates, chlorates, chromates and the halogens. Strong oxidizing agents will also react violently with most organic compounds, powdered metals, sulphur, phosphorus, boron, silicon, and carbon.

Water reactives: Chemicals that combine with water or moisture in the air to produce heat, flammable, explosive or toxic gases are termed water reactive chemicals. These chemicals present a severe fire hazard because sufficient heat is often released to self-ignite the chemical or ignite nearby combustibles. In addition, contact with the skin can cause severe thermal and alkali burns. Common examples include strong acids and bases, alkali metals such as sodium and potassium, hydrides, and carbides.

Air reactives: Air reactives (also called pyrophoric materials) ignite spontaneously in air at temperatures below 130 degrees F. Finely divided metal powders that do not have a protective oxide coat may ignite when a specific surface area is exceeded. The degree of reaction depends on the size of the particle, its distribution, and surface area. Examples include white phosphorus, fine zirconium powder, and activated zinc.

Safety Procedures

Planning: The procedures and risks involved should be thoroughly reviewed before working with reactive chemicals. Work should be performed with the smallest possible quantity of the chemical.

Personal protective equipment: Safety glasses, face shield, gloves, and a laboratory coat should be worn at all times when handling, transporting, or manipulating reactive chemicals.

Safety equipment: Adequate portable fire extinguishers should be immediately available. Approved eye-wash stations and emergency showers must be in the work area. Safety shields should be used as necessary.

Explosives: Explosives should be protected from heat and shock. Large quantities of explosives may need to be stored in heavily constructed magazines. Explosives should be stored in a cool, dry area, separated from flammables, corrosives, and other reactive chemicals. Areas in which explosives are handled or stored should be posted with a sign stating "Caution Explosion Hazard." Access to the area should be restricted. Efforts should be made to reduce static electricity discharges such as using cotton gloves, wearing conductive-soled shoes, and working on conductivity mats.

Ethers: Ethers should not be stored in clear bottles. Storage should be in a cool place, preferably an explosion safe refrigerator. Ethers should be dated when purchased and discarded after six months if opened, or after one year if unopened. Inhibitors such as copper mesh or BHT may be ineffective and should not be relied on to prevent peroxide formation. Ethers that do not have an inhibitor, such as those used for anesthesia, should be handled with particular caution. Old containers of ether should not be handled. The Safety Manager should be notified to dispose of these containers.

9.3 Compressed Gas Cylinders

Compressed gases is a term, which represents three different types of gas products: compressed gases, liquefied gases, and cryogenic gases. Compressed gases may be grouped into various hazard classifications based on their physical or health properties. A gas could be corrosive, flammable, toxic or an oxidizer. An additional hazard is due to the fact that gases are stored under pressure. Cryogens create unique hazards including embrittlement of materials and skin or eye burns upon contact with the liquid. Pressure is a hazard because of the large expansion ratio from liquid to gas, causing pressure to build up in containers.

Compressed gas cylinders are especially dangerous because they possess both mechanical and chemical hazards. Due to the large amount of pressure resulting from compression of the cylinder, gas cylinders should be handled as high energy sources and as a potential explosive. If a cylinder falls and breaks a valve, the energy released is sufficient to propel the cylinder through concrete walls.

In addition, the gases contained in the cylinders are hazardous because of flammable, toxic or corrosive properties. The most common hazard associated with gas cylinders is leakage from regulators that can allow the gas to diffuse throughout the room. Flammable gases can mix with the air and present fire and explosion risks. Most flammable gases have explosive ranges greater than flammable liquid vapors.

Additional hazards arise from the high toxicity and corrosive properties of many gases. Usually, there is no visual warning or odor associated with the escaping gases. Some gases are toxic at concentrations below the odor threshold and some gases with strong odors can quickly paralyze the sense of smell. Even harmless gases such as nitrogen may displace the oxygen in an unventilated room and cause asphyxiation. The best protection against accidents is knowledge of proper handling and storage techniques.

Classes

Compressed gas cylinders may be classified into the following six groups based on similar chemical and physical properties, storage compatibility, and handling procedures. Common examples of each group are included.

1. Highly toxic gases: Phosgene, phosphene, nitric oxide, nitrogen dioxide, chlorine, fluorine, hydrogen cyanide, ozone
2. Non-flammable, non-corrosive, low toxicity gases: Air, argon, helium, neon, carbon dioxide, nitrogen, nitrous oxide, oxygen
3. Flammable, non-corrosive, low toxicity gases: Acetylene, butane, ethylene, hydrogen, isobutane, methane, natural gas, propane
4. Flammable, toxic, corrosive gases: Carbon monoxide, ethylene oxide, hydrogen sulfide
5. Acid and alkaline gases: Ammonia, hydrogen chloride, hydrogen fluoride, sulfur dioxide
6. Spontaneously flammable gases: Silane

Safety Procedures

Identification: The contents of compressed gas cylinders should be clearly identified and bear the appropriate DOT hazard label. Labels should not be removed or defaced. Color coding systems used to identify contents are not reliable because cylinder colors vary among manufacturers. If the labeling on a cylinder becomes defaced, the cylinder should be marked "contents unknown" and returned to the manufacturer.

Transportation: Manual transportation of cylinders should always be done with a handtruck. Cylinders should be securely fastened with a strap or rope. The valve cap must be in place. Cylinders should never be lifted by the valve cap or dragged, rolled, dropped, or permitted to strike hard objects or another cylinder.

Training: Persons who handle flammable, corrosive, or toxic gas cylinders should be adequately trained in the physical and chemical properties of the gas and the proper methods to use the cylinders.

General storage: Cylinders shall be stored upright where they are unlikely to be knocked over, or secured by a heavy chain, strap, or base support. Cylinders cannot be stored in stairwells or within a required exit corridor. The valve protection cap must always be in place when the cylinder is not being used. Cylinders should never be stored on their sides or near a heat or ignition source. Storage areas shall be posted with the name of the gases stored. Storage areas should be well ventilated and dry. Storage rooms should be of fire resistive construction. Temperatures shall not exceed 130 degrees F. Containers shall not be stored near readily ignitable substances such as gasoline, waste, or bulk combustibles.

Outdoor storage: Cylinders may be stored outdoors if adequately protected from the weather and direct sunlight. It is recommended that cylinders be stored under a non-combustible canopy and protected from the ground by a concrete pad.

Handling flammable gas cylinders: Flammable gas cylinders stored inside occupied buildings shall be separated from flammable liquids, highly combustible materials, and oxidizing cylinder by at least 20 ft. or a five ft. high wall with a 1/2-hour fire rating. Flammable gas cylinders in storage and in use should be kept away from arcing electrical equipment, open flames, or other sources of ignition. Adequate portable fire extinguishers shall be located in storage areas and "No Smoking" signs posted. Hydrogen gas systems shall not exceed 400 cubic feet unless the Safety Manager has approved the system.

Handling oxidizing gases: Oxidizing gas cylinders in storage shall be separated from flammable gas cylinders or combustible materials such as oil or grease by at least 20 feet or by a five foot high wall with a 1/2-hour fire rating. Oxidizing gas cylinders, valves, regulators, and hoses shall be kept free from oil or grease.

Handling acid and alkaline gases: Proper protective clothing such as goggles, face shields, rubber gloves, and aprons shall be worn when working with acid and alkaline gases. Areas in which acid and alkaline gases are used shall be equipped with an OSHA approved deluge shower and eye-wash station. Acid and alkaline gases should be used in a well ventilated area. Corrosive gases should be used only with compatible equipment. The total quantity of gases on site should be kept to a minimum. Proper respiratory equipment shall be readily available for use in an emergency.

Handling highly toxic gases: Highly toxic gas cylinders shall be stored outdoors or in an unoccupied building or room with a one-hour fire rating. Areas in which toxic gas cylinders are used or stored should be posted with an appropriate warning sign. The quantity of highly toxic gas cylinders should be kept to a minimum. Highly toxic gas cylinders shall be used only in forced ventilation areas. Highly toxic gases should be used only with compatible equipment. Gases emitted in high concentrations shall be discharged into appropriate scrubbing equipment. Users shall only be exposed to concentrations of highly toxic gases that are below OSHA permissible levels. Proper respiratory equipment shall be readily available for use during an emergency.

Dispensing contents: The cylinder should be secured, and the protective cap removed. The proper regulator should be connected being careful not to cross thread or over tighten the connections. Never stand in front of or behind the pressure gauge as the main tank valve is opened. Pressure gauges can explode. When opening the valve on a cylinder containing a corrosive or toxic gas, the user should stand on the side opposite the valve opening. Safety glasses should be worn when dispensing compressed gases to prevent eye damage from equipment failure.

Regulators: Always use the appropriate regulator. Regulators for non-corrosive gases are usually made of brass. Corrosion resistant regulators should be used with gases such as ammonia, chlorine, hydrogen chloride, hydrogen sulfide, and sulfur dioxide. Special regulators should be used with carbon dioxide because of potential freeze-up and corrosion problems. Connections should never be forced. Regulators and valves should never be oiled or greased. A fire or explosion could result. Pressure should be removed from the regulator when not in use. The main tank valve should be closed and the pressure bled off from the regulator valves. To prevent explosions, regulators made of brass or copper should not be used with acetylene.

Traps: A trap, check valve, or vacuum break should be used to prevent the back-flow of contamination into the cylinder.

Empty cylinders: Cylinders should not be completely emptied. Approximately 25 pounds of pressure should remain in the cylinder. The tank valve should be closed to prevent contamination from air and water. Empty cylinders should never be refilled by the user. Remove the regulator, replace the cap, mark the cylinder empty, and return it to the storeroom and vendor as soon as possible. Segregate empty cylinders from full cylinders to reduce handling by the supplier. The cylinder should be securely fastened in the storeroom.

Cryogenic Liquids

Cryogenic liquids are liquefied gases that are handled at very low temperatures, typically below -150 degrees F. The primary risks associated with the use of these materials are the physical injuries caused by exposure of tissue to extreme cold, the potential for fires and explosions, and asphyxiation.

Even very brief skin contact with a cryogenic liquid is capable of causing frostbite injury. Prolonged contact may result in blood clots. Flooding the affected tissue with warm water as soon as possible is the recommended treatment for exposure to cryogenic liquids.

Gases such as hydrogen, methane, and acetylene present obvious fire and explosion hazards. Liquid oxygen greatly increases the flammability of ordinary combustibles and may even cause non-combustibles to burn. Because oxygen has a higher boiling point than nitrogen, helium, or hydrogen it can be condensed out of the atmosphere during the use of these lower boiling cryogenic liquids. Conditions may exist for an explosion, particularly with hydrogen.

Water vapor condensing to ice on vents or pressure relief valves blocking the route of gas escape can result in a pressure explosion in the vessel. Liquid nitrogen is commonly transported in vacuum flasks called Dewars. If the vacuum in the Dewar flask should fail, the nitrogen would rapidly escape and could displace enough air in a small confined space to asphyxiate someone. However, the most likely consequence of a sudden vacuum loss would be an implosion that could result in flying glass.

Safety Procedures

Personal protection: Personnel should wear suitable eye protection such as chemical splash goggles or a face shield. Long sleeves, long pants and hand protection should be worn. Adequate hand protection must be worn to prevent contact with the cold liquid. It is recommended that pads or pot holders be used instead of gloves to prevent the cold fluid from being trapped inside the glove.

Containers: All exposed glass surfaces of vacuum flasks used to transport or store cryogenic fluids must be taped to guard against flying glass from an implosion. Containers should be handled and stored in an upright position. Containers must not be dropped, tipped, or rolled on their sides. Containers and systems should be periodically inspected to guard against ice buildup on vents and pressure relief valves. Vessels used for the storage and handling of liquefied gases should not be filled to more than 80% capacity to reduce the likelihood of expansion of the contents and rupture of the vessel. Cryogenic liquids should be handled in multi-wall, vacuum insulated containers specifically designed for cryogenic liquid. Store-bought glass thermos bottles are not appropriate.

Pressure relief devices: Containers shall be provided with pressure relief devices adequate to prevent excessive pressure within the container.

Ventilation: Cryogenic fluids should be used and stored in well ventilated areas to prevent excessive accumulation of the gas.

9.4 Health Hazards

OSHA uses the following definition for health hazards:

The term "health hazard" includes chemicals which are corrosives, irritants, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic systems, agents which damage the lungs, skin, eyes, or mucous membranes, toxic or highly toxic agents, carcinogens, mutagens, and reproductive toxins.

The major classes of "hazardous" and "particularly hazardous substances (aka acute hazardous substances)" and their related health and safety risks are detailed below.

Corrosive Chemicals

Chemicals that cause severe local injury to living tissue are called corrosive chemicals. Accidents involving splashes of corrosive chemicals are very common in the work place. These chemicals or their vapors can burn the skin, cause severe bronchial irritation, and blindness if splashed into the eyes. The seriousness of the damage depends on the type and concentration of corrosive material, length of the exposure, the body part contacted, and first aid measures taken.

Usually minor exposure to corrosive materials is reversible and healing is normal. However, severe exposure may cause permanent damage. Depending on the severity of the exposure, damage to the skin may range from redness and peeling to severe burns and blistering. Chronic exposure may result in dermatitis. Exposure to the respiratory system may range from mild irritation, to inflammation, chest pain, difficulty in breathing, pulmonary edema, and death. Mild exposure to the eyes may cause pain, tearing, and irritation. Severe exposure may cause ulcerations, burns and blindness. Ingestion of corrosive chemicals may cause immediate pain and burning in the mouth, throat, and stomach followed by vomiting and diarrhea. Perforation of the esophagus and stomach is possible.

The concentration of a corrosive material also determines the extent of damage to the tissues. For example, a weak solution of acetic acid (vinegar) can be ingested and contact the skin without any harmful effects. However, concentrated acetic acid is highly corrosive and can cause serious burns to the tissues.

First aid measures must be taken immediately if corrosive chemicals contact the tissues. Corrosive chemicals that contact the skin or eyes should be immediately washed off with water for at least fifteen minutes. Inhalation victims should be moved to fresh air and artificial respiration started if breathing has stopped. If a corrosive material has been ingested, 2-4 glasses of water should be administered to the victim and the poison control center called immediately.

If mixed or stored incorrectly corrosive chemicals can generate excessive heat, pressure, flammable, and toxic gases that can damage equipment, ignite combustibles, and lead to injury. During a fire, highly toxic gases may be released. Many corrosive chemicals have other serious hazards and may be classified as flammables, reactives, or toxins.

Classes

Strong acids: All concentrated strong acids can attack the skin and permanently damage the eyes. Acids usually cause irritation and pain immediately. Adding water to acids can cause the contents to be violently ejected. Burns from acids are typically more painful, though less destructive than alkaline burns. The vapors from many acids such as hydrochloric acid are soluble in water and cause irritation of the nose and upper respiratory tract. Vapors from other acids, however, are not soluble in water and do not cause irritation. For example, vapors from nitric acid may travel deep into the lungs and cause permanent damage and not be immediately noticed.

Strong acids are also hazardous because they can combine with other chemicals in storage and cause fires and explosions. Common strong acids include hydrochloric, nitric, and sulfuric.

Strong alkalis: The metal hydroxides, especially the alkali metal hydroxides, are extremely hazardous to the skin and the eyes. In contact with water considerable heat can be generated that can cause splattering of the material. Burns from alkaline substances are less painful than acid burns but possibly more damaging. The healing of serious alkaline burns is extremely difficult. Concentrated alkaline gases such as ammonia can cause severe damage to the skin, eyes, and respiratory tract. Dry bases can react with the moisture on the skin, eyes, and mucous membranes, causing serious burns. Examples of strong alkalis include sodium hydroxide, potassium hydroxide, and ammonia.

Halogens: The halogens are toxic and corrosive to the skin, mucous membranes, and the eyes. Fluorine gas is highly reactive with organic matter and will cause deep penetrating burns on contact with the skin. Chlorine is less reactive but still extremely hazardous. Bromine is a common source of eye damage because of its use as a pool disinfectant. In contact with the skin it can also cause severe, long lasting burns. Iodine vapor is irritating to the eyes and respiratory tract and may cause pulmonary edema. Skin contact may produce burns.

Oxidizing agents: Besides being corrosive to the skin, mucous membranes, and eyes, oxidizing agents are also fire and explosion hazards. Oxidizing agents readily release oxygen, increasing the ease of ignition of flammable and combustible materials and increasing the intensity of burning. Some compounds give up their oxygen at room temperatures while others require the application of heat. Powerful oxidizers such as nitric and sulfuric acids may react with organic compounds and readily oxidizable materials causing fires and explosions. Oxidizers include chlorates, perchlorates, bromates, peroxides, and nitrates. The halogens are also considered oxidizing agents because they react the same as oxygen under some conditions.

Due to the hazardous nature of hydrofluoric acid and perchloric acid, additional training and protocols are required. Contact EHS <u>prior</u> to purchasing any amount or concentration of hydrofluoric acid or perchloric acid.

Safety Procedures

Transportation: Corrosive chemicals should always be transported in unbreakable safety containers. Carts used for moving chemicals should have a lip to prevent accidents.

Storage: Strong oxidizing agents should always be stored in glass or other inert material (preferably unbreakable). In most cases, these materials should be segregated from other chemicals and require secondary containment when in storage. Corrosive chemicals should not be stored with combustibles, flammables, organics, and other highly reactive and toxic compounds. Containers and equipment used for storage shall be corrosion resistant. Corrosive chemicals should be stored below eye level to prevent splashes in the eyes or face. Acids and bases shall be stored separately. Fire, explosion, or the release of dangerous gases or vapors may result if these chemicals combine.

Reactions: Acids should always be added to water to prevent excessive heat generation and splashing. All corrosives should be mixed slowly. Organic acids shall be stored separate from oxidizers including oxidizing acids.

Ventilation: Corrosive chemicals producing hazardous vapors and corrosive gases should be used with adequate exhaust ventilation.

Spills: Neutralizing chemicals, absorbent materials, and cleaning supplies should be readily available to clean up corrosive chemical spills. All spills should be cleaned up immediately.

PPE: Chemical goggles, aprons, and rubber gloves must be worn when handling corrosive chemicals. Gauntlets (sleeve coverings) may also need to be worn. Goggles should be supplemented with a face mask if the possibility of significant splashing exists. Contact lenses must never be worn when working with corrosive chemicals because they can trap chemicals against the eye. Suitable respiratory equipment should be available if a danger exists from inhaling toxic fumes.

Irritants

Irritants are defined as non-corrosive chemicals that cause reversible inflammatory effects on living tissue by chemical action at the site of contact. A wide variety of organic and inorganic compounds, including many chemicals that are in a powder or crystalline form, are irritants. The most common example of an irritant may be ordinary smoke which can irritate the nasal passages and respiratory system.

Consequently, eye and skin contact with all laboratory chemicals should always be avoided. Symptoms of exposure can include reddening or discomfort of the skin and irritation to respiratory systems.

Sensitizers

A sensitizer (allergen) is a substance that causes exposed people to develop an allergic reaction in normal tissue after repeated exposure to the substance. Examples of sensitizers include diazomethane, chromium, nickel, formaldehyde, isocyanates, arylhydrazines, benzylic and allylic halides, and many phenol derivatives. Sensitizer exposure can lead to all of the symptoms associated with allergic reactions, or can increase an individual's existing allergies.

Hazardous Substances with Toxic Effects on Specific Organs

Substances included in this category include:

Hepatotoxins: Chemicals that damage the liver. Effects include jaundice and liver enlargement. Examples include mercury, uranium, carbon tetrachloride, heavy metals, and chlorinated hydrocarbons.

Nephrotoxins: Chemicals that produce kidney damage. Effects include anemia, excessive amounts of protein in the urine and renal failure. Examples include arsenic, uranium, chromium, lead, mercury, cadmium, and halogenated hydrocarbons.

Neurotoxins: Neurotoxins interfere with the transfer of signals between nerves and may cause a collapse of the nervous system. Effects include narcosis, behavior changes, and decreases in motor function. Examples include ethanol, methanol, general anesthetics, mercury, acrylamide, carbon disulfide and tetraethyl lead.

Agents that act on the blood: Chemicals that cause decreased hemoglobin function that deprives the tissues of oxygen. Symptoms include cyanosis and loss of consciousness. Examples include carbon monoxide and cyanides.

Hematopoietic system: Chemicals that interfere with the production of red blood cells. Symptoms include anemia, and leukemia. Examples include arsenic, benzene, fluoride, and iodide.

Agents which damages lung tissue – e.g., asbestos and silica.

Symptoms of exposure to these materials vary. Staff working with these materials should review the SDS for the specific material being used and should take special note of the associated symptoms of exposure.

Organic solvents: The vapor pressure of a chemical determines if it has the potential to be a hazard from inhalation. The vapor pressure is the pressure of the vapor in equilibrium with its liquid or solid form. The more volatile a chemical the higher its vapor pressure and the lower its boiling point. Solvents are a problem because they vaporize easily and produce high concentrations of vapor in the air. Common solvents have vapor pressures that can produce concentrations in the breathing zones of workers between 10 to 1000 ppm.

Inhalation of the vapors from organic solvents can pass to the heart and central nervous system very rapidly and cause a toxic reaction. An acute exposure to very high concentrations can cause unconsciousness and death. Chronic exposure can cause nausea, headaches, fatigue, and mental impairment. Injury to the organs of the body and damage to the blood may also occur. Studies have shown that low concentrations of common solvents in the air can adversely affect behavior, judgement and coordination. There is also evidence that chronic exposure to some solvents can cause cancer (e.g., benzene, carbon tetrachloride, and chloroform).

Contact with the skin may cause irritation, dermatitis, or an allergic reaction. Some solvents such as benzene and xylene may be absorbed through the skin and enter the bloodstream. Common solvents include toluene, xylene, benzene, carbon tetrachloride, formaldehyde, chloroform, and methyl alcohol.

Organic solvents are commonly divided into two classes: chlorinated and non-chlorinated solvents. Chlorinated solvents are usually non-flammable. Examples include carbon tetrachloride, chloroform, and trichloroethylene. Non-chlorinated solvents are generally flammable. Examples include xylene, benzene, and toluene.

Heavy metals and their compounds: Heavy metals are relatively harmless in the metallic state, but their fumes, dust, and soluble compounds are well-known toxins. Some are carcinogenic, others are nephrotoxins, hepatotoxins, or neurotoxins. The most common heavy metals are arsenic, beryllium, cadmium, chromium, lead, mercury, nickel, and silver. Acute toxic effects from exposure to heavy metals result from inhalation and ingestion of dusts or inhalation of fumes. Metal fumes are generally more hazardous than dusts because the particles in fumes can enter the bloodstream easily. Bronchitis, chemical pneumonia, and pulmonary edema may result. Beryllium and cadmium are two of the most toxic metals when inhaled. Symptoms include nausea, vomiting, abdominal pain, and diarrhea.

Chronic exposure to heavy metals may lead to long-term effects. For example, chronic exposure to lead may damage the nervous system, brain and kidneys. Exposure to mercury over a long time can permanently damage the liver, kidney, and brain. Chronic inhalation of cadmium can cause emphysema and kidney damage. Carcinogenic effects have been shown from exposure to chromium, nickel, arsenic, cadmium, and beryllium. Prenatal effects have been observed from exposure to methyl mercury. In addition, some lead compounds are embryotoxic.

Some metals and their compounds can be absorbed through the skin. Mercury metal, and tetraethyl lead for example can enter the bloodstream through this route. Nickel, arsenic, chromium, and beryllium cannot penetrate the skin but they can damage the skin or cause allergic-type reactions.

Phosphorus: Organic phosphorus compounds are widely used as pesticides. These compounds may cause acute and chronic poisoning. Poisoning may result from ingestion, inhalation, or absorption through the skin. Organophosphates act by inhibiting an enzyme called cholinesterase. Examples include malathion, diazinon, parathion, and TEPP.

<u>Particularly Hazardous Substances</u>

OSHA recognizes that some classes of chemical substances pose a greater health and safety risk than others. To differentiate this different risk characteristic, OSHA identifies two categories of hazardous chemicals:

Hazardous chemicals;
Particularly hazardous substances (aka acute hazardous substances or "p-listed" substances).

Substances that pose such significant threats to human health are classified as "particularly hazardous substances" (PHSs). The OSHA Laboratory Standard and PESH regulation require that special provisions be established to prevent the harmful exposure of employees to PHSs, including the establishment of designated areas for their use. Use of these chemicals in the laboratories is prohibited. **Permission for the use of these chemical products must have the written approval of the chemical hygiene officer and the safety officer.**

Particularly hazardous substances are divided into three primary types:

- Acute Toxins
- Carcinogens
- Reproductive Toxins

Acute Toxins

Substances that have a high degree of acute toxicity are interpreted by OSHA as being substances that "may be fatal or cause damage to target organs as the result of a single exposure or exposures of short duration." These chemicals, associated chemical waste, and storage containers must be handled with care to prevent cross contamination of work areas and unexpected contact. These chemicals must be labeled as "Toxic." Empty containers of these substances must be packaged and disposed of as hazardous waste without rinsing trace amounts into the sanitary sewer system.

Carcinogens

Cancer is the second leading cause of death in the United States. Approximately 25% of the population will develop some form of cancer during their lifetime. Cancer is not a single disease, but a group of diseases characterized by uncontrolled growth of abnormal cells. These cells are destructive and often can migrate to new sites to form secondary growths. Among the causes of cancer, environmental agents acting in combination with genetic susceptibilities are believed to be the most prominent. Approximately 60% to 90% of all cancers may be related to environmental factors such as sunlight, radiation, chemicals, diet, and viruses.

Agents that cause cancer or increase the risk of cancer either by initiating or promoting it, are called carcinogens. Carcinogens can enter the body through the skin, lungs, or the digestive system and interact with the body by direct or indirect means. Direct acting carcinogens usually cause cancer at the site of exposure, for example, skin contact with coke oven emissions may cause skin cancer. Indirect acting carcinogens are changed by the body into carcinogenic substances that cause cancer at sites other than the initial exposure site. Common examples include solvents such as benzene and carbon tetrachloride. Other substances, called promoters, do not cause cancer themselves but are necessary for some chemicals to express their carcinogenicity.

Chemical carcinogens were among the first agents associated with an increased incidence of cancer. In 1775, a positive association was demonstrated between exposure to soot and scrotum cancer among chimney sweeps in England. Since then, chemical components of tar, smoke, air pollution, and automobile exhausts have been shown to be carcinogenic. Several occupational chemicals are carcinogens, including asbestos, arsenic, benzene, beryllium, and cadmium.

Carcinogens differ in the length of time needed for the cancer to develop after the initial exposure. This latency period may be as short as five years for the development of leukemia from benzene exposure to as long as 20 years to develop lung cancer from cigarette smoking.

The existence of a safe level or threshold has not been demonstrated for most carcinogens. Because of this, it must be assumed that low doses can cause cancer also but at a proportionately lower rate than high doses. Therefore, it is prudent to reduce exposures to known or suspected carcinogens to the lowest level possible. Exposure to several carcinogens at once may result in cancer rates higher than would be expected by adding the risks from each carcinogen separately. This is known as a synergistic effect. For example, both cigarette smoking and exposure to asbestos have been show to cause cancer. The cancer rate among asbestos workers who smoke is much greater than would be expected by adding the risk from smoking to the risk from asbestos.

Mechanism

The mechanism that causes a normal cell to become cancerous is not well understood. The process is usually characterized by three stages: initiation, promotion, and progression. During the initiation stage, the DNA in the cell that carries the genetic information for cell division is altered either spontaneously or by an external agent. This altered cell may replicate during the promotion stage into a malignant tumor. The appearance of the tumor following initiation may take 5-30 years. This latency period is probably related to a gradual weakening of the immune system or hormonal changes as the body ages. Another theory states that the cells remain dormant until another stimulus from an environmental agent causes it to start dividing. During the progression stage, the tumor invades adjoining tissue and may spread throughout the body.

Testing

OSHA considers a chemical to be a carcinogen if the chemical causes cancer in humans or two different mammal species. The carcinogenic potential of a chemical in humans is usually discovered through epidemiological (population) studies. In these studies, the incidence of cancer in a group of exposed workers is compared to a comparable unexposed population. For example, when compared to unexposed workers, an excess of liver cancer was found among PVC workers and an excess of lung cancer was found in asbestos workers. Another study on members of the American Chemical Society has shown a significantly higher incidence of cancer deaths among chemists than would be expected in the general population.

Human population studies are not always adequate to determine if a chemical is carcinogenic. Large populations are needed, cancers may not develop for 30 years, and there are many variables that must be controlled. Therefore, tests are usually performed on experimental animals under controlled conditions. Tests on animals can identify human carcinogens because chemicals that cause cancers in one mammalian species are likely to cause cancers in another. Except arsenic, all human carcinogens have also been demonstrated to be carcinogenic in animals. It must be assumed that agents that cause cancers in animals are likely to be carcinogenic in humans.

Animal studies are performed to demonstrate the potential for a chemical to cause cancer. Because small populations are used, it is necessary to use large doses of chemicals to demonstrate an effect. This does not mean that only large doses of the chemical will cause cancer. Smaller doses would cause cancer also but in proportionately smaller numbers, numbers so small that they might be missed in a small population.

Screening tests using cells growing in laboratory cultures, require only a few days or weeks to provide preliminary results on the carcinogenic potential of chemicals. The suspect chemical is added to the cells and any mutation is noted. Approximately 90% of chemicals found to be carcinogenic in humans or animals have also shown mutagenic changes in these tests.

Classes

Chemical carcinogens are commonly found in the following groups. Carcinogenic chemicals should also be considered mutagenic.

Polycyclic aromatic hydrocarbons (PAHs): PAHs were the first group of chemicals shown to be carcinogenic in man. PAHs are produced from the combustion of fossil fuels and tobacco. PAHs are probably the most widespread chemical carcinogens in the environment and some of the most powerful carcinogens are found in this group.

Nitroso compounds: Nitroso compounds are widely distributed in the environment and can also form in the body. These compounds may be one of the most important groups of carcinogens in man. Sodium nitrite is a commonly used preservative in meat that is converted to carcinogenic nitrosamines in the body.

Halogenated hydrocarbons: Several of these compounds are commonly used as solvents. Examples include carbon tetrachloride, chloroform, trichloroethylene, and methylene chloride.

Inorganic metals and minerals: Several carcinogens are known among metals or their salts. Examples of these include beryllium, cadmium, nickel, cobalt, and chromium. Only two minerals are known to cause cancer: asbestos and arsenic.

Naturally occurring: Several natural occurring carcinogens are known. Among these is aflatoxin, probably the most potent of all carcinogens. Aflatoxins are produced by molds that grow on peanuts and corn. Other naturally occurring carcinogens are present in sassafrass and chili peppers.

Reproductive Toxins

Reproductive toxins include any chemical that may affect the reproductive capabilities, including chromosomal damage (mutations) and effects on fetuses (teratogenesis). Reproductive toxins include chemicals that can cause birth defects, spontaneous abortions, or sterility. Examples include lead and PCBs.

Mutagens

Mutagenic substances cause an alteration in the genetic instructions on the DNA molecule. If the alteration occurred on a somatic (non-sex cell) the results could be the development of cancer. An alteration of a germ cell (sex cell) in either sex can produce genetic defects that will be transmitted to the next generation. Since all genes are composed of DNA, a mutagenic substance that can produce alterations in one species is considered capable of producing alterations in another.

Because approximately 90% of chemical carcinogens have been shown to be mutagenic, the carcinogenic potential of a chemical can be determined by assessing its ability to produce mutations. The potential mutagenic potential of a chemical can be rapidly determined by performing short term "in vitro" (in the tube) tests. In vitro tests use a microbial organism, such as a bacterium, to assess the potential of a chemical to produce alterations in the genetic material and produce mutations. This procedure is commonly known as the Ames Test.

Long term "in vivo" (in the animal) studies are only needed for a few chemicals. Insects, mice, rats, and hamsters are used for these tests to evaluate mutagenicity in an animal system. Chemicals producing positive animal results can be considered a genetic risk for humans.

Teratogens

Women of child bearing potential must be especially concerned about exposure to hazardous chemicals because many chemicals may be hazardous to the embryo or fetus. Embryotoxins are substances that may kill, deform, retard the growth, affect the development of specific functions in the unborn child, or cause postnatal functional problems. Agents that only produce malformations of the embryo are called teratogenic. Approximately 60-70% of all malformations are the result of chemical, physical and infectious agents. The developing embryo depends on the environment to supply the substances needed for growth and differentiation of the tissues and organs of the embryo. Because of this, various chemical, physical, and infectious agents may alter or arrest growth in the developing embryo.

The influence of embryotoxins depends on when the exposure took place. The period of greatest susceptibility to embryotoxins is the first trimester, which includes a period when the woman may not know she is pregnant. The embryo is undergoing rapid growth and differentiation and significant malformations can be produced. Although the development of the fetus is not as sensitive as the embryo, alterations may still occur, particularly in the nervous system.

Classes

Medicines: Medicines that have been shown to be embryotoxic in humans include thalidomide, diethylstilbestriol, some male hormones similar to methyltestosterone, and some anticancer drugs.

Solvents: Growth retardation and abortions, but not malformations, have been shown in animals exposed to chloroform, carbon tetrachloride, trichloroethylene, perchloroethylene, benzene, xylene, and propylene glycol.

Heavy metals: Organomercurials and lead compounds have demonstrated embryotoxic properties in humans. Cadmium, arsenic, selenium, chromium, and nickel compounds have been shown to be embryotoxic in animals and are classified as potentially harmful to the human embryo.

Pesticides: Pesticides producing malformations in animals include parathion, demeton, paraquat, and penthion.

Anesthetic gases: Anesthetic gases demonstrating embryotoxic properties in animals include ethylene oxide, and nitrous oxide.

Organic compounds: Organic compounds that have shown embryotoxic properties in animals include azo dyes, and formaldehyde.

Safety Procedures for Handling Carcinogens

The following procedures should also be used when working with highly toxic chemicals, mutagens, and embryotoxins.

Protective clothing: Protective clothing such as a fully fastened laboratory coat and disposable gloves should be worn to prevent contact of carcinogenic chemicals with the skin. Contaminated clothing should not be worn out of the work area.

Protective equipment: Appropriate eye protection should be available and used in the work area. Contact lenses should not be worn. Appropriate respiratory equipment should be worn if the procedure generates airborne particulates or gases. The face mask or respirator should not be worn out of the work area.

Eating, drinking, & smoking: There shall be no eating, drinking, smoking, chewing of gum or tobacco, or application of cosmetics in areas where carcinogenic chemicals are used or stored. Storage of food or food containers in these areas is also prohibited.

Pipetting: Under no circumstances is oral pipetting of carcinogenic chemicals permitted. Pipetting should always be performed with the aid of a mechanical pipetting device.

Personal hygiene: Workers should wash their hands immediately after the completion of any procedure involving the use of carcinogenic materials.

Storage: Carcinogens should be stored in a designated area or cabinet and posted with the appropriate hazard sign. Volatile chemicals should be stored in a ventilated storage area in a secondary container having sufficient volume to contain the material in case of an accident. Storage areas should be separated from flammable solvents and corrosive liquids.

Labeling: All containers should be labeled as to contents and bear the appropriate hazard warning information.

Containment: Procedures involving the use of volatile chemical carcinogens or procedures that may generate aerosols should be conducted in a chemical fume hood or glove box. Procedures involving non-volatile compounds and procedures with a low aerosol potential should be done in a controlled area that is designated for carcinogenic materials.

Transport: Carcinogens should be transported in unbreakable outer covers such as metal cans. Contaminated materials that are to be transported to a disposal area should be placed in a plastic bag or other impervious material, sealed, and labeled appropriately before transport.

Housekeeping: To minimize the production of aerosols, dry mopping and dry sweeping should not be done in areas where finely divided solid carcinogens are used. Wet mopping or a vacuum cleaner equipped with a HEPA filter should be used.

Working quantities: Working quantities (outside of storage) should be kept to a minimum and should not exceed the amounts required for use in one week.

Spill control: Spills and accidents must be immediately reported to supervisory personnel and to the Safety Office. Because of aerosol production, the area should be evacuated immediately unless the spill is small and well contained. Personnel performing decontamination should wear adequate protective clothing including respirators or self-contained breathing apparatus. As much of the spill as possible should be absorbed into paper towels, rags or sponges. Dry solids should be covered with paper towels moistened with water or an appropriate solvent. Care should be taken not to generate aerosols. Large spills may require a HEPA filtered vacuum cleaner. Decontamination of the spill should be attempted only after the bulk of the spill has been removed by mechanical means.

Disposal: Volatile carcinogens should never be disposed of by evaporation. Chemicals and contaminated materials should be decontaminated or removed for subsequent disposal. Contaminated waste, and cleaning devices should be collected in plastic bags or other impervious containers, sealed, labeled as to contents and hazard and disposed of by approved methods.

Handwashing facilities: Handwashing facilities should be available in the work area where carcinogens are used. Foot or elbow operated faucets are preferable.

Eye-wash & deluge showers: OSHA approved eye-wash units and deluge showers should be readily available to personnel working with carcinogens having corrosive properties or that can penetrate the skin.

Work area identification: Entrances to work areas where significant quantities of carcinogens are used or stored should be posted with a sign stating "Danger Carcinogen - Authorized Personnel Only." In addition, the area should also be posted with a sign stating "No Eating, Drinking, or Smoking."

Access: Only authorized personnel should be allowed in areas where carcinogens are used and stored. Casual visitors should be prohibited. Doors should be closed at all times.

Work surfaces: Work surfaces on which carcinogenic chemicals are handled should be protected from contamination by using an impervious material such as stainless steel, plastic trays or absorbent plastic backed paper. Work surfaces should be decontaminated or disposed of properly after the procedure has been completed.

10. PURCHASING, INVENTORY, LABELING, STORAGE and TRANSPORT

10.1 Purchasing

Chemicals will only be acquired through the University purchasing system. Chemicals will not be brought in from home, nor may a department accept a donation of chemicals without permission of EHS. If required, lab personnel will provide the CHO with safety concerns and required engineering controls related to a particular chemical. Similarly, no chemical(s) should be donated to an outside institution.

Anyone who purchases a chemical assumes responsibility for ownership of that chemical. Before purchasing a chemical, the following points must be considered:

Has the purchase been reviewed to ensure that any special requirements can be met?

a. Is the material already available? Can it be obtained from within the department or from another department's excess supply?
b. What is the minimum quantity that will suffice for the current use? The potential savings when buying in bulk is often outweighed by the disposal cost for expired or excess chemicals.
c. What is the maximum size container or overall quantity allowed in the lab where the chemical will be used and/or stored? Contact EHS for assistance in determining maximum quantities.
d. Can the chemical be safely stored when it arrives? Is any special storage such as a dry box or freezer available? Will arrangements need to be made to notify someone as soon as the chemical arrives?
    i. Is the proper PPE available in the lab to handle the chemical?
    ii. Does the lab fume hood provide proper ventilation?
e. Has a SOP been developed that addresses proper handling, storage, security and disposal for the chemical?
f. Are there special containment considerations in the event of a spill, fire or flood?

Chemicals should be delivered to the RU Warehouse/Mailroom or to a central location in the building where someone is available to accept the delivery, e.g. gas cylinders. Chemicals must not be delivered to administrative offices.

Any person accepting delivery of a chemical must be trained to:

- Check for an identifying label.
- Be able to identify signs of breakage (e.g. rattling) and leakage (e.g. wet spot or stain).
- Respond appropriately if a cylinder of compressed gas is leaking.

<u>Restricted Chemicals</u>

The acquisition of certain hazardous materials is restricted at Radford University and requires special authorization. Restricted materials include:
Select Agent Toxins
Select agents and toxins are specific biological materials that have been identified by the federal government as agents that have potential to cause substantial harm to human, animal, or

plant health and are high-risk agents for illegitimate use in biological terrorism or warfare. These organisms are considered Select Agents and High Consequence Livestock Pathogens and Toxins. PI/LS who wish to acquire, possess, use, or transfer select agents and toxins must notify EHS for assistance in registering with the CDC and/or APHIS and be in compliance with pertinent United States Department of Health and Human Services and/or United States Department of Agriculture regulations before these materials may be acquired. No substance described in 42 CFR 73.4 or 73.5 ("Select Agents and Toxins") http://www.gpo.gov/fdsys/granule/CFR-2010-title42-vol1/CFR-2010-title42-vol1-sec73-4 will be permitted on University property. Contact EHS for more information regarding select agents and toxins.

Controlled Substances in Research

Due to the responsibilities associated with the acquisition, administration, and storage of controlled substances, Radford University requires that all individuals conducting research with controlled substances be appropriately licensed with the State of Virginia and registered with the Drug Enforcement Administration (DEA).

If the license and registration holder ("Licensee/Registrant") travels frequently or is not routinely present at the registered location where controlled substances are administered, it is recommended that the laboratory manager, or other staff, also obtain a separate individual State of Virginia controlled substance license and DEA registration.

The State of Virginia and DEA can impose administrative, civil, and criminal actions against a Licensee/Registrant for non-compliance, theft, or loss associated with the storage and administration of controlled substances for research use. As a result, Licensee/Registrants must have the proper authority and research laboratory infrastructure to design, implement, and maintain necessary security and record keeping controls to maintain compliance.

Both State of Virginia and federal regulations [21 U.S.C § 802(2)] require non-licensed and non-registered authorized agents to administer controlled substances in the presence of the Licensee/Registrant.

The Licensee/Registrant is responsible for the inventory and safe storage of controlled substances at their licensed and registered location.

The Licensee/Registrant may be authorized to purchase and store controlled substances at their registered laboratory location.

Note: State of Virginia controlled substance licenses and DEA registrations acquired by key permanent staff may only be used for administration purposes when the Laboratory Director is not present. Other employees or students may work as designated authorized agents under the supervision of the licensed and registered laboratory manager.

Radioactive materials

Radioactive materials orders must be placed and received by the Radiation Safety Officer or other designated EHS personnel. See the Radioisotope Safety Manual for more information.

Purchasing Tax-Free Alcohol

Grain alcohol, ethanol 95% or greater, is used for a variety of applications in research. To purchase and use grain alcohol tax-free, two permits are required: an Industrial Alcohol User Permit issued by the Alcohol and Tobacco Tax and Trade Bureau (TTB) of the Department of Treasury, and a permit to purchase and transport alcohol issued by the Virginia Department of Alcohol Beverage Control (ABC). Procurement maintains the University's Industrial Alcohol User Permit. Individual units or departments must coordinate with Procurement and EHS to order these materials. These permits are only required for the tax-free purchase of alcohol. The following steps must be followed to order and manage inventory of grain alcohol:

a. Consult and coordinate with Procurement and EHS to obtain the alcohol.
b. Upon receipt of a package of alcohol, the package should be inspected for any damage. The outside of the package should be dated with date of receipt.
c. All grain alcohol should be placed in a secure and lockable flammable storage cabinet. This cabinet should be kept locked except when accessing material.
d. A written continuous log on material in storage should be maintained. The quantity and date of receipt should be recorded in the log when the alcohol is first placed into storage. When a new container of alcohol is needed, the size of the container and the date of receipt of alcohol removed from the flammable storage locker should be noted on the log. The date when the container is first opened should be noted on the outside of the container. In order to maintain an accurate inventory, grain alcohol should not be shared with other laboratories.
e. Opened containers should be returned to the flammable storage cabinet when not in use.
f. Empty containers should be disposed of with regular laboratory glassware. All labels should be removed or the contents should be conspicuously marked out with an indelible marker, i.e. deface the container.

10.2 Chemical Inventory and Barcoding

OSHA Title 8 Section 5194 (e) (1) requires that employers develop and maintain a list of the hazardous chemicals known to be present in the workplace. This is a long standing regulatory requirement and is an important component of our lab safety inspections. In order for Radford University to remain in compliance of this regulation, each laboratory should review the chemicals in the space, make sure the SDSs are up to date, and an updated Table of Contents of SDSs or chemical inventory must be maintained.

Radford University utilizes CHIMERA for Chemical Inventory Management & Electronic Reporting. The online Inventory Management interface is where users are able to add, edit, transfer, and remove inventory. When barcoding a container, CHIMERA allows the user to select whether the chemical container is static or not and enter the barcode accordingly.

When a hazardous substance is received, information on the proper handling, storage and disposal will be disseminated to those individual employees that will be handling the material. While Safety Data Sheets are available in CHIMERA, a Safety Data Sheet (SDS) will be filed in the laboratory's SDS binder or folder.

The chemical inventory should be reviewed prior to ordering new chemicals and only the minimum quantities of chemicals necessary should be purchased. As new chemicals are added to the inventory, each Department must confirm that they have access to the Safety Data Sheets (SDS) for those chemicals. Where practical, each chemical should be dated so that expired chemicals can be easily identified for disposal. Inventory the materials in your laboratory frequently (at least annually) to avoid overcrowding with materials that are no longer useful and note the items that should be replaced, have deteriorated, or show container deterioration. Unneeded items should and compromised items should be discarded as chemical waste.

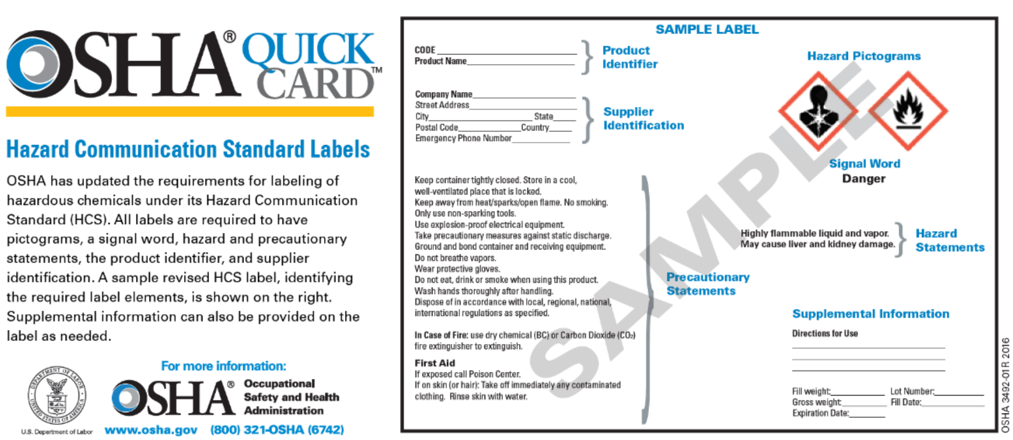
Indications for disposal include:

- Cloudiness in liquids
- Color change
- Evidence of liquids in solids, or solids in liquids
- "Puddling" of material around outside of containers
- Pressure build-up within containers
- Obvious deterioration of containers

Access to hazardous chemicals, including toxic and corrosive substances, should be restricted at all times. These materials must be stored in laboratories or storerooms that are kept locked when laboratory personnel are not present. Locked storage cabinets or other precautions are always recommended, and in some cases may be required in the case of unusually toxic, hazardous, or chemicals that are regulated by other agencies (such as 190 proof or greater ethanol). Unusually toxic chemicals may include those that are associated with very low immediately dangerous to life or health (IDLH) conditions. For guidance on locked storage requirements, please contact the Environmental Health and Safety Office. On termination or transfer of laboratory personnel, all related hazardous materials should be properly disposed of, or transferred to the laboratory supervisor or a designee.

10.3 Chemical Labeling

All chemical containers, including water, found in the laboratory must be properly labeled. Most chemicals come with a manufacturer's label that meets the OSHA GHS labeling requirements, so care should be taken to not damage or remove these labels.

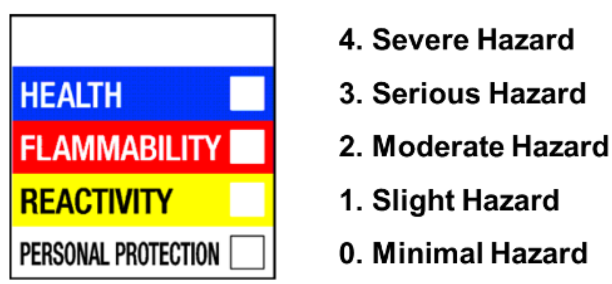


All secondary containers, e.g., diluted chemical solutions, must be labeled with its contents and the hazards associated with this chemical. Secondary chemical container labels can be generated with CHIMERA. It is recommended that each bottle also be dated when received and when opened to assist in determining which chemicals are expired and require disposal. When new chemicals and compounds are generated by laboratory operations, these new chemical bottles must be labeled with the name, date, and hazard information; the generator or other party responsible for this chemical should be named on the container so that they may be contacted if questions arise about the container's contents.

Chemical Label Compliance Challenges

Labels from the supplier or secondary containers may be labeled with alternatives, such as third party systems (e.g., National Fire Protection Association (NFPA) or Hazardous Materials Identification System (HMIS)) in addition to the other required information. Any container of hazardous chemicals in the workplace must at a minimum include the product identifier and general information concerning the hazards of the chemical. Whatever method is used, employees need to have access to and understand the complete hazard information.

NFPA 704 is a standard system developed by the U.S.-based National Fire Protection Association (NFPA) for indicating the health, flammability, reactivity and special hazards for many hazardous chemicals through the use of the NFPA 704 Diamond. NFPA is a fire protection hazard warning system designed to provide rapid, clear information to emergency responders on materials under conditions of fire, chemical spill, or other emergency situations. Like HMIS which is intended for everyday safety, it includes labels and a numerical rating system, but the basic purpose of the label information is different.

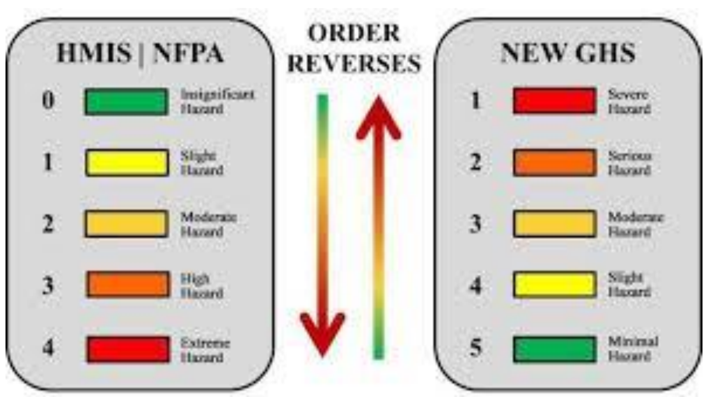


As the two popular workplace labeling systems in pre-GHS area in the United States, HMIS and NFPA labeling systems do appear quite similar; both have four sections colored blue, red, yellow and white. However, there are many differences between HMIS and NFPA labels.

Target Audience	• HMIS label is intended to be used by employers and workers;

	• NFPA label is intended to be used by emergency response personnel;
Label Shape	• HMIS uses bar shape; • NFPA uses diamond shape;
Health Hazard Communication	• HMIS covers both acute and chronic health hazards; • NFPA only covers acute health hazards;
White Section	• HMIS uses this section to show the recommended personnel protective equipment (PPE); • NFPA uses this section to display other special hazards.

Every level of hazard (category) within each hazard class has one single hazard statement assigned to it. It is important to understand the ratings and differentiate them on the SDS and the labels. The Hazard Material Identification System (HMIS) on the label is similar to that on the National Fire Protection Association (NFPA). The NEW GHS Category is also a numeric system, but it is reversed from that of the NFPA system. Since the hazard classification numbering system used by the GHS system looks identical to but directly contradicts the legally required NFPA diamond or HMIS, the GHS hazard classification numbering system **will not be used** on secondary labels at the University.



It is important that labels on products be read and reviewed by the individuals who will be working with the product. Directions for safe handling should be followed.

Containers don't require a label if the product transferred into the container will be used immediately by the employee who is transferring the product, i.e., under immediate use. For example, a bucket with floor cleaner or a beaker used in a lab experiment.

Peroxide forming chemicals (e.g., ethers) must be labeled with a date on receipt and on first opening the bottle. These chemicals are only allowed, at most, a one year shelf life or six months from opening and should be disposed of as waste within the appropriate time frame (See Peroxide Formers section of CHP for more details). These chemicals can degrade to form shock sensitive, highly reactive compounds and should be stored and labeled very carefully.

Particularly Hazardous Substances require additional labeling. These chemicals should be segregated from less hazardous chemicals to help with proper access control and hazard identification.

10.4 Chemical Storage & Segregation

Establish and follow safe chemical storage & segregation procedures for your laboratory.

Storage guidelines are included for materials that are flammable, oxidizers, corrosive, water-reactive, explosive and highly toxic. The specific Safety Data Sheet (SDS) should always be consulted when doubts arise concerning chemical properties and associated hazards. All procedures employed must comply with OSHA, Fire Code and building code regulations. Always wear appropriate personal protective equipment (e.g., laboratory coat, apron, safety glasses/goggles, gloves) when handling hazardous chemicals. Be aware of the locations of the safety showers and emergency eyewash stations. Each laboratory is required to provide appropriate laboratory-specific training on how to use this equipment prior to working with hazardous chemicals.

Chemical Safety Storage Priorities

Every effort should be made to separate chemicals that may react together and create a hazardous situation. A common and unsafe practice is storing chemicals alphabetically. This practice can cause explosions, or the release of toxic vapors. Chemicals should be stored according to chemical class.

Keep in mind that most chemicals have multiple hazards and a decision must be made as to which storage area would be most appropriate for each specific chemical. First you have to determine your priorities:

Flammability: When establishing a storage scheme, the number one consideration should be the flammability characteristics of the material. If the material is flammable, it should be stored in a flammable cabinet.
Isolate: If the material will contribute significantly to a fire (e.g., oxidizers), it should be isolated from the flammables. If there were a fire in the laboratory and response to the fire with water would exaggerate the situation, isolate the water reactive material away from contact with water.
Corrosivity: Next look at the corrosivity of the material, and store accordingly.
Toxicity: Finally, consider the toxicity of the material, with particular attention paid to regulated materials. In some cases, this may mean that certain chemicals will be isolated within a storage area. For example, a material that is an extreme poison but is also flammable, should be locked away in the flammable storage cabinet to protect it against accidental release.

There will always be some chemicals that will not fit neatly in one category or another, but with careful consideration of the hazards involved, most of these cases can be handled in a reasonable fashion.

General recommendations for safe storage of chemicals

Each chemical in the laboratory must be stored in a specific location and returned there after each use. Acceptable chemical storage locations may include corrosive cabinets, flammable cabinets, laboratory shelves, or appropriate refrigerators or freezers. Fume hoods should not be used as general storage areas for chemicals, as this may seriously impair the ventilating capacity of the hood. Figure 6.2 depicts improper fume hood storage. Chemicals should not be routinely stored on bench tops or stored on the floor. Additionally, bulk quantities of chemicals (i.e., larger than one-gallon) should be stored in a separate storage area, such as a stockroom or supply room.

Figure 6.2 – Improper Fume Hood Storage

Chemicals should be stored in cabinets treated, coated, or constructed of materials that are compatible with the chemicals being stored. Laboratory shelves should have a raised lip along the outer edge to prevent containers from falling. Storage areas and cabinets should be easily accessible and clearly labeled as chemical storage areas by labeling that indicates primary hazard contained within. Hazardous liquids or corrosive chemicals should not be stored on shelves above eye-level and chemicals which are highly toxic or corrosive should be in unbreakable secondary containers. Solid should be stored above liquids.

Chemicals must be stored at an appropriate temperature and humidity level and should **never** be stored in direct sunlight or near heat/ignition sources, such as laboratory ovens. Chemicals must be segregated by chemical compatibility. Incompatible materials should be stored in separate cabinets, whenever possible. If these chemicals must be stored in one cabinet, due to space limitations, adequate segregation and secondary containment must be ensured to prevent adverse reactions. Secondary containment should be used to control spills for containers of hazardous liquids greater than 1.3 gallons (5L). All stored containers and research samples must be appropriately labeled and tightly capped to prevent vapor interactions and to alleviate nuisance odors. Flasks with cork, rubber or glass stoppers should be avoided because of the potential for leaking.

Laboratory refrigerators and freezers must be labeled appropriately with “No Food/Drink” and must **never** be used for the storage of consumables. Freezers should be defrosted periodically so that chemicals do not become trapped in ice formations. *Never store peroxide formers (e.g., ether) in a refrigerator!*

Flammable and combustible liquids

Large quantities of flammable or combustible materials should not be stored in the laboratory. The maximum total quantity of flammable and combustible liquids must be no than more than 60 gallons of Class I or Class II liquids, nor more than 120 gallons of Class III liquids may be stored in a storage cabinet. The maximum quantity allowed to be kept outside a flammable storage cabinet, safety can, or approved refrigerator/freezer is 10 gallons. Only the amounts needed for the current procedure should be kept on bench tops and the remainder should be kept in flammable storage cabinets, explosion proof refrigerators/freezers that are approved for the storage of flammable substances, or approved safety cans or drums that are grounded. Always segregate flammable or combustible liquids from oxidizing acids and oxidizers. Flammable materials must never be stored in domestic-type refrigerators/freezers and should not be stored in a refrigerator/freezer if the chemical has a flash point below the temperature of the equipment. Laboratory refrigerators and freezers must be labeled appropriately with "No Flammables." Flammable or combustible liquids must not be stored on the floor or in any exit access.

Handle flammable and combustible substances only in areas free of ignition sources and use the chemical in a fume hood whenever practical. Only the amount of material required for the experiment or procedure should be stored in the work area. Always transfer flammable and combustible chemicals from glass containers to glassware or from glass container/glassware to plastic. Transferring these types of chemicals between plastic containers may lead to a fire hazard due to static electricity.

Flammable materials. Containers of flammable and combustible liquids are limited to the following sizes:

Class	Glass or Metal	Plastic	Metal Safety Cans (non DOT)	Metal Safety Cans (DOT)
Class IA	1 pt	1 gal	60 gal	2 gal
Class IB	1 qt	5 gal	60 gal	5 gal
Class IC	1 gal	5 gal	60 gal	5 gal
Class II	1 gal	5 gal	60 gal	5 gal

Class III	1 gal	5 gal	60 gal	5 gal

Pyrophoric & water reactive substances

Because pyrophoric substances can spontaneously ignite on contact with air and/or water, they must be handled under an inert atmosphere and in such a way that rigorously excludes air and moisture. Some pyrophoric materials are also toxic and many are dissolved or immersed in a flammable solvent. Other common hazards include corrosivity, teratogenicity, or peroxide formation.

Only minimal amounts of reactive chemicals should be used in experiments or stored in the laboratory. These chemicals must be stored as recommended in the SDS. Reactive materials containers must be clearly labeled with the correct chemical name, in English, along with a hazard warning.

Suitable storage locations may include inert gas-filled desiccators or glove boxes; however, some pyrophoric materials must be stored in a flammable substance approved freezer. If pyrophoric or water reactive reagents are received in a specially designed shipping, storage or dispensing container, ensure that the integrity of that container is maintained. Ensure that sufficient protective solvent, oil, kerosene, or inert gas remains in the container while pyrophoric materials are stored. Never store reactive chemicals with flammable materials or in a flammable liquids storage cabinet.

Never return excess reactive chemical to the original container. Small amounts of impurities introduced into the container may cause a fire or explosion. For storage of excess chemical, prepare a storage vessel in the following manner:

a. Dry any new empty containers thoroughly.
b. Insert the septum into the neck in a way that prevents atmosphere from entering the clean dry (or reagent filled) flask.
c. Insert a needle to vent the flask and quickly inject inert gas through a second needle to maintain a blanket of dry inert gas above the reagent.
d. Once the vessel is fully purged with inert gas, remove the vent needle then the gas line. To introduce the excess chemical, use the procedure described in the handling section, below.
e. For long-term storage, the septum should be secured with a copper wire.
f. For extra protection a second same-sized septa (sans holes) can be placed over the first; and use parafilm around the outer septa and remove the parafilm and outer septum before accessing the reagent through the primary septum.

Oxidizers

Oxidizers (e.g., hydrogen peroxide, ferric chloride, potassium dichromate, sodium nitrate) should be stored in a cool, dry place and kept away from flammable and combustible materials (wood, paper, Styrofoam, plastics, flammable organic chemicals), and away from reducing agents (zinc, alkaline metals, and formic acid).

Peroxide forming chemicals

Peroxide forming chemicals (e.g., ethyl ether, diethyl ether, cyclohexene) should be stored in airtight containers in a dark, cool, and dry place and must be segregated from other classes of chemicals that could create a serious hazard to life or property should an accident occur (e.g., acids, bases, oxidizers). The containers should be labeled with the date received and the date opened. This information, along with the chemical identity should face forward to minimize container handling during inspection. Minimize the quantity of peroxide forming chemicals stored in the laboratory and dispose of peroxide forming chemicals before peroxide formation.

Carefully review all cautionary material supplied by the manufacturer prior to use. Avoid evaporation or distillation, as distillation defeats the stabilizer added to the solvents. Ensure that containers are tightly sealed to avoid evaporation and that they are free of exterior contamination or crystallization. Never return unused quantities back to the original container and clean all spills immediately.

If old containers of peroxide forming chemicals are discovered in the laboratory, (greater than two years past the expiration date or if the date of the container is unknown), do not handle the container. If crystallization is present in or on the exterior of a container, do not handle the container. Secure it and contact the Environmental Health and Safety Office for pick-up and disposal.

Corrosives

Store corrosive chemicals (i.e., acids, bases) below eye level and in secondary containers that are large enough to contain at least 10% of the total volume of liquid stored or the volume of the largest container, whichever is greater. Acids must always be segregated from bases and from active metals (e.g., sodium, potassium, magnesium) at all times and must also be segregated from chemicals which could generate toxic gases upon contact (e.g., sodium cyanide, iron sulfide).

Specific types of acids require additional segregation. Mineral acids must be kept away from organic acids. Oxidizing acids must be segregated from flammable and combustible substances. Perchloric acid should be stored by itself, away from other chemicals. Picric Acid is reactive with metals or metal salts and explosive when dry and must contain at least 10% water to inhibit explosion.

Toxic chemicals

Toxic chemicals should be stored away from fire hazards, heat, and moisture, and isolated from acids, corrosives, and reactive chemicals. Special care should be taken to ensure that toxic chemicals are not released into the environment. Access to the storage area should be restricted for highly toxic chemicals. Highly toxic chemicals should be stored in unbreakable secondary containers.

Carcinogens

Carcinogens should be stored in a designated area or cabinet and posted with the appropriate hazard sign. Volatile chemicals should be stored in a ventilated storage area in a secondary container having sufficient volume to contain the material in case of an accident. Storage areas should be separated from flammable solvents and corrosive liquids.

Special Storage Requirements

Compressed Gas Cylinders

Compressed gas cylinders must be stored with the safety cap in place when not in use. Cylinders must be stored either chained to the wall or chained within in a cylinder storage rack. The cylinders must be restrained by two chains; one chain must be placed at one third from the top of the cylinder, and the other placed at one third from the bottom of the cylinder (see Figure 6.3). For wall storage, no more than three cylinders may be chained together in the laboratory. Bolted “clam shells” may be used in instances where gas cylinders must be stored or used away from the wall. Store liquefied fuel-gas cylinders securely in the upright position. Cylinders containing certain gases are prohibited from being stored in a horizontal position, including those which contain a water volume of more than 5 liters. Do not expose cylinders to excessive dampness, corrosive chemicals or fumes.

Certain gas cylinders require additional precautions. Flammable gas cylinders must use only flame-resistant gas lines and hoses which carry flammable or toxic gases from cylinders and must have all connections wired. Compressed oxygen gas cylinders must be stored at least 20 feet away from combustible materials and flammable gases.

Figure 6.3 – Cylinders Stored & Chained Correctly

Gas cylinder connections must be inspected frequently for deterioration and must never be used without a regulator. Never use a leaking, corroded or damaged cylinder and never refill compressed gas cylinders. When stopping a leak between cylinder and regulator, always close the valve before tightening the union nut. The regulator should be replaced with a safety cap when the cylinder is not in use. Move gas cylinders with the safety cap in place using carts designed for this purpose.

Liquid Nitrogen

Because liquid nitrogen containers are at low pressure and have protective rings mounted around the regulator, they are not required to be affixed to a permanent fixture such as a wall. However, additional protection considerations should be addressed when storing liquid nitrogen in a laboratory. The primary risk to laboratory personnel from liquid nitrogen is skin or eye thermal damage caused by contact with the material. In addition, nitrogen expands 696:1 when changing from a cryogenic liquid to a room temperature gas. The gases usually are not toxic, but if too much oxygen is displaced, asphyxiation is a possibility. Always use appropriate thermally insulated gloves when handling liquid nitrogen. Face shields may be needed in cases where splashing can occur.

Labs can increase their security by simply keeping lab doors closed and locked when unoccupied, maintaining a current and accurate chemical inventory, training personnel on security procedures, and controlling access to keys. Labs should report any suspicious activity to RUPD (540-831-5500).

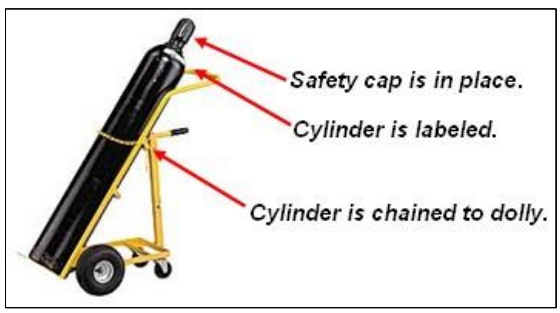
10.5 Transportation

On-Campus Distribution of Hazardous Chemicals

Precautions must be taken when transporting hazardous substances between laboratories. Chemicals must be transported between stockrooms and laboratories in break-resistant, secondary containers such as commercially available bottle carriers made of rubber, metal, or plastic, that include carrying handle(s) and which are large enough to hold the contents of the chemical container in the event of breakage. Transport chemicals in freight elevators rather than passenger elevators, if available. Transport of hazardous chemicals between buildings is strongly discouraged.

When transporting cylinders of compressed gases, always secure the cylinder with straps or chains onto a suitable hand truck and protect the valve with a cover cap. Avoid dragging, sliding, or rolling cylinders and use a freight elevator when possible. Figure 6.4 illustrates correct cylinder transport.

Figure 6.4 – Correct Cylinder Transport



Off-Campus Distribution of Hazardous Chemicals

The transportation of hazardous chemicals and compressed gases over public roads, or by air, is strictly governed by international, federal, and state regulatory agencies, including the U.S.

Department of Transportation (DOT) and the International Air Transport Association (IATA). Any person who prepares and/or ships these types of materials must ensure compliance with pertinent regulations regarding training, quantity, packaging, and labeling. Without proper training, it is illegal to ship hazardous materials. Those who violate the hazardous materials shipment regulations are subject to criminal investigation and penalties. Individuals who wish to ship or transport hazardous chemicals or compressed gases off-campus, even when using University vehicles need to contact EHS for assistance. Personal vehicles should not be used.

11. CHEMICAL DISPOSAL

Regulation of Hazardous Waste

In Virginia, the Department of Environmental Quality (DEQ) regulates hazardous waste. Federal EPA regulations also govern certain aspects of hazardous waste management, since most of our waste is treated and disposed out of state. These hazardous waste regulations are part of the Resource Conservation and Recovery Act, or RCRA.

Chemical Waste Program

Each employee must comply with the campus Hazardous Waste Management Program requirements and all applicable regulations. Laboratory personnel are responsible for identifying waste, labeling it, and storing it properly in the laboratory. The Department Chair is responsible for coordinating the disposal of all chemicals from his/her laboratories prior to closing down laboratory operations.

For a more depth look at Radford University's Hazardous Waste Program, refer to the Hazardous Waste Management Program Guidebook.

Upon the termination or leave of an employee, for whatever reason, all chemicals for which that person had responsibility for shall be accounted for and inventoried. These chemicals will be returned to the stockroom, transferred to another individual or designated for disposal. Inventories must be updated in CHIMERA. This process shall be activated by the department chair immediately upon knowledge of the leave or termination.

Broken glassware should be placed into an appropriate broken glassware container. Since they will be picked up by the housekeeping staff these containers should be labeled with the words "TRASH - Broken Glass." **Do not place broken glassware, glass containers, pipettes, or other sharp-edged materials of any type into the regular trash**.

11.1 Definition of Hazardous Waste

The Environmental Protection Agency (EPA) defines solid waste as any garbage or refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semi-solid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities. Hazardous wastes fall into two categories, Listed and Characteristic Waste.

11.1.1 Listed Wastes

Listed wastes are wastes the EPA has determined are hazardous. The lists include:

F-list (wastes from common manufacturing and industrial processes – non-specific source wastes). Examples include such as solvents that have been used in cleaning or degreasing operations.
K-list (wastes from specific industries), such as petroleum refining or pesticide manufacturing wastes.
P- and U-lists (wastes from commercial chemical products) such as specific commercial chemical products in an unused form, some pesticides and some pharmaceutical products when discarded.

11.1.2 Characteristic Wastes

Waste that has not been specifically listed may still be considered a hazardous waste if exhibits one of the four characteristics defined in 40 CFR Part 261 Subpart C:

Ignitability (D001): Ignitable wastes can create fires under certain conditions, are spontaneously combustible, or have a flash point less than 60 °C (140 °F). Examples include waste oils and used solvents.
Corrosivity (D002): Corrosive wastes are acids or bases (pH less than or equal to 2, or greater than or equal to 12.5) that are capable of corroding metal containers, such as storage tanks, drums, and barrels. Battery acid is an example.
Reactivity (D003): Reactive wastes are unstable under "normal" conditions. They can cause explosions, toxic fumes, gases, or vapors when heated, compressed, or mixed with water. Examples include lithium-sulfur batteries and explosives.
Toxicity (D004 - D043): Toxic wastes are harmful or fatal when ingested or absorbed (e.g., containing mercury, lead, etc.). When toxic wastes are land disposed, contaminated liquid may leach from the waste and pollute ground water posing a hazard to the environment.

The EPA's definition of hazardous waste also extends to the following items:

- Abandoned chemicals
- Unused or unwanted chemicals
- Chemicals in deteriorating containers
- Empty containers that have visible residues
- Containers with conflicting labels
- Unlabeled or unknown chemicals

Chemicals not in frequent use must be carefully managed to prevent them from being considered a hazardous waste. This is especially true for certain compounds that degrade and destabilize over time and require careful management so that they do not become a safety hazard (see the section below titled "Wastes that Require Special Handling").

11.1.3 Acutely hazardous waste

Some wastes are on a sub-list of what the USEPA calls "acutely hazardous wastes" (also called "P-listed" wastes because their USEPA waste numbers all start with a "P" for "poison"). The acutely hazardous wastes are specifically identified in Appendix C of Hazardous Waste Management Program Guidebook by name. Wastes containing these chemicals are limited to one total quart per accumulation area [your laboratory]. Containers that have held acutely hazardous wastes (P-listed) are deemed empty if the containers have been triple rinsed with appropriate rinsate and no residue can be removed from the container. The rinsate is considered a hazardous waste mixture and must be managed accordingly. If the container is not rinsed out prior to disposal, then the container and the contents must be managed as a hazardous waste but only the weight of the chemical waste counts toward the generator status.

11.2 Proper Hazardous Waste Management

11.2.1 Training

All personnel who are responsible for handling, managing or disposing of hazardous waste must attend training **prior** to working with these materials. Personnel must be thoroughly familiar with waste handling, managing, disposing of hazardous waste and emergency procedures relevant to their responsibilities during normal facility operation and emergencies. NOTE: Regulations do not require training of personnel working in SAAs. As the ones actually generating hazardous waste, however, personnel working in SAAs need to be familiar enough with the chemicals with which they are working to know when they have generated a hazardous waste so that it will be managed in accordance with the RCRA regulations.

11.2.2 Waste Identification

All the chemical constituents in each hazardous waste stream must be accurately identified by knowledgeable laboratory personnel. This is a critical safety issue for both laboratory employees and the waste technicians that handle the waste. Mixing of incompatible waste streams has the potential to create violent reactions and is a common cause of laboratory accidents. If there is uncertainty about the composition of a waste stream resulting from an experimental process, laboratory workers must consult the Instructor, Principal Investigator, or EHS. In most cases, careful documentation and review of all chemical products used in the experimental protocol will result in accurate waste stream characterization. The manufacturer's SDS provides detailed information on each hazardous ingredient in laboratory reagents and other chemical products, and also the chemical, physical, and toxicological properties of that ingredient.

11.2.3 Storage

Hazardous waste containers must be clearly labeled at all times. Waste must be collected and stored at or near the point of generation (Satellite Accumulation Area (SAA). (see following section) The maximum amount of flammable solvents allowed to be stored in a laboratory is 60 gallons; this figure also includes waste solvents. All hazardous waste containers in the laboratory must be kept closed when not in use. Hazardous waste streams must have compatible constituents, and must be compatible with the containers that they are stored in. Hazardous waste containers must be stored in secondary containment at all times. Containers must be in good condition with leak proof lids. Containers must be less than 90% full.
Dry wastes should be double-bagged in clear, 3-mil plastic bags (these do not require secondary containment).

11.2.4 Satellite Accumulation Areas

Generators may accumulate up to a total of 55 gallons of hazardous waste, or a total of *one (1) quart of acutely hazardous waste,* **at or near the point of generation** [your laboratory], provided that the waste:

- Remains under the control of the PI or Supervisor and their assistants
- Containers are closed and in good condition
- Contents are marked on the outside of the container

11.2.5 Ten Golden Rules of Hazardous Waste Accumulation:

1. Use only collection containers that are capable of safely storing the waste and that are in good condition.
2. Place supplied "Hazardous Waste" labels on all containers, indicate the contents and the nature of the hazard, as soon as hazardous waste is first added. Position the containers so that the waste labels are visible (face forward).
3. Keep the waste container closed, except when adding waste.
4. Store all liquid containers in secondary containment.
5. Segregate containers, keeping incompatible wastes, radioactive wastes, and regulated medical wastes separate.
6. Maintain ten percent (10%) free space in waste containers to allow for expansion.
7. Conduct weekly inspections of hazardous waste accumulation area and maintain an inspection log.
8. Submit the completed Request for Hazardous Waste Disposal form to EHS when the containers are 90% full. Forms are available at the Radford University EHS website
9. Attend and document all annual training for all persons generating hazardous waste.
10. Post the name and phone numbers for responsible person to contact 24 hours a day in case of an emergency.

11.2.6 Segregation

All hazardous materials must be managed in a manner that prevents spills and uncontrolled reactions. Stored chemicals and waste should be segregated by hazard class. Examples of proper segregation are:

- Segregate acids from bases
- Segregate oxidizers from organics
- Segregate cyanides from acids

Segregation of waste streams should be conducted in a similar manner to segregation of chemical products. Refer to Appendix C for chemical segregation guidelines.

11.2.7 Incompatible Waste Streams

Mixing incompatible waste streams, or selecting a container that is not compatible with its contents, is a common cause of accidents in laboratories and waste storage areas. Reactive mixtures can rupture containers and explode, resulting in serious injury and property damage. All chemical constituents and their waste byproducts must be compatible for each waste container generated. Waste tags must be immediately updated when a new constituent is added to a mixed waste container, so that others in the laboratory will be aware and manage it accordingly.

Oxidizers added to any fuel can create an exothermic reaction and explode. The most frequent is acids oxidizing flammable liquids. For this reason, all flammable liquids are pH tested before they are consolidated.

11.2.8 Wastes that Require Special Handling

Unknowns
Unlabeled chemical containers and unknown/unlabeled wastes are considered unknowns, and additional fees must be paid to have these materials analyzed and identified. These containers must be labeled with the word "unknown".

Peroxide Forming Chemicals
Peroxide forming chemicals, or PFCs, include a number of substances that can react with air, moisture or product impurities, and undergo a change in their chemical composition during normal storage. The peroxides that form are highly reactive and can explode upon shock or spark. Peroxides are not particularly volatile and thus tend to precipitate out of liquid solutions. It is particularly dangerous to allow a container of these materials to evaporate to dryness, leaving the crystals of peroxide on the surfaces of the container.

Each container of peroxide forming chemicals should be dated with the date received and the date first opened. There are three classes of peroxide forming chemicals, with each class having different management guidelines. Review the safety information provided by the manufacturer for any chemicals you purchase.

Ensure containers of PFCs are kept tightly sealed to avoid unnecessary evaporation, as this inhibits the stabilizers that are sometimes added. Visually inspect containers periodically to ensure that they are free of exterior contamination or crystallization. PFC containers must be disposed of prior to expiration date. If old containers of peroxide forming chemicals are discovered in the laboratory, (greater than two years past the expiration date or if the date of the container is unknown), ***do not handle the container***. If crystallization is present in or on the exterior of a container, ***do not handle the container***. Secure it and contact EHS for pick-up and disposal.

Dry Picric Acid
Picric acid (also known as trinitrophenol) must be kept hydrated at all times, as it becomes increasingly unstable as it loses water content. When dehydrated, it is not only explosive but also sensitive to shock, heat and friction. Picric acid is highly reactive with a wide variety of compounds (including many metals) and is extremely susceptible to the formation of picrate salts. Be sure to label all containers that contain picric acid with the date received, and then monitor the water content every 6 months. Add distilled water as needed to maintain a consistent liquid volume.

If old or previously unaccounted for bottles of picric acid are discovered, **do not touch the container**. Depending on how long the bottle has been abandoned and the state of the product inside, even a minor disturbance could be dangerous. Visually inspect the contents of the bottle without moving it to evaluate its water content and look for signs of crystallization inside the bottle and around the lid. If there is even the slightest indication of crystallization, signs of evaporation, or the formation of solids in the bottle, **do not handle the container** and contact **Environmental Health and Safety (540-831-7790) immediately**. Secure the area and restrict access to the container until it can be evaluated by EHS personnel.

Explosives and Compounds with Shipping Restrictions

NO EXPLOSIVES MAY BE USED ON RADFORD UNIVERSITY PROPERTY WITHOUT THE WRITTEN APPROVAL OF THE ASSISTANT DIRECTOR OF ENVIRONMENTAL HEALTH AND SAFETY. If approval for use of these substances is given, a special procedure for disposal will be worked out in writing. A variety of other compounds that are classified as water or air reactive are used in laboratories. These compounds often have shipping restrictions and special packaging requirements. When disposing of these compounds, employees must ensure that they are stored appropriately for transport. Flammable metals must be completely submerged in oil before they are brought to a waste pick-up. Many pyrophoric and reactive compounds can be stabilized using a quenching procedure prior to disposal. Chemicals classified by the Department of Transportation (DOT) as explosives (e.g., many nitro- and azo- compounds) will require special packaging and shipping, and may require stabilization prior to disposal. Consult with the Laboratory Safety Officer for disposal considerations of these compounds.

11.2.9 Managing Empty Containers

Broken glassware should be placed into an appropriate broken glassware container. Since they will be picked up by the housekeeping staff these containers should be labeled with the words "TRASH - Broken Glass." **Do not place broken glassware, glass containers, pipettes, or other sharp-edged materials of any type into the regular trash.**

A container that held any hazardous waste is empty if:

a. All wastes have been removed that can be removed using the practices commonly employed to remove materials from the type of container (*e.g.*, pouring, pumping, and aspirating) **AND** it does not contain acutely hazardous waste.
b. If the waste container held acutely hazardous (P-Listed) waste, the container **MUST** be handled as "Hazardous Waste" and EHS will handle this accordingly.
c. The solvent can be water or any liquid that will remove the hazardous residue in the container.
d. Make sure you collect *all* wash solvent and add to a compatible hazardous waste accumulation container in the lab.

Under no circumstances may a container labeled with the International Radioactive Symbol or with the words "Hazardous Waste" be disposed of in the general trash.

When empty, so it is clear that the container no longer contains hazardous materials, do one of the following:

- Remove the label, or
- Completely deface the label, or

- Tape over the label.
- If the container that held acutely hazardous waste is not triple rinsed, then it is **not empty** and the **CONTAINER MUST have a hazardous waste label attached and be properly disposed of as hazardous waste.**

11.2.10 Pickup of Waste Containers

When hazardous waste containers in laboratory satellite accumulation areas are no more than 90% full:

1. Complete DATE WHEN FULL on the hazardous waste label.
2. Complete the "Request for Hazardous Waste Disposal" form from the EHS website, and send to ehs@radford.edu.
   The first page of the form is for listing generator information, hazardous wastes, etc.
   The second page has the instructions for completing the form.

11.2.11 Hazardous Waste Minimization

As a generator of hazardous waste, EHS has developed a Hazardous Waste Minimization Program, in an effort to minimize the costs, health hazards, and environmental impacts associated with the disposal of hazardous waste.

Administrative Controls

In order to reduce the amount of chemicals that become waste, administrative and operational waste minimization controls can be implemented. Usage of chemicals in the laboratory areas should be reviewed to identify practices which can be modified to reduce the amount of hazardous waste generated.

Purchasing Control; when ordering chemicals, be aware of any properties that may preclude long term storage, assess whether adequate storage space exists and order only exact volumes to be used.

Inventory Control: Rotate chemical stock to keep chemicals from becoming outdated. Prior to purchasing, locate surplus/unused chemicals and attempt to redistribute these to other users.

Operational Controls: Review your experimental protocol to ensure that chemical usage is minimized. Reduce total volumes used in experiments; employ small scale procedures when possible. Instead of wet chemical techniques, use instrumental methods, as these generally require smaller quantities of chemicals. Avoid mixing hazardous and non-hazardous waste streams. Use less hazardous or non-hazardous substitutes when feasible. Some examples include:
Specialty detergents can be substituted for sulfuric acid/chromic acid cleaning solutions
Gel Green and Gel Red are recommended in place of ethidium bromide

11.2.12 Drain Disposal

Disposal of hazardous waste using sinks, intentional evaporation, and general trashcans is prohibited. Dilution of a waste is not a legitimate form of disposal. Radford University laboratory personnel must abide by strict state and federal waste disposal requirements.

Household commodities used as intended and approved for septic/sanitary disposal (e.g. hand soap, laundry detergent, etc.) are permitted down the drain. A review any other waste stream is required, as need arises, for any waste stream that is desired to be drain disposed. All waste streams (except excluded household commodities mentioned above) must be identified to EHS for approval and submission to the POTW for evaluation prior to any potential drain disposal by utilizing the Zero Discharge Exemption Form. In addition, the following protocol must be used for any waste stream that has been approved for drain disposal. For any waste stream that is authorized for drain disposal (indicated by the receipt of an approved submitted form), the following applies:

- Contains no radioactive or infectious biological materials
- It is discharged to sewer via a laboratory sink drain only
- pH of any liquid waste stream must be between 5.0 and 10.5
- Flushed with copious amounts of water (approximately 15-20 times the original volume)
- Previous waste stream must be completely flushed before disposing of an additional waste stream.

12. ACCIDENTS AND CHEMICAL SPILLS

Laboratory emergencies may result from a variety of factors, including serious injuries, fires and explosions, spills and exposures, and natural disasters. All laboratory employees should be familiar with and aware of the location of their laboratory's emergency response plans and safety manuals. *Before beginning any laboratory task*, know what to do in the event of an emergency situation. Identify the location of safety equipment, including first aid kits, eye washes, safety showers, fire extinguishers, fire alarm pull stations, and spill kits. Plan ahead and know the location of the closest fire alarms, exits, and telephones in your laboratory.

Emergency equipment (fire extinguishers, emergency shower and eyewash stations, and fire doors) should never be blocked.

12.1 Special Needs

Faculty and instructors should discuss evacuation procedures with all mobility–impaired persons in the laboratory to determine their needs for assistance at the beginning of each semester.

12.2 What to do in the event of an Accident or Emergency

The first priority in an emergency response is the protection of life and health. **The following basic steps apply to ALL emergencies**:

1. Make sure everyone in the immediate vicinity is aware of the problem and stays a safe distance away from the incident.
2. Contain the emergency if it can be done safely without causing harm to you.

3. Pull the fire alarm to evacuate the building if the emergency cannot be contained or if there is any doubt as to the severity of the situation.
4. **For all incidents requiring emergency response, call 5500 from a campus phone, 540-831-5500 from cell phones, 911 for off-campus labs.**
5. After the event, complete an Accident Investigation Report, Appendix A, form and send it to EHS (ehs@radford.edu).

12.3 Incidents and Accidents

Instructors are responsible for ensuring that their students receive appropriate medical attention in the event of an occupational injury or illness. All accidents and near misses must be reported to the Environmental Health and Safety Office. EHS will conduct an accident investigation and develop recommendations and corrective actions to prevent future accidents. At a minimum, each laboratory must have the following preparations in place:

- Fully stocked first aid kit
- Posting of emergency telephone numbers and locations of emergency equipment
- SDS for all chemicals in use or storage on hand

Accident Prevention Methods	
Do	**Don't**
Always wear appropriate eye protection Always wear appropriate laboratory coat Always wear appropriate gloves Always wear closed-toe shoes and long pants Always confine long hair and loose clothing Always use the appropriate safety controls (e.g., certified fume hoods and biosafety cabinets) Always label and store chemicals properly Always keep the work area clean and uncluttered	Never enter the laboratory wearing inappropriate clothing (e.g., open-toe shoes and shorts) Never work alone on procedures involving hazardous chemicals, biological agents, or other physical hazards Never eat, drink, chew gum or tobacco, smoke, or apply cosmetics in the laboratory Never use damaged glassware or other equipment

If an employee/student has a severe or life threatening injury, call for emergency response. Employees/students with minor injuries should be treated with first aid kits as appropriate, and sent to the Student Health/Medical Provider for further evaluation and treatment. After normal business hours, treatment can be obtained at designated medical centers and emergency rooms.

Exposure Incident:

Eye Contact: Promptly flush with water for at least 15 minutes. Contact Student Health. After hours, contact RUPD.

Skin Contact: Promptly flush with water. If body is exposed to a chemical product, use the safety shower to adequately flush. Remove contaminated clothing. Contact Student Health. After hours, contact RUPD.

Ingestion: Consult the Safety Data Sheet (SDS). Contact Student Health. After hours, contact RUPD.

Serious occupational injuries, illnesses, and exposures to hazardous substances must be reported to the Assistant Director of Environmental Health and Safety as soon as possible but at least within 8 hours of occurrence. EHS will report the event to the appropriate agencies, investigate the accident, and complete exposure monitoring if necessary. Serious injuries include those that result in permanent impairment or disfigurement, or require hospitalization. Examples include amputations, lacerations with severe bleeding, burns, concussions, fractures and crush injuries. As soon as a Department Chair becomes aware of a potentially serious incident, they must contact EHS.

12.4 Fire-Related Emergencies

If you encounter a fire, or a fire-related emergency (e.g., abnormal heating, smoke, burning odor), immediately follow these instructions:

1. Pull the fire alarm pull station and call 911.
2. Evacuate and isolate the area.
3. Use portable fire extinguishers to facilitate evacuation and/or control a small fire (i.e., size of a small trash can), if safe to do so.
4. If possible, shut off equipment before leaving.
5. Close doors.
6. Evacuate the building when the alarm sounds. *It is against state law to remain in the building when the alarm is sounding.* If the alarm sounds due to a false alarm or drill, you will be allowed to re-enter the building as soon as the Fire Department determines that it is safe to do so. *Do not go back in the building until the alarm stops and you are cleared to reenter.*
7. Remain safely outside the affected area to provide details to emergency responders.

If your clothing catches on fire, go to the nearest emergency shower immediately. If a shower is not immediately available, then stop, drop, and roll. A fire extinguisher may be used to extinguish a fire on someone's person. Report any burn injuries to the supervisor immediately and seek medical treatment. You are required to report every time a fire extinguisher is discharged to the Fire Safety Officer (7792), ehs@radford.edu, RUPD (5500), or Facilities Work Control (7800).

FIRE EXTINGUISHERS

Faculty members, with the assistance of Environmental Health and Safety, should review the hazards in their laboratory on an ongoing basis to determine if the fire extinguisher(s) present are appropriate. If additional or different class extinguishers are needed, the faculty member should notify EHS (540-831-7792). Classes and types of extinguishers are described in following table:

TYPES and CLASSES OF FIRE EXTINGUISHERS	
Class (Type)*	**Use**
A (Water)	For ordinary combustibles (e.g., paper, wood, cloth, rubber, plastics)

B (CO_2)	For flammable liquids or electrical equipment (e.g., computers, ovens, instruments)
ABC (Dry Chemical)	For all types of fire, including flammable liquids other than paper, metal and grease fires
K (Chemical)	Grease fires
* = Classes: Class A - wood, cloth, paper, rubber, and plastic Class B - flammable liquids, oils, greases, tars, oil-based paints, and flammable gases. Class C - energized electrical equipment. not in above list Class D - combustible metals such as magnesium, titanium, zirconium, sodium, lithium, and potassium. not in above list Class K- kitchen grease fires	

12.5 Chemical Spills

Chemical spills can result in chemical exposures and contaminations. Chemical spills become emergencies when:

- The spill results in a release to the environment.
- The material or its hazards are unknown.
- Laboratory staff cannot safety manage the hazard because the material is too hazardous or the quantity is too large (> 1L).

Effective emergency response to these situations is imperative to mitigate or minimize adverse reactions when chemical incidents occur. After emergency procedures are completed, all personnel involved in the incident should follow Radford University chemical exposure procedures as appropriate (see *Section 5: Chemical Exposure Assessment*).

In the event of a significant chemical exposure or contamination, immediately try to remove or isolate the chemical if safe to do so.

Factors to Consider Before Spill Clean-Up

- Size of spill area
- Quantity of chemical
- Toxicity
- Volatility
- Clean up materials available

When skin or eye exposures occur, remove contaminated clothing and flush the affected area using an eyewash or shower for at least 15 minutes. If a chemical is ingested, drink plenty of water. Obtain medical assistance as indicated. Remember to wear appropriate PPE before helping others. Instructors/Department Chairs must review all exposure situations, make sure affected students/employees receive appropriate medical treatment and/or assessment, and arrange for containment and clean-up of the chemical as appropriate.

Small chemical spills can be cleaned up by laboratory personnel who have been trained in spill clean-up and with the appropriate materials. A small spill is generally defined as < 1 liter of chemical that is not highly toxic, does not present a significant fire or environmental hazard, and is not in a public area such as a common hallway. **Large chemical spills** include spills of larger quantities, spills of any quantity of highly toxic chemicals, or chemicals in public areas or adjacent to drains. Large spills require emergency response. Call **5500** from a campus phone, **540-831-5500** from cell phone, **911** for off-campus labs for assistance.

WHAT TO DO WITH A SMALL CHEMICAL SPILL (<1 LITER)

1. Evacuate all non-essential persons from the spill area.
2. If needed, call for medical assistance by dialing **5500** from a campus phone, **540-831-5500** from cell phone, **911** for off-campus labs.
3. Help anyone who may have been contaminated. Use emergency eyewashes/showers by flushing the skin or eyes for *at least 15 minutes*.
4. Post someone just outside the spill area to keep people from entering. Avoid walking through contaminated areas.
5. You must have the proper protective equipment and clean-up materials to clean-up spills. Check the chemical's Safety Data Sheet (SDS) in your laboratory for spill clean-up procedures, or call Environmental Health and Safety for advice.
6. Turn off sources of flames, electrical heaters, and other electrical apparatus, and close valves on gas cylinders if the chemical is flammable.
7. Confine the spill to a small area. Do not let it spread.
8. Avoid breathing vapors from the spill. If the spill is in a non-ventilated area, do not attempt to clean it up. Call for emergency personnel to respond and clean up the spill.
9. Wear personal protective equipment, including safety goggles, gloves, and a laboratory coat or other protective garment to clean-up the spill.
10. Work with another person to clean-up the spill. Do not clean-up a spill alone.
11. DO NOT ADD WATER TO THE SPILL. Use an appropriate kit to neutralize and absorb inorganic acids and bases. For other chemicals, use the appropriate kit or absorb the spill with sorbent pads, paper towels, vermiculite, dry sand, or diatomaceous earth. For specific procedures for all other spills see Appendix D.
12. Collect the residue and place it in a clear plastic bag. Double bag the waste and label the bag with the contents.

WHAT TO DO WITH A LARGE CHEMICAL SPILL (>1 LITER)

Large chemical spills require emergency response. Call **5500** from a campus phone, **540-831-5500** from cell phone, **911** for off-campus labs.

1. If the spill presents a situation that is immediately dangerous to life or health (IDLH) or presents a significant fire risk, activate a fire alarm, evacuate the area and wait for emergency response to arrive.
2. Remove the injured and/or contaminated person(s) and provide first aid.
3. Call for emergency medical response.

4. As you evacuate the laboratory, close the door behind you, and post someone safely outside and away from the spill area to keep people from entering.
5. Confine the spill area if possible and safe to do so.
6. Leave on or establish exhaust ventilation.
7. If possible, turn off all sources of flames, electrical heaters, and other electrical equipment if the spilled material is flammable.
8. Avoid walking through contaminated areas or breathing vapors of the spilled material.
9. Any student/employee with known contact with a particularly hazardous chemical must shower, including washing of the hair as soon as possible unless contraindicated by physical injuries.

Highly Toxic Chemical Spills

Do not try to clean up spills of any size. All Highly Toxic chemical spills require emergency response.

Appendix A – Accident Investigation Report

RADFORD UNIVERSITY
ENVIRONMENTAL HEALTH & SAFETY

LABORATORY ACCIDENT INVESTIGATION REPORT

Directions: Complete this form to promptly report incidents/accidents occurring in labs or other research/ clinical work spaces that involve 1) injury, illness or harmful exposure (or potential illness/ harmful exposure) of persons in the lab or space, 2) spill or release of harmful materials, 3) fire or explosion, 4) property or environmental damage or loss, 5) unsafe conditions or acts that must be addressed. Prompt reporting of incidents to EHS is essential for determining how to minimize the occurrence of future incidents.

NOTE: If the incident has resulted in *employee* injury/illness, the employee and/or employee's supervisor must complete an Employers Accident Report (EAR) within 24 hours of the incident so the employee can be eligible for workers compensation. The EAR and this Accident Report serve completely different functions and are not interchangeable. The EAR can be accessed on Human Resources website.

REQUIRED INFORMATION *(Individual reporting the incident)*		
Last Name, First Name:	**Email:**	
Address *(Home or Work)*		
Phone:	**Incident Was Reported On:** *(MM/ DD/ YYYY)*	**Time Reported:** *(HH:MM)* __ am __ pm
My status: ___ Undergrad Student ___ Grad Student ___ Faculty ___ Staff ___Visitor Other: ________________________		
I provided prompt notification of the incident to: ___The Principal Investigator ___ The Lab Manager ___ The Area's Supervisor Other: __________________________		
INCIDENT INFORMATION		
Date of Incident: *(MM/ DD/ YYYY)*	**Time:** *(HH:MM)* __ am __ pm	**Location of Incident:** *(Building; Room #)*
Type of Incident: ___ Injury/ Illness ___Spill/ Release ___ Fire/ Explosion ___ Property/ Environmental Damage or Loss ___ Unsafe Condition Other: ____		
Hazard(s) Involved: *(Select all that apply.)* ___ Biological/ Genetically Modified Material ___Chemical/ Particulate/ Nanomaterial ___Hazardous Energy (laser, x-ray, UV) ___ Electrical/ High Voltage ___ Radiation ___ Physical Hazard (heat, cold, pressurized, spinning/rotating, sharp, mechanical, confined space) Other: ____		
Description of Incident: (Visitors, please include your purpose for being at the location of the incident.)		

Names of Parties Involved and/or Witnesses to the Incident: (PLEASE INCLUDE CONTACT INFORMATION FOR EACH PERSON.)

Description of Personal Protective Equipment and Engineering Controls/ Safety Equipment in Use at the Time of the Incident:

INJURY OR ILLNESS

Type:

___ **None** ___ **Physical Injury** ___ **Occupationally-Related Illness** ___ **Potential Harmful Exposure**

Name of Parties Affected and Description of Injury/ Illness/ Exposure:

Treatment: *(Select all that apply.)*

___ **None** ___ **First Aid** ___ **Student Health Services** ___ **Emergency Medical Services** ___ **Personal Physician**

___ **Hospital (outpatient)** ___ **Hospital (admitted)** ___ **Panel Physician**

PROPERTY / ENVIRONMENTAL DAMAGE OR LOSS

___ **Not Applicable**

Description of Damage or Loss:

Promptly send completed Accident Reports to Environmental Health and Safety:

- By campus mail to PO Box 6909
- By U.S. mail (EHS mailing address is PO Box 6909, Radford, VA 24142)
- By scanning and emailing to ehs@radford.edu

Appendix B – Container Labeling

Appendix B: Container Labeling

Chemical container labels are a good resource for information on chemical hazards. All containers of hazardous chemicals must have labels attached. Figure C.1 displays the label requirements.

The warning may be a single word (e.g. Danger, Caution, Warning) or may identify the primary hazards, including both physical (e.g. water reactive, flammable, or explosive) and health (e.g. carcinogen, corrosive or irritant), such as what is found on an NFPA diamond and hazard warnings from the label or SDS.

Most labels provide additional safety information to help workers protect themselves from the substance. This information may include protective measures and/or protective clothing to be used, first aid instructions, storage information and emergency procedures.

Chemical Labeling – What are Laboratory Personnel Responsible for?

Inspecting incoming containers to be sure that labels are attached and are in good condition and contain the information outlined above.

Reading the container label each time a newly purchased chemical is used. It is possible that the manufacturer may have added new hazard information or reformulated the product since the last purchase.

Ensuring that chemical container labels are not removed or defaced, except when containers are empty.

Labeling any secondary containers used in the laboratory, to prevent unknown chemicals or inadvertent reaction.

Verifying that chemical waste containers have complete and accurate chemical waste labels.

Labeling is important for the safe management of chemicals, preventing accidental misuse, inadvertent mixing of incompatible chemicals, and facilitating proper chemical storage. Proper labeling helps ensure quick response in the event of an accident, such as a chemical spill or chemical exposure incident. Finally, proper labeling prevents the high costs associated with disposal of "unknown" chemicals.

With the exception of transient containers that will contain chemicals for immediate use, all containers of chemicals being used or generated must be labeled sufficiently to indicate the contents of the container. On original containers, the label must not be removed or defaced in any way until the container is emptied of its original contents. Incoming containers must be inspected to make sure the label is in good condition. It is also advisable to put a date on new chemicals when they are received in the laboratory, and to put a date on containers of chemicals generated in the laboratory, as well as the initials of the responsible person.

Chemical formulas, abbreviations or other acronyms should not be used to label containers of chemicals, including hazardous waste, in the laboratory. Persons entering the lab, such as first responders are not usually knowledgeable of common chemical abbreviations or acronyms. Small containers, such as vials and test tubes, can be labeled as a group by labeling the outer container (e.g., rack or box). Alternatively, a placard can be used to label the storage location for small containers (e.g., shelf, refrigerator, etc.). This information must be provided to janitorial and maintenance staff as part of their hazard communication training.

Containers of practically non-toxic and relatively harmless chemicals must also be labeled with content information, including containers such as squirt bottles containing water.

With respect to chemical labeling, all potentially hazardous chemicals transferred from their original container to a second container must be labeled with the chemical name and the principal hazards found on the primary container label or SDS. For more information on labeling, see Section 6: Inventory, Labeling, Storage, and Transport.

Figure C.1. – Example of proper Container Labeling

Chemical Name (required)
Level of hazard (required)
3,4) Type of hazard type (required- note it can be word, pictogram or both)
5,6,7) Additional information (optional)

Appendix C – Segregation of Incompatible Chemicals

Appendix C: Segregation of Incompatible Chemicals

Table C.1 contains a list of incompatible chemicals. The following chemicals, listed in the left column, should not be used with chemicals listed in the right column, except under specially controlled conditions. Chemicals in the left column should not be stored in the immediate area with chemicals in the right column. Incompatible chemicals should always be handled, stored or packed so that they cannot accidentally come into contact with one another. This list is representative of chemical incompatibilities and is not complete, nor are all incompatibilities shown.

Table C.1 – Incompatible Chemicals

Chemical	Keep Out of Contact with:
Alkaline metals, such as powdered aluminum, magnesium, sodium,	Carbon tetrachloride or other chlorinated hydrocarbons, carbon dioxide and water
Acetic Acid	Chromic acid, nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides and permanganates
Acetylene	Chlorine, bromine, copper, fluorine, silver and mercury
Ammonia	Mercury, chlorine, calcium hypochlorite, iodine, bromine and hydrofluoric acid
Ammonium nitrate	Acids, metal powders, flammable liquids, chlorates, nitrites, sulfur, finely divided organic or combustible materials
Carbon, activated	Calcium hypochlorite
Copper	Acetylene and hydrogen peroxide
Chromic acid	Acetic acid, naphthalene, camphor, glycerin, turpentine, alcohol and flammable liquids
Chlorine	Ammonia, acetylene, butadiene, butane, methane, propane, hydrogen, sodium carbide, turpentine, benzene and finely divided
Cyanides	Acids - organic or inorganic
Hydrogen peroxide	Copper, chromium, iron, most metals, alcohols, acetone, organic materials, aniline, nitromethane, flammable liquids and combustible
Hydrogen sulfide	Fuming nitric acid and oxidizing gases
Hydrocarbons (butane, propane, benzene, gasoline, turpentine etc.)	Fluorine, chlorine, bromine, chromic acid and sodium peroxide
Iodine	Acetylene, ammonia and hydrogen
Nitric acid	Acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids, flammable gases, copper, brass and any heavy metals
Perchloric acid	Acetic anhydride, bismuth and its alloys, alcohol, paper, wood, ether, oils and grease
Phosphorous	Oxidizing agents, oxygen, strong bases
Potassium chlorate	Sulfuric and other acids
Potassium permanganate	Glycerin, ethylene glycol, benzaldehyde and sulfuric acid

Sodium	Carbon tetrachloride, carbon dioxide and water
Sodium nitrite	Ammonium nitrate and other ammonium salts
Sodium peroxide	Ethyl or methyl alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerin, ethylene glycol, ethyl acetate, methyl acetate and furfural
Sulfides, inorganic	Acids Sulfuric acid Potassium chlorate, potassium perchlorate and potassium permanganate

Special Segregation of Incompatible Chemicals

In addition to the segregation noted in Table M.1, dangerously incompatible substances, even in small quantities, should not be stored next to each other on shelves or in such a position that accidental rupture of containers may allow mixing. Table M.2 contains examples of dangerously incompatible substances. Table M.3 contains examples of incompatible oxidizing agents and reducing agents.

Table C.2 – Dangerously Incompatible Substances

Chemical	Keep out of contact with:
Chlorine	Acetylene
Chromic acid	Ethyl alcohol
Oxygen (compressed, liquefied)	Propane
Sodium	Chloroform and aqueous solutions
Nitrocellulose (wet, dry)	Phosphorous
Potassium permanganate	Sulfuric acid
Perchloric acid	Acetic acid
Sodium chlorate	Sulfur in bulk

Table C.3 – Incompatible Oxidizing Agents and Reducing Agents

Oxidizing Agents	Reducing Agents
Chlorates	Ammonia
Chromates	Carbon
Dichromates	Metals
Chromium trioxide	Metal hydrides
Halogens	Nitrates
Halogenating agents	Organic Compounds
Hydrogen peroxide	Phosphorus
Nitric acid	Silicon
Nitrates	Sulfur
Perchlorates	
Peroxides	
Permanganates	
Persulfates	

Appendix D – Minor Spill Clean-Up

Appendix D: Minor Spill Clean-Up

Laboratory personnel can clean up small spills if trained and competent to do so. Small spills include chemical spills that are up to 1 liter in size and of limited toxicity, flammability and volatility. If respiratory protection is needed for spill clean-up, the spill is too large to be handled by laboratory personnel – Call **5500** from a campus phone, **540-831-5500** from cell phone, **911** for off-campus labs for assistance. Commercial chemical and mercury spill kits are available, which include protective equipment such as goggles and gloves, neutralizing and absorbing materials, bags, and scoops. You can also make your own spill kits to include the materials described below:

Sodium Bicarbonate
Citric Acid
Vermiculite or other diking material
pH paper
1 pair neoprene or nitrile gloves
1 pair goggles
1 scoop
Spill pillows, sorbent pads
Disposable shoe covers (plastic bags may work)

Weak Inorganic Acid or Base Spill Clean Up Procedure

Wear gloves, goggles, laboratory coat and shoe covers.
To clean-up a spill of weak inorganic acid or base, neutralize the spilled liquid to pH 5 to 8 using a **Neutralizing Agent** such as:

Sodium bicarbonate	Soda ash
Sodium bisulfate	Citric acid

Absorb the neutralized liquid with an **Absorbent** such as:

Sorbent pads	Diatomaceous earth	Dry sand
Sponges	Paper towels	Vermiculite

Rinse the absorbent pads or sponges in a sink with water. Scoop or place the other absorbent materials into a clear plastic bag. Double bag and tag the bag with a chemical waste tag.

Solvent Spill Clean up

Absorb the spill with a non-reactive material such as:
Vermiculite
Dry sand
Paper towels
Sponges
Package as described above. Do not rinse or dispose of any chemicals down the sink or into any drain.

Appendix E – Template: Laboratory Chemical Hygiene Plan – Teaching Lab

Laboratory Chemical Hygiene Plan -- Teaching Lab

A chemical hygiene plan is a written program developed to establish procedures, protective equipment requirements and standard work practices that promote a safe work environment for employees handling hazardous chemicals in a laboratory. At Radford University, laboratory personnel are responsible for the preparation of their own Lab Specific Chemical Hygiene Plan. The plan may cover one or more rooms/laboratories associated with a work group or laboratory course and should consider all health and safety issues when work involves the use of hazardous substances.

The Chemical Hygiene Plan provided is a template that can be used by any Radford University laboratory. This plan was developed to meet the guidelines of 29 CFR 1910.1450, *Occupational Exposure to Hazardous Chemicals in Laboratories*, a standard issued by the Occupational Safety and Health Administration (OSHA). Filling in this template for your laboratory will complete the plan.

The Principal Investigator of the research lab acts as the Lab Safety Coordinator to implement the plan, unless he or she delegates that responsibility to a member of his or her research group.

The plan must then be reviewed by all researchers working in the lab and made readily available to lab personnel. The plan must be reviewed, at a minimum, annually by the Laboratory Supervisor and/or Instructor(s).

This template should be completed by the Laboratory Supervisor and/or Instructor(s), by filling in the sections highlighted in gray and adding additional information as appropriate for the lab. It is a convenient way to compile all required documentation into a single manual or location.

Template last reviewed and modified May 2020

Introduction

Instructor of Record/Laboratory Coordinator
The Instructor of Record/Laboratory Coordinator has ultimate responsibility for chemical hygiene within the laboratory and must, with other administrators, provide continuing support for laboratory chemical hygiene.

Laboratory Safety coordinator
The laboratory safety coordinator has the responsibility for chemical hygiene in the laboratory. This is often the same person as the Instructor of Record/Laboratory Coordinator.

Student Laboratory Instructors (if present in course)
The Student Laboratory Instructors are responsible for planning each operation in accordance with the chemical hygiene procedures set forth for the lab and for communicating safety information to the students enrolled in the lab.

Students Enrolled in the Lab
The students enrolled in the course are expected to follow safety rules and procedures and are subject to grade penalties and/or expulsion from the lab for failure to do so.

All persons in the lab have the responsibility for safety in the laboratory and for addressing any concerns and/or reporting them to the Laboratory Supervisor, Department, or EHS personnel.

It is the responsibility of the Instructor of Record/Laboratory Coordinator to compile, review, and update this information. The Environmental Health and Safety Office will verify the completeness of this section during laboratory audits.

Laboratory Unit:
Laboratory Courses taught in this unit:

Instructor of Record or Laboratory Coordinator:
Office Location:
Work Phone Number:
Alternate Phone Number:

Responsibilities

The Instructor of Record or Laboratory Coordinator shall:

- Be familiar with universal requirements of this program, such as hazardous waste disposal and departmental emergency planning.
- Compile all information listed under "Checklist" and include in a Laboratory CHP manual.
  - The inventory of PHSs and written SOPs are the responsibility of the Lab Supervisor or Coordinator unless these responsibilities have been delegated to another employee.
  - The inserted information must be reviewed and updated annually.
- Train Student Laboratory Instructors when the assignment begins and when there is new information or increased hazard is introduced. Document training as appropriate.
- Coordinate interaction with the Chemical Hygiene Officer and Environmental Health and Safety Office, as needed for laboratory audits, incident/accident investigation, medical examinations, exposure monitoring, and emergency response.

Student Laboratory Instructors (if present in course) shall:

- Read this Chemical Hygiene Plan and complete Lab Safety Signature Page.
- Not make any changes to the experimental procedure without the approval of the Instructor of Record or Laboratory Coordinator.
- Report significant chemical spills and injuries, illnesses, possible over-exposures, unsafe conditions, and any other concerns to their supervisor.

Safety Data Sheets (SDSs)

The SDS, or Safety Data Sheet, is a document produced by the chemical manufacturer that includes important chemical information, including:

  - Identification;
  - Manufacturer's name and address;
  - Physical and chemical characteristics;
  - Physical and health hazards, including relevant exposure limits;
  - Precautions for safe handling and clean-up of spills, including recommended personal protective equipment (PPE); and
  - Emergency and first aid procedures.

Every teaching assistant and student should be instructed on the use and access of SDS files.

SDS for our chemicals can be found:

☐ In this laboratory, located

☐ In CHIMERA

General Principles for Work with Laboratory Chemicals

Minimize All Chemical Exposures

It is prudent to minimize all chemical exposures. Skin contact with chemicals should be avoided as a cardinal rule. The best way to prevent exposure to airborne substances is to prevent their escape into the working atmosphere by use of hoods and other ventilation devices.

Control Measures

The following control measures are present in this laboratory:

- Chemical Fume Hood(s)
- Emergency Shower
- Emergency Eyewash Station(s)

The Department of Environmental Health and Safety may be contacted at any time regarding issues with any of these control measures (831-7790). Chemical fume hoods and safety showers will be tested at a minimum of annually by EHS. Lab personnel should activate all emergency eyewash stations on a weekly basis.

Personal Protection

- Assure that appropriate eye protection is worn by all persons, including visitors, where chemicals are stored or handled.
- Wear appropriate gloves when the potential for contact with toxic materials exists.
- Use any other protective and emergency apparel and equipment as appropriate.
- It is advisable to avoid the use of contact lenses in the laboratory; if they are used, inform supervisor.
- Remove laboratory coats immediately on significant contamination.

If there are any general lab guidelines that apply to all chemicals in this lab (i.e. anyone who enters this lab will wear protective safety glasses provided by the lab), they are listed below:

Controlling Exposures – Standard Operating Procedures (SOPs)

A Standard Operating Procedure (SOP) describes how your lab will handle a hazardous chemical safely, including special handling procedures, engineering controls, and personal protective equipment.

Written SOPs for any hazardous procedure or use of higher hazard materials must be developed and included in your lab's safety binder.

Procedures for Waste Disposal

Assure that the plan for each laboratory operation includes plans for appropriate waste disposal. Deposit chemical waste in appropriately labeled receptacles. All chemical waste will be disposed of in accordance with the Radford University Hazardous Waste Management Program.

Any questions about chemical waste disposal should be directed to EHS at 831-7790.

Emergency Response

Evacuation – Employees should be familiar with how to get out of the building in the event of an emergency, and the location of the lab's designated Emergency Assembly Point.

Spill Cleanup Information – An Emergency Spill Kit is located in the lab. This spill kit is designed for:

Signature

I affirm that this Laboratory-Specific Chemical Hygiene Documentation is accurate and that it provides information for the chemical safety of employees and students in this laboratory.

Instructor of Record or Laboratory Coordinator

______________________	______________________	______________
Signature	Printed Name	Date

Safety Binder/Information Checklist

Check each line item once all of the required information has been incorporated into the appropriate section of the Laboratory Safety Binder(s).

- ☐ Safety Data Sheets (paper/electronic)
- ☐ Chemical Inventory for laboratory (paper/electronic)
- ☐ Chemical Hygiene Plan (this document)
- ☐ Standard Operating Procedures (SOPs)
- ☐ Description of procedures for chemical waste disposal (including Hazardous Waste Determination Forms)
- ☐ Lab Safety Orientation Document
- ☐ Training Documentation –Lab Safety Information Signature Page
- ☐ Emergency Eyewash Testing Log

EHS Contact Information

Main Phone: 540-831-7790

ehs@radford.edu

Appendix F – Template: Laboratory Chemical Hygiene Plan – Research Lab

Laboratory Chemical Hygiene Plan – Research Lab

A chemical hygiene plan is a written program developed to establish procedures, protective equipment requirements and standard work practices that promote a safe work environment for employees handling hazardous chemicals in a laboratory. At Radford University, laboratory personnel are responsible for the preparation of their own Lab Specific Chemical Hygiene Plan. The plan may cover one or more rooms / laboratories associated with a work group or laboratory course and should consider all health and safety issues when work involves the use of hazardous substances.

The Chemical Hygiene Plan provided is a template that can be used by any Radford University laboratory. This plan was developed to meet the guidelines of 29 CFR 1910.1450, *Occupational Exposure to Hazardous Chemicals in Laboratories*, a standard issued by the Occupational Safety and Health Administration (OSHA). Filling in this template for your laboratory will complete the plan.

The Principal Investigator of the research lab acts as the Lab Safety Coordinator to implement the plan, unless he or she delegates that responsibility to a member of his or her research group.

The plan must then be reviewed by all researchers working in the lab and made readily available to lab personnel. The plan must be reviewed, at a minimum, annually by the Principal Investigator and/or Lab Safety Coordinator.

This template should be completed by the Principal Investigator and/or Laboratory Safety Coordinator, by filling in the sections highlighted in gray and adding additional information as appropriate for the lab. It is a convenient way to compile all required documentation into a single manual or location.

Template last reviewed and modified May 2020

Introduction

Principal Investigator

The Principal Investigator has ultimate responsibility for chemical hygiene within the laboratory and must, with other administrators, provide continuing support for laboratory chemical hygiene.

Laboratory Safety coordinator

The Laboratory Safety Coordinator has the responsibility for chemical hygiene in the laboratory. This may or may not be the same person as the Principal Investigator.

Researchers (Post-docs, Graduate Students, and Undergraduate Students)

The Researchers are responsible for planning each operation in accordance with the chemical hygiene procedures set forth for the lab and for following safety rules and procedures.

All persons in the lab have the responsibility for safety in the laboratory and for addressing any concerns and/or reporting them to the Principal Investigator, Department, or EHS personnel.

It is the responsibility of the Principal Investigator and/or Laboratory Safety Coordinator to compile, review, and update this information. The Environmental Health and Safety Office will verify the completeness of this document during annual laboratory audits.

Laboratory Unit:

Principal Investigator:
Office Location:
Work Phone Number:
Alternate Phone Number:

Laboratory Safety Coordinator (LSC):
Office Location:
Work Phone Number:
Alternate Phone Number:

Responsibilities

The Principal Investigator shall:

- Be familiar with the universal requirements of this program, such as hazardous waste disposal and departmental emergency planning.
- Compile all information listed under "Checklist" and include in a Laboratory Safety Manual.
    - The chemical inventory and written SOPs are the responsibility of the Principal Investigator unless these responsibilities have been delegated to another researcher.
    - The inserted information must be reviewed and updated annually.
- Train Researchers when their work begins and when new information or increased hazard is introduced, or when the researchers move to a new project. Document training using the appropriate signature page provided with this document. Training must be documented for all researchers in the laboratory.
- Coordinate interaction with the Laboratory Safety Manager and Environmental Health and Safety Office, as needed for laboratory audits, incident/accident investigation, medical examinations, exposure monitoring, and emergency response.

Researchers shall:

- Read this Chemical Hygiene Plan.
- Sign the appropriate signature page associated with this plan.
- Not begin any new procedure or project without the approval of the Principal Investigator.
- Report significant chemical spills and injuries, illnesses, possible over-exposures, unsafe conditions, and any other concerns to their supervisor.

Safety Data Sheets (SDSs)

The SDS, or Safety Data Sheet, is a document produced by the chemical manufacturer that includes important chemical information, including:

- Identification;
- Manufacturer's name and address;
- Physical and chemical characteristics;
- Physical and health hazards, including relevant exposure limits;

- Precautions for safe handling and clean-up of spills, including recommended personal protective equipment (PPE); and
- Emergency and first aid procedures.

Every lab employee and researcher should be instructed on the use and access of SDS files.

SDS for our chemicals can be found:

☐ In this laboratory, located

☐ In CHIMERA

General Principles for Work with Laboratory Chemicals

Minimize All Chemical Exposures

It is prudent to minimize all chemical exposures. Skin contact with chemicals should be avoided as a cardinal rule. The best way to prevent exposure to airborne substances is to prevent their escape into the working atmosphere by use of hoods and other ventilation devices.

Control Measures

The following control measures are present in this laboratory:

- ☐ Chemical Fume Hood(s)
- ☐ Emergency Shower
- ☐ Emergency Eyewash Station(s)

The Department of Environmental Health and Safety may be contacted at any time regarding issues with any of these control measures (831-7790). Chemical fume hoods and emergency showers will be tested at a minimum of annually. Lab personnel should flush all emergency eyewash stations on a weekly basis.

Personal Protection

- Assure that appropriate eye protection is worn by all persons, including visitors, where chemicals are stored or handled.

- Wear appropriate gloves when the potential for contact with toxic materials exists.
- Use any other protective and emergency apparel and equipment as appropriate.
- It is advisable to avoid the use of contact lenses in the laboratory; if they are used, inform supervisor.
- Remove laboratory coats immediately on significant contamination.

If there are any general lab guidelines that apply to all chemicals in this lab (i.e. anyone who enters this lab will wear protective safety glasses provided by the lab), they are listed below:

Controlling Exposures – Standard Operating Procedures (SOPs)

A Standard Operating Procedure (SOP) describes how your lab will handle a higher hazard chemical safely, including special handling procedures, engineering controls, and personal protective equipment.

Written SOPs for any hazardous procedure or use of higher hazard materials must be developed and included in your lab's safety binder.

Procedures for Waste Disposal

Assure that the plan for each laboratory operation includes plans for appropriate waste disposal. Deposit chemical waste in appropriately labeled receptacles. All chemical waste will be disposed of in accordance with the Radford University Chemical Waste Policy and the Laboratory Chemical Waste Management Practices.

Any questions about chemical waste disposal should be directed to EHS at 831-7790.

Emergency Response

Additional information can be found on the "Lab Emergency" posters.

Evacuation – Employees should be familiar with how to get out of the building in the event of an emergency, and the location of the lab's designated Emergency Assembly Point.

Spill Cleanup Information – An Emergency Spill Kit is located in the lab. This spill kit is designed for

Signature

I affirm that this Laboratory-Specific Chemical Hygiene Documentation is accurate and that it provides information for the chemical safety of employees and students in this laboratory.

Principal Investigator

________________________	________________________	_______________
Signature	Printed Name	Date

Safety Binder/Information Checklist

Check each line item once all of the required information has been incorporated into the appropriate section of the Laboratory Safety Binder(s).

- ☐ Safety Data Sheets (paper/electronic)
- ☐ Chemical Inventory for laboratory (paper/electronic)
- ☐ Chemical Hygiene Plan (this document)
- ☐ Standard Operating Procedures (SOPs)
- ☐ Description of procedures for chemical waste disposal (including Hazardous Waste Determination Forms)
- ☐ Lab Safety Orientation Document
- ☐ Training Documentation –Lab Safety Information Signature Page
- ☐ Emergency eyewash Testing Log

EHS Contact Information

Main Phone: 540-831-7790
ehs@radford.edu

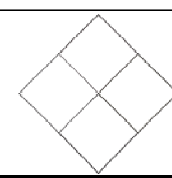
Appendix G – Link to Hazardous Waste Management Program Guidebook [Click Here]

Appendix H – Laboratory Door Sign Worksheet

Laboratory Door Sign Worksheet

Date ____________

Contact Information	
Building: **Rm:** **Lab Name:**	
Primary Contact (PI):	**Phone:**
Alternate 1:	**Phone:**
Alternate 2:	**Phone:**
24 Hr Emergency Contact Number:	***Note: Failure to provide contact information may prevent timely notification in the event of an emergency.***

✓	Hazard	Indicate each hazard in you lab based on the following: # of Signs Needed:
(☐)	**Biohazard**	Contains any agent that is capable of causing disease in humans, plants or animals. *Indicate Biosafety Containment Level (☐) BSL-1 (☐) BSL-2 (☐) BSL-2+*
(☐)	**Carcinogen**	Known or suspected carcinogens are in use (see attached guidance).
(☐)	**Compressed Gas**	Rooms or cabinets contain compressed gases.
(☐)	**Corrosive**	Corrosive liquids in quantities greater than 1 gallon in use.
(☐)	**Flammable**	Flammable liquids in quantities greater than 1 gallon in use, contains a flammable gas or flammable storage cabinet.
(☐)	**High Voltage**	Equipment capable of generating high-voltages (> 420 volts) in the course of its operation.
(☐)	**Laser**	Laser(s) in use: *Indicate Laser Classification: (☐) Class 3B (☐) Class 4 Other:*
(☐)	**Oxidizer**	Oxidizers in quantities greater than 1 gallon or 4 kg in use.
(☐)	**Live Animals**	Indicate if the live animals are present or housed in the lab.
(☐)	**Toxic**	Material rated toxic in quantities greater than 10 pounds in use.
(☐)	**X-Ray**	List the type of equipment in use: *(☐) XRD (☐) XRF Other:*
(☐)	**Water Reactive**	List any chemicals in the lab that could react with water.
(☐)	**No Custodial Services Required**	Rooms should not be entered for cleaning due to potential hazards in the lab. *Cleaning to be conducted by lab staff or coordinated independently with Facilities Management..*
	NFPA Diamond	Using the guidance accompanying this worksheet, **indicate in the appropriate diamond to the right** which number (0 – 4) best describes the hazards for Health, Flammability and Reactivity for the type(s) of materials used in the lab. 

Indicate which "Warnings" you would like on your sign. You can also edit them or add your own.	
(☐) Authorized Individuals Only	**(☐) No Food or Drink In Lab**
(☐) Keep Lab Locked While Unattended	**(☐) Personal Protective Equipment Required**
(☐) Live Animals Present In Lab	**Custom:**
Custom:	**Custom:**

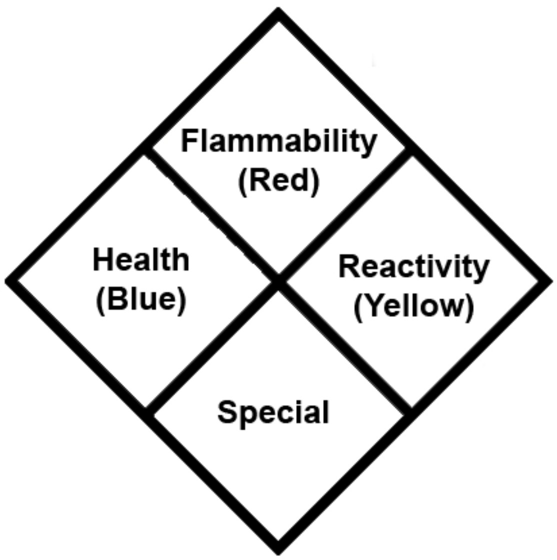
Add any laboratory-specific information for Emergency Responders:

Return completed worksheet to Environmental Health and Safety, P.O. Box 6909. Worksheets can also be emailed to ehs@radford.edu EHS will place a customized, laminated door sign on the lab door using the information provided above. Please direct all questions to ehs@radford.edu or call 831-7790.

NFPA Diamond Labeling Guidance

Flammability (Susceptibility of Materials to Burning)				
0 - Materials that will not burn.	**1** - Materials that must be preheated before ignition can occur.	**2** - Materials that must be moderately heated or exposed to relatively high ambient temperatures before ignition can occur.	**3** - Liquids and solids that can be ignited under almost all ambient temperature conditions.	**4** - Materials which will rapidly or completely vaporize at atmospheric pressure and normal ambient temperature, or which are readily dispersed in air and which will burn readily.

Health Hazard (Type of Possible Injury)
4 - Materials which on very short exposure could cause death or major residual injury even though prompt medical treatment was given.
3 - Materials which on short exposure could cause serious temporary or residual injury even through prompt medical treatment was given.
2 - Materials which on intense or continued exposure could cause serious temporary incapacitation or possible residual injury unless prompt medical treatment was given.
1 - Materials which on exposure could cause serious temporary incapacitation or possible residual injury even if medical treatment is given.
0 - Materials which on exposure under fire conditions would offer no hazard beyond that of ordinary combustible material.



Special Warning

Any special warning is placed in this section. The most common would be water reactive or compounds with strong oxidizing potential.

Key:

Oxy	Oxidizing Agent
W	Water Reactive
G	Compressed Gas
LN_2	Liquid Nitrogen
LHE	Liquid Helium
LAS	Laser
BL	Biosafety Level
RAD	Radioactive Material
X-Ray	XRD/XRF
MAG	Magnetic Fields
HVO	High Voltage

Reactivity (Susceptibility to Release Energy)
4 - Materials which in themselves are readily capable of detonation or of explosive decomposition or reaction at normal temperatures and pressures.
3 - Materials which in themselves are capable of detonation or of explosive reaction but require a strong initiating source or which must be heated under confinement before initiation or which react explosively with water.
2 - Materials which in themselves are normally unstable and readily undergo violent chemical change but do not detonate. Also materials which may react violently with water or which may form potentially explosive mixtures with water.
1 - Materials which in themselves are normally stable, but which can become unstable at elevated temperatures and pressures or which may react with water with some release of energy, but not violently.
0 - Materials which in themselves are normally stable, even under fire exposure conditions, and which are not reactive with water.

Carcinogens

For the purpose of the laboratory door sign, indicate if you are using any of the "known carcinogens" listed below. These items are defined as agents with "sufficient evidence of carcinogenicity from studies in humans, which indicates a causal relationship between exposure to the agent, substance or mixture and human cancer." If any other chemical you are using is known to be or highly suspected as a carcinogen, be sure to check the carcinogen hazard on the worksheet.

Aflatoxins
4-Aminobiphenyl
Analgesic Mixtures Containing Phenacetin
Arsenic Compounds, Inorganic
Azathioprine
Benzene
Benzidine
Beryllium and Beryllium Compounds
1,3-Butadiene
1,4-Butanediol Dimethanesulfonate (Myleran®)
Cadmium and Cadmium Compounds
Chlorambucil
1-(2-Chloroethyl)-3-(4-methylcyclohexyl)-1-nitrosourea (MeCCNU)
bis(Chloromethyl) Ether and Technical-Grade
Chloromethyl Methyl Ether
Chromium Hexavalent Compounds
Coal Tar Pitches
Coal Tars
Cyclophosphamide
Cyclosporin A
Diethylstilbestrol
Dyes Metabolized to Benzidine
Erionite
Estrogens, Steroidal
Ethylene Oxide
Hepatitis B Virus
Hepatitis C Virus
Human Papillomas Viruses: Some Genital-Mucosal Types
Melphalan
Methoxsalen with Ultraviolet A Therapy (PUVA)
Mineral Oils (Untreated and Mildly Treated)
Mustard Gas
2-Naphthylamine
Nickel Compounds
Silica, Crystalline (Respirable Size)
Soots
Strong Inorganic Acid Mists Containing Sulfuric Acid
Tamoxifen
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD); "Dioxin"
Thiotepa
Thorium Dioxide
Vinyl Chloride
Wood Dust

Appendix I – Standard Operating Procedure Template

Standard Operating Procedure (SOP)

Procedure Name (Identify the intended scope of the SOP here)

Revision Date: Insert Date

Procedure [Provide additional information as it pertains to a protocol, hazardous material, or specific equipment]

Provide an exact description of the procedure, equipment, hazardous chemicals, concentration, quantity required, and approximate frequency of use.

Potential Hazards [Describe the nature of the hazards, be they chemical, physical, equipment, electrical, lasers, etc.]

State route of exposure (skin, inhalation, ingestion, injection), when/how exposure might occur (inhalation of gases/vapors, inhalation during weighing and mixing, splashes, cleaning up spills, etc.). Be sure to indicate if material is a gas, liquid, powder, pellet, etc. Hazards will be found in the SDS or equipment manual. Look for information on whether the chemical is flammable, corrosive, toxic, carcinogenic, pyrophoric, an irritant, etc.

Occupational Exposure Limits (OELs):

Provide OEL's for chemicals.

Engineering Controls [Prior to performing this procedure, the following safety equipment must be accessible and ready for use.]

State the safety equipment that must be used (ex. chemical fume hood, Biological Safety Cabinet (BSC), laminar flow hood, vented ovens, furnaces, glove boxes, chemical spill kit, etc.). If this is a new process and the appropriate engineering controls do not seem to be available in the lab, discuss with lab staff whether the process can be done and how to obtain what is needed. If no engineering controls are needed please cite this fact. Consider if liquid form would be less hazardous than powder and, if so, purchase in liquid form. If possible, indicate that the chemical will be purchased in small quantities or dilute solutions to reduce the risk of exposure and minimize waste. If weighing powder and balance cannot be located in a fume hood or BSC, tare a container then add powder in the hood and cover before returning to the balance to weigh the powder.

Work Practice Controls

Describe work practices to be used that reduce exposure to hazardous chemicals. Describe required hand washing and the frequency for changing PPE. Describe additional safe work practices, such as keeping containers closed, working away from open flames, etc.

Personal Protective Equipment

Describe PPE requirements for each task involving the hazardous material. (Examples: type of gloves, lab coat/apron/gown, safety glasses/goggles, face shield, respirator, etc.).

Note: Respirators are masks designed to protect the wearer from specific airborne hazards and are different from surgical masks, which protect the wearer only from splashes and are primarily intended to protect others from infectious aerosols exhaled by the wearer. Respirator use requires employee participation in the Respiratory Protection Program, which involves medical clearance and annual fit testing and training.

Storage and Handling Requirements

Describe where will you store hazardous materials in the lab, e.g., solvent, acid, or base cabinet, refrigerator, etc. Be aware of incompatibility with other chemicals already in use in the lab. Chemical containers must be labeled with chemical name (& concentration, if diluted) and hazard warnings at a minimum. Describe transportation strategy (use of secondary containers, travel through low-traffic hallways). State chemical segregation strategies (list incompatibles).

Waste Disposal

Provide guidance on how waste generated will be disposed. Be specific and describe the specific disposal procedure to be used, i.e., do not write "Dispose of in accordance with applicable regulations".

Because most spent, unused, and expired chemicals/materials are considered hazardous wastes, they must be properly disposed of. **Do not dispose of chemical wastes by dumping them down a sink, flushing in a toilet or discarding in regular trash containers, unless authorized by Environment, Health & Safety (EHS) Hazardous Materials Management (HMM)**. Contact EHS at (540) 831-7790 or ehs@radford.edu for waste containers, labels, manifests, waste collection and for any questions regarding proper waste disposal. Also, refer to the EHS Request for Hazardous Waste Disposal form for more information.

Exposures

Describe what actions to take in an exposure incident i.e. leaving the area for inhalation hazards, removing contaminated clothing and/or PPE, flushing eyes and skin. Describe procedures to contact Occupational Health Services for medical advice on occupational exposures and completing the work-related injury and illness form.

⚠ ***If the employee is in need of emergency medical attention, call 911 immediately.*** ⚠

For a chemical exposure/injury:

INJURY TYPE	ACTION	NOTES
Exposure-Eyes	1. Flush with water for at least 15 minutes 2. Seek medical attention.	Removal of contact lenses after an eye injury should only be undertaken by skilled personnel.
Exposure-Skin	1. Flush with water for at least 15 minutes. 2. Remove contaminated clothing. 3. Seek medical attention.	
Inhalation (including from spills outside the fume hood)	1. Remove patient from the contaminated area. 2. Encourage patient to blow nose to ensure clear breathing passages. 3. Ask patient to rinse mouth with water but to not drink the water. 4. Seek medical attention.	
Ingestion	1. If swallowed, refer for medical attention, where possible, immediately.	Urgent hospital treatment is likely to be needed.
NOTE: If an ambulance is needed, call the Radford University Police Department (RUPD) at 540-831-5500 to request assistance.		

If the individual is an employee of the University, the employee or their supervisor or PI must complete the Employer's Accident Report, found in Appendix A, and submit to Human Resources within 24 hours.

All individuals injured or exposed while working at Radford University must notify his/her supervisor or PI and either the injured individual or their supervisor fill out an Accident Investigation Report, found in Appendix B, and submit it to EHS within 24 hours.

For accidents also resulting in a known or suspected exposure to an infectious agent, an Exposure Incident Report form must be completed and submitted to EHS.

Complete the Sharps Injury Report form.

Spill Procedure

Describe how employees should handle spills. Are there specific absorbents that should be used? If it's a gas leak, what do you do when the detectors go off? Be specific. Are there specific concerns to be considered in the event of a fire? For example, some chemicals are water reactive, and using water on a fire where these chemicals are involved will make the problem worse.

A **minor (small) chemical spill** is one that the laboratory staff is capable of handling safely without the assistance of safety and emergency personnel, i.e., less than 1 liter. In the event of a minor chemical spill, use the following information for a safe spill response.

- Alert people in immediate area of spill.
- If spilled material is flammable, turn off ignition and heat sources. Don't light Bunsen burners or turn on other switches.
- Open outside windows, if possible.
- Wear protective equipment, including safety goggles, gloves and long-sleeve lab coat.
- Avoid breathing vapors from spill.
- Confine spill to as small an area as possible.
- **Do not wash spill down the drain**.
- Use appropriate spill kits/sorbents to neutralize corrosives and/or absorb spill. Collect contaminated materials and residues and place in container. For powdered chemicals sweep carefully to avoid generation of dust or, if appropriate, use moist sorbent pads or wet the powder with a suitable solvent and then wipe with a dry cloth. Label and manifest waste and contact EHS at (540) 831-7790 for proper disposal.
- Clean spill area with water.

A **major (large) chemical spill** requires active assistance from emergency personnel. Report large spills (greater than 1 liter) in corridors or common areas, e.g., hallways, elevators, eating areas, rest rooms, offices, etc., to Radford University at 911.

Do not attempt to clean up a major chemical spill or one that occurs outside a fume hood. In the event of a major chemical spill, use the following information for a safe spill response.

- Attend to injured or contaminated persons and remove them from exposure.
- Alert people in the laboratory to evacuate.
- If spilled material is flammable, turn off ignition and heat sources. Don't light Bunsen burners or turn on other switches.
- **Call University of Michigan Division of Public Safety and Security (DPSS) at 911 immediately for assistance.**
- Close doors to affected area.
- Post warnings to keep people from entering the area.
- Have person available that has knowledge of incident and laboratory to assist emergency personnel.

For additional information regarding spill response procedures, refer to the EHS Hazardous Waste Spill Response Web page.

Emergency Reporting

Report all emergencies, suspicious activity, injuries, spills, and fires to the Radford University Police Department (RUPD) by calling 911 or texting 377911. Register with the University of Michigan Emergency Alert System via Wolverine Access.

Training of Personnel

All personnel are required to complete the **General Laboratory Safety Training** session (**BLS025w** or equivalent) vis EHS' My LINC website. Furthermore, all personnel shall read and fully adhere to this SOP when handling acrylamide.

Certification

I have read and understand the above SOP. I agree to contact my Lab Director if I plan to modify this procedure.

NAME	SIGNATURE	UMID #	DATE

Lab Director　　　　　　　　　　　　　　　　Revision Date

Major Revisions (Tracking purposes only -- Do not print as part of SOP)

DATE	REVISION

Appendix J – Laboratory Self-Inspection Checklist

RADFORD UNIVERSITY
ENVIRONMENTAL HEALTH & SAFETY

Laboratory Self-Inspection Checklist

Building:	Room:	Primary PI:
Inspected By:	Date Completed:	

All laboratory spaces containing hazardous chemicals should be inspected at semi-annually. For each item check Yes, No, or N/A. Refer to the checklist key for more detailed explanation. Be sure to retain all documentation regarding inspections, including findings and corrective actions taken for any "No" responses, for a minimum of 3 years. EHS will conduct at least one laboratory inspection annually. Contact EHS at 540-831-7790 or ehs@radford.edu for questions or additional information.

	General Laboratory Safety	Yes	No	N/A
1	Do lab staff know how and when to report accidents, incidents, or near-misses?			
2	Lab is maintained secure; door is locked when no one is in the lab?			
3	Appropriate clothing (e.g. closed toe shoes) worn by everyone in lab?			
4	Personal protective equipment (PPE) (e.g. lab coats, gloves, safety glasses, goggles, face shields, etc.) is available in labs handling chemicals, biohazardous materials, or any other health/physical hazard?			
5	Is PPE properly stored (lab coats on hangers or racks, eyewear, etc.)?			
6	No food or drinks found in lab?			
7	Laboratory Door Sign(s) posted on laboratory entrance(s)?			
8	Laboratory Door Sign(s) are up to date with current PI, contact, and hazard information?			
9	Work and storage areas clear of clutter; access to exit is unrestricted?			
10	Areas around fire extinguishers are clear and accessible?			
11	Areas around emergency eyewash/shower clear and accessible?			
12	Are eyewashes activated weekly?			
13	All objects stored at least 18 inches away from fire sprinklers?			
14	Lab floors, aisles, and adjacent hallways unobstructed?			
15	Floors dry and free of slip and/or trip hazards?			
16	Do suspended ceilings have all of their ceiling tiles in place?			
17	Are all class 3B and/or Class 4 lasers inventoried and registered with EHS?			
18	Are fire doors closed and not propped open (fire doors are usually easily identified due to their self-closing nature)?			
19	Is there an N95 or other type of respirator (half-face, full-face, etc.) present or being utilized in the lab? [Enrollment with Respiratory Protection is required if "Yes".]			
20	Are all points of operation, rotating components, and other moving parts of machinery properly guarded to prevent injury (e.g. belts, pulleys, etc.)?			
21	Is Bunsen burner tubing damaged, compromised, brittle, or cracked?			
22	Is laboratory equipment with potential hazards routinely inspected and maintained or serviced as recommended by the manufacturer?			
	Chemical Safety	**Yes**	**No**	**N/A**
23	Does your lab use any chemicals or hazardous materials (chemicals can include many household products not generally considered as "chemicals" to most people)? (**If "N/A", skip to question 58.**)			
24	Written Chemical Hygiene Plan available for lab?			
25	Have all lab personnel reviewed the Lab Safety Manual/Chemical Hygiene Plan/SOPs?			
26	Laboratory personnel have attended EHS Laboratory Safety Training and received site-specific training?			
27	First aid and chemical spill kits available?			

Laboratory Self-Inspection Checklist

	Chemical Safety Continued	Yes	No	N/A
28	Are spills cleaned up promptly?			
29	Are assessments of hazards conducted for new work and chemical usage?			
30	Safety Data Sheets readily accessible (hard copies)?			
31	Have all chemicals been barcoded and entered into the lab's chemical inventory within CHIMERA?			
32	Has the lab's chemical inventory been reviewed and audited within the last 12 months (or within 30 days of a significant change – such as a move to a new location or addition of a large quantities of new chemicals)? [Audits must be documented and kept on file.]			
33	Is the lab free of chemicals that are old and no longer needed?			
34	Chemical fume hoods tested within the last 12 months and clearly identified as having passed testing?			
35	Are fume hoods free of clutter and not used for long-term storage of equipment, chemicals, or supplies that are not regularly used?			
36	Are personnel using the fume hood with the sash open no higher than 18"? Is the fume hood sash closed when not in use?			
37	Refrigerator/freezer and microwaves within the lab clearly labeled as "No Food or Drink" or similar?			
38	Refrigerator/freezer not rated for flammable storage identified as "No Flammable Storage" or similar?			
39	Flammable materials requiring refrigeration/freezing are placed in explosion-proof or flammables refrigerators/freezers only? (No flammable chemicals may be stored in a regular refrigerator/freezer.)			
40	Flammable liquids stored in flammable storage cabinets (no more than 10 gallons of flammable liquids may be stored in the lab outside of a flammable storage cabinet)?			
41	Storage quantities of chemicals within the lab are minimized?			
42	Containers, including for non-hazardous chemicals and water (including squirt bottles), legibly labeled with the full chemical or trade name and any associated hazard(s)? (Note: abbreviations/formulas are not acceptable.)			
43	Chemical containers are clean, structurally sound, and closed when not in use?			
44	Hazardous liquid chemicals and oil pumps stored in adequate secondary containment?			
45	Secondary containers clean and free of spilled material?			
46	Are incompatible chemicals stored appropriately (e.g. acids separated from bases, oxidizers separated from flammables, etc.)?			
47	Are containers of hazardous materials not stored on the floor?			
48	Materials with shelf lives are dated and disposed of per supplier's recommendations?			
49	Are peroxide formers (such as isopropyl ether, tetrahydrofuran (THF), and diethyl ether) stored away from light and heat and clearly labeled with the date they were opened as well as the expiration date (expiration 1 year from date of purchase, 6 months from date of opening)?			
50	Are bottles of Chloroform within acceptable use dates (1 year from date of purchase, 6 months from date of opening)?			
51	Hazardous chemical containers stored below eye level?			
52	Are hazardous material quantities within limits allowed by the Virginia Fire Code?			
53	Broken, non-contaminated glass, in lined, sturdy cardboard boxes clearly identified as containing "broken glass"?			
54	Are consumer commodities/equipment (food coloring, popcorn, ice machines, etc.) labeled as "Not For Human Consumption", "For Research Purposes Only", "For Experimental Use Only" or similar?			

55	Are process that emit vapors, gases, or fumes adequately captured by local ventilation (fume hoods, exhaust vent, snorkel)?			
56	Is ethanol 190 proof and greater stored in a locked flammable storage cabinet ?			
57	Are flame resistant labs coats worn when working with pyrophoric materials?			
	Electrical Safety	**Yes**	**No**	**N/A**
58	Extension cords only used temporarily and power strips not daisy chained together?			
59	No exposed wiring or damaged electrical cords?			
60	Is equipment with motors, heaters, and other high amperage needs (e.g. large appliances such as refrigerator) plugged directly into a wall receptacle?			
61	Are ground fault circuit interrupters (GFCIs) employed in wet locations?			
62	Circuit breaker and electrical panels unobstructed (at least 36” clearance is required in front a panel)?			
	Hazardous Waste	**Yes**	**No**	**N/A**
63	Hazardous chemical waste is generated in this area? (**If “N/A”, skip to question 75.**)			
64	Hazardous waste containers labeled with EHS provided “Hazardous Waste” tag?			
65	Each waste container is marked with full chemical names identifying the contents stored inside (no abbreviations or formulas)?			
66	All hazardous waste in lab is less than 12 months old?			
67	Waste containers are kept closed unless adding waste?			
68	Waste containers are in good condition (not leaking, rusted, bulging, damaged, etc.) and compatible with their contents?			
69	Waste containers storing liquid hazardous waste are stored within secondary containment?			
70	Secondary containment is in good condition (free of cracks, gaps, impervious to leaks)?			
71	Incompatible waste segregated?			
72	Satellite Accumulation Area (SAA) is located at or near where waste is generated?			
73	Maximum SAA storage capacity not exceed (55 gallons)?			
74	Weekly SAA checklists completed and documented?			
	Biosafety	**Yes**	**No**	**N/A**
75	The lab is a BSL-1 or BSL-2 laboratory or an ABSL? (**If “N/A”, skip to question 83.**)			
76	If lab is BSL/ABSL, are a sink, soap, and paper towels available for handwashing?			
77	Biohazard signs are posted outside of all labs handling biohazardous materials?			
78	Lab coats, gowns, or scrubs, eyewear, gloves, etc. are in use in labs handling biohazardous materials?			
79	Disinfectants are on hand for disinfecting bench tops, equipment, and treating spills?			
80	Are biohazard warnings on freezers, refrigerators, storage units, and other types of equipment where biozhards are used and/or stored?			
81	Are vacuum lines protected with high efficiency particulate air (HEPA) filters or their equivalents?			
82	Biological safety cabinets were certified within the last 12 months?			
	Biohazardous Waste/Regulated Medical Waste	**Yes**	**No**	**N/A**
83	Regulated medical waste/biohazardous waste or “sharps” (needles, razors, etc.) generated in this area? (**If “N/A”, skip to question 86.**)			
84	Is biohazardous BSL-1, BSL-2 and/or ABSL waste autoclaved in a timely manner or appropriately disinfected per laboratory SOPs?			
85	Sharps are disposed in a proper and labeled sharps container that is kept closed unless waste is being added.			

	Radiation Safety	**Yes**	**No**	**N/A**
86	Is radioactive material or radiation producing equipment used in this lab? (**If "N/A", skip to question 93.**)			
87	If radioactive material or radiation producing equipment is present is a proper sign posted on the lab door?			
88	Are all laboratory personnel and users of radioactive material and or radiation producing equipment properly trained and registered with EHS?			
89	The radioactive material use area is marked properly?			
90	Radioactive materials are locked up when not in use?			
91	The GM meter is calibrated?			
92	Required Virginia Department of Health (VDH) Radiological postings are present in the lab?			
	Radioactive Waste	**Yes**	**No**	**N/A**
93	Radioactive waste is generated in this area? (**If "N/A", skip to question 95.**)			
94	Radioactive waste containers are properly labeled?			
	Cryogenic Materials	**Yes**	**No**	**N/A**
95	Cryogenic materials used in this area? (**If "N/A", skip to question 100.**)			
96	Personal protective equipment (i.e. gloves, goggles, faceshield) used to avoid skin/face contact?			
97	Used/dispensed with good ventilation?			
98	Is appropriate tubing for transferring of cyrogenic materials (e.g. metal or Teflon® tubing) being used?			
99	Containers vented or pressure relief devices provided?			
	Compressed Gases	**Yes**	**No**	**N/A**
100	Compressed gases used/stored in this area? (**If "N/A", the self-inspection is complete.**)			
101	Are compressed gas cylinders secured, in upright position, to prevent them from falling or tipping?			
102	Are all cylinders have labels that are legible and that clearly indicate if the cylinder is "Full", "In-Use", or "Empty"?			
103	Are incompatible gas cylinders in storage segregated (e.g. flammable and oxidizing gas cylinders must be separated by a distance of either 20 feet or a 5 foot high, ½ hour rated non-combustible wall)?			
104	Cylinder valves closed and valve caps in place when cylinders not in use?			
105	Are highly toxic gas cylinders stored in a gas cabinet, ventilated enclosure, or fume hood?			

Appendix K – Laboratory Self-Inspection Checklist Explanations

See Explanations and Citations Below - Contact EHS With Any Questions

Contact EHS at 540-831-7790 or ehs@radford.edu for questions or additional information.

	General Laboratory Safety
1	All accidents and exposures to harmful chemicals, no matter how minor, need to be reported to the supervisor, Human Resources (HR), and EHS.
2	The laboratory door must be closed and locked when no one is in the lab to secure hazardous materials and equipment. [Radford University Chemical Hygiene Plan; BMBL V 2009, Section IV, Page 30 & 33]
3	Feet must be covered when working in a lab. Closed toe shoes must be worn. [29 CFR 1910.132(d)(1)(i); Radford University Chemical Hygiene Plan]
4	Dependent on the specific hazards present in the lab, proper personal protective equipment must be used whenever there is a risk of exposure and when engineering controls are not a viable option. [29 CFR 1910.132; 29 CFR 1910.133; 29 CFR 1910.136; Prudent Practices 2011 Page 175-176; Radford University Chemical Hygiene Plan]
5	Store PPE properly and in a condition which will keep it maintained and prevent contamination. [29 CFR 1910.132; Radford University Chemical Hygiene Plan.]
6	Food and beverages may not be consumed, stored, or prepared in lab areas. [29 CFR 1910.1030(d)(2)(ix); Prudent Practices 2011 Page 109 Section 6.C.2.3]
7	Laboratory Door Sign(s) shall be posted with specific warning signs for the hazards present (chemicals, biohazards, radioactive materials or radiation producing equipment, Laser(s), etc.). [29 CFR 1910.145; 21 CFR 1040.10(g); Radford University Chemical Hygiene Plan]
8	Laboratory Door Sign(s) shall be posted with specific warning signs for the hazards present (chemicals, biohazards, radioactive materials or radiation producing equipment, laser(s), etc.). [29 CFR 1910.145; 21 CFR 1040.10(g); Radford University Chemical Hygiene Plan]
9	Dispose of clutter, including unnecessary boxes, old equipment, and trash. [29 CFR 1910.22(a)(1)]
10	Fire extinguisher must be unobstructed. [NFPA 10.6.1.3.1 to 10.6.1.3.3; 29 CFR 1910.157(c)(1)]
11	Remove obstruction(s) blocking emergency shower/eyewash to ensure clear access to this safety equipment. [ANSI Z358.1-2009 Section 4.5.2; 29 CFR 1910.151(c)]
12	Lab personnel must activate eyewash units once weekly. Keep a log to record weekly activation of eyewash units (EHS will provide an Eyewash Activation Log or tag upon request). [Radford University Chemical Hygiene Plan; ANSI Z358.1-2009]
13	Remove all items stored within the 18" plane below the level of the sprinkler heads, throughout the room. [NFPA 1.10.19.3]
14	Evacuation/exit routes must be clear of obstructions. [NFPA 101.3.3.161, 29 CFR 1910.36]
15	Floors dry and free from obstacles which could cause a trip or fall. [Prudent Practices 2011 Page 77 Section 4.E.10; 29 CFR 1910.22(a)(3)]
16	Missing/damaged ceiling tiles must be replaced to maintain smoke barrier. Submit a request to Facilities Work Control (540-831-7800). [NFPA 101.8.4.2(1)(2)]
17	Class IIIb and Class IV lasers must be registered with EHS and comply with provision of the Laser Safety Program. [Radford University Laser Safety Program; Radford University Chemical Hygiene Plan]

18	Lab doors must be kept closed to maintain fire barriers and proper ventilation in lab areas. [NFPA 45.8.3.3; NFPA 45.7.4; 29 CFR 1910.1450 App A]
19	Use of respirators will require enrollment in the University Respiratory Protection Program. [29 CFR 1910.134; Radford University Respiratory Protection Program]
20	Guard all exposed and moving parts of equipment, including pinch points and belts. [29 CFR 1910.212(a)(1); Prudent Practices 2011 Page 163 Section 7.C.8.4.2; Radford University Chemical Hygiene Plan]
21	Inspect rubber tubing for defects or degradation that could lead to leakage of natural gas or improper seal around the gas outlet nozzle. Replace rubber tubing if it is damaged or defective. [ASTM D 2531 Standard]
22	Inspect routinely laboratory equipment with potential hazards and maintain or service as recommended by the manufacturer. [Radford University Chemical Hygiene Plan]
Chemical Safety	
23	Does your lab use any chemicals or hazardous materials (chemicals can include many household products not generally considered as “chemicals” to most people)? (**If “N/A”, skip to question 58**)
24	A Chemical Hygiene Plan is required for either each lab or the department as a whole to cover the individual work spaces. [29 CFR 1910.1450(e)(1)]
25	Lab staff must review the Lab Safety Manual/Chemical Hygiene Plan/SOPs prior to beginning work. [29 CFR 1910.1450(e)(4); 29 CFR 1910.1450(f)(1); 29 CFR 1910.1200(g)(8)]
26	Laboratory employees must be provided general Hazard Communication and/or Laboratory Safety Training prior to beginning work in the lab. Work Area Specific Training must also be provided prior to beginning work. All training must be documented and kept on file. [Radford University Hazard Communication Program; Radford University Chemical Hygiene Plan; 29 CFR 1910.1200(h)(1)]
27	First aid and chemical spill kits shall be available in the lab. [29 CFR 1910.151(b); Radford University Chemical Hygiene Plan]
28	Clean up spilled material. [Radford University Chemical Hygiene Plan; 29 CFR 1910.1450]
29	Conduct assessments of hazards for new work and chemical usage. [29 CFR 1910.132(d)(1)]
30	Safety Data Sheets must be readily accessible. [29 CFR 1910.1200(b)(3)(ii); 29 CFR 1910.1450(h)(1)(ii)]
31	All chemicals must be barcoded and entered into the lab's chemical inventory within CHIMERA. [Radford University Chemical Hygiene Plan; 29 CFR 1910.1200]
32	Review and audit the lab's chemical inventory every 12 months (or within 30 days of a significant change – such as a move to a new location or addition of a large quantities of new chemicals). [Audits must be documented and kept on file.] [Radford University Chemical Hygiene Plan; 29 CFR 1910.1200]
33	Keep the lab free of chemicals that are old and no longer needed. [9VAC20-60; Radford University Hazardous Waste Guide; Radford University Chemical Hygiene Plan]
34	Chemical fume hoods must be tested annually. [29 CFR 1910.1450(e)(3)(iii)]
35	Remove clutter and/or chemicals stored in the fume hood and return them to storage cabinets or satellite accumulation areas. [NFPA 45.9.2.3.7; Prudent Practices 2011 Page 223 Section 9 C.2.5, Page 110 Section 6.C.2.4.1; Radford University Chemical Hygiene Plan]
36	Pull the fume hood sash down completely when hood is unattended. Pull down to lowest working level when working in the hood (no higher than 18"). [NFPA 45.8.8.3; Radford University Chemical Hygiene Plan]
37	Food/beverages must be stored in areas outside of the lab. Food/drinks and chemicals may not be stored in the same refrigerator/freezer. [Prudent Practices 2011 Page 97-98, Page 109 Section 6.C.2.3; Radford University Chemical Hygiene Plan]
38	Flammable chemicals may not be kept in a household style or commerical refrigerator/freezer or in a walk-in-cooler. The indication regarding non-flammable storage must be posted. [NFPA 45.12.2.2.2.1, Prudent Practices 2011 Page 98 Section 5.E.4]

Laboratory Self-Inspection Checklist
Explanations and Citations

39	Flammable chemicals needing refrigeration must be kept in a refrigerator/freezer that is safe for flammable storage. Flammable chemicals may not be kept in a household style or commerical refrigerator/freezer or in a walk-in-cooler. [NFPA 45.12.2.2.2.1]
40	Store flammable chemicals in a flammable storage cabinet. [NFPA 30.9.5]
41	Minimize storage quantities of chemicals to what is only necessary. [VCC Table 307.1(1); 29 CFR 1910.1450; Radford University Waste Minimization Plan; Radford University Chemical Hygiene Plan]
42	Ensure that all container (squeeze bottles, flasks, dilutions, etc.) are labeled with the complete name of the contents, even those that contain water or a part of equipment or experiments. The label should also include words, pictures, and/or symbols (e.g. pictograms) to notify users of the hazards of the chemical. Replace fading/deteriorated labels. [29 CFR 1910.1200(f)(9), Radford University Chemical Hygiene Plan]
43	Chemical containers must be clean, structurally sound, and closed when not in use. [29 CFR 1910.1200; 29 CFR 1910.1450; Radford University Chemical Hygiene Plan]
44	Secondary containment should be utilized to contain any leaks that may occur. [Radford University Chemical Hygiene Plan; 40 CFR Part 262]
45	Secondary containers shall be clean and free of spilled material. [Radford University Chemical Hygiene Plan]
46	Segregate chemicals by hazard class (flammable, corrosive, oxidizer, reactive, toxic) or other approved segregation method. Do not store chemicals alphabetically. [NFPA 45.9.2.3.2, Radford University Chemical Hygiene Plan]
47	Do not store chemicals directly on the floor. Rather, store them in approved cabinets or in secondary containment large enough to hold the entire contents of the bottle in case of a spill/leak. [Prudent Practices 2011 Page 95 Section 5.E.1, Page 113 Section 6.C.3; Radford University Chemical Hygiene Plan]
48	Periodically review chemical inventory and dispose of old chemicals that are no longer used. Label-non time-sensitive chemicals that are still in use with current "in use" date. [Radford University Chemical Hygiene Plan]
49	Explosive peroxide forming chemicals and oxidants such as ethyl ether, tetrahydrofuran (THF), perchloric acid, cyclohexane, butadiene, isopropyl ether, and dioxanes must be used within 1 year of purchase or 6 months after opening and must be disposed of before the expiration date. Tag these chemicals for disposal immediately if past these time constraints. [NFPA 45.9.2.3; Radford University Chemical Hygiene Plan]
50	Chloroform should be used within 1 year of purchase or 6 months after opening, it can form phosgene gas upon decomposition. Dispose of any chloroform once these time limits have passed. This is also true for chlorform with stabilizers added. [NPFA 45.9.2.3.4]
51	Do not store hazardous liquid chemicals above the eye level of the shortest person working in the lab. [Prudent Practices 2011 Page 95 Section 5.E.1, Page 114 Section 6.C.5; Radford University Chemical Hygiene Plan]
52	Hazardous material quantities must be within limits allowed by the Virginia Fire Code. [VCC Table 307.1(1)]
53	Dispose of broken glass in a covered sturdy box marked "BROKEN GLASS". Do not overfill glass waste container. [Prudent Practices 2011 Page 100 Section 5.E.6; Radford University Chemical Hygiene Plan]
54	Label consumer commodities/equipment (food coloring, popcorn, ice machines, etc.) as "Not For Human Consumption", "For Research Purposes Only", "For Experimental Use Only" or similar. [Radford University Chemical Hygiene Plan; 29 CFR 1910.1200; 29 CFR 1910.1450]
55	Process that emit vapors, gases, or fumes shall be adequately captured by local ventilation (fume hoods, exhaust vent, snorkel). [29 CFR 1910.1450 App A; Radford University Chemical Hygiene Plan]
56	Ethanol greater than 190 proof must be stored in a locked flammable storage cabinet. [3VAC5-70-60; Radford University Chemical Hygiene Plan]
57	Flame resistant labs coats must be worn when working with pyrophoric materials. [NFPA 45.6.6.2; Radford University Chemical Hygiene Plan]

Laboratory Self-Inspection Checklist
Explanations and Citations

	Electrical Safety
58	Extension cords are for temporary use only. Replace with fuse-protected power strip or permanent wiring. Extension cords/power strips should be plugged directly into wall receptacle, not "daisy-chained" or connected in series. [IFC 605.5]
59	No exposed wiring or damaged electrical cords. [NFPA 70; NFPA 70E; 29 CFR 654.5(a)(1); Radford University Chemical Hygiene Plan]
60	Equipment with motors, heaters, and other high amperage needs are to be plugged directly into a wall receptacle. [NFPA 70; NFPA 70E; NFPA Electrical Safety Guide]
61	GFCIs should be installed for electrical outlets located within 6 feet of wet areas. [NFPA 70.210.8(B)(5)]
62	Circuit breaker and electrical panels shall be unobstructed (at least 36" clearance is required in front a panel). [NFPA 70; NFPA 70E]
	Hazardous Waste
63	Hazardous chemical waste is generated in this area? (**If "N/A", skip to question 75**)
64	Label chemical waste container utilizing the EHS supplied "Hazardous Waste" label. [Radford University Hazardous Waste Guidebook; Radford University Chemical Hygiene Plan]
65	List the chemical contents on the "Hazardous Waste" label, ensuring that the complete name of each of the contents is identified. [NFPA 45.9.3; 29 CFR 1910.1200(f)(9); Radford University Hazardous Waste Guidebook; Radford University Chemical Hygiene Plan]
66	Hazardous waste in lab should be less than 12 months old. [9VAC20-60; 40 CFR Part 262; Radford University Hazardous Waste Guide; Radford University Chemical Hygiene Plan]
67	Waste containers shall be kept closed unless adding waste. [9VAC20-60; 40 CFR Part 262; Radford University Hazardous Waste Guide; Radford University Chemical Hygiene Plan]
68	Waste containers shall be in good condition (not leaking, rusted, bulging, damaged, etc.) and compatible with their contents. [9VAC20-60; 40 CFR Part 264.171; Radford University Hazardous Waste Guide; Radford University Chemical Hygiene Plan]
69	Waste containers storing liquid hazardous waste shall be stored within secondary containment. [9VAC20-60; 40 CFR Part 267.195; Radford University Hazardous Waste Guide; Radford University Chemical Hygiene Plan]
70	Secondary containment shall be in good condition (free of cracks, gaps, impervious to leaks). [9VAC20-60; 40 CFR Part 267.195; Radford University Hazardous Waste Guide; Radford University Chemical Hygiene Plan]
71	Incompatible waste must be segregated. [9VAC20-60; 40 CFR Part 265.177; Radford University Hazardous Waste Guide; Radford University Chemical Hygiene Plan]
72	Satellite Accumulation Area (SAA) must be located at or near where waste is generated. [9VAC20-60; 40 CFR Part 262.15; Radford University Hazardous Waste Guide; Radford University Chemical Hygiene Plan]
73	Maximum SAA storage capacity not to exceed (55 gallons). [9VAC20-60; 40 CFR Part 262.15; Radford University Hazardous Waste Guide; Radford University Chemical Hygiene Plan]
74	Weekly SAA checklists to be completed and documented. [9VAC20-60; 40 CFR Part 265.174; Radford University Hazardous Waste Guide; Radford University Chemical Hygiene Plan]
	Biosafety
75	The lab is a BSL-1 or BSL-2 or an ABSL laboratory? (**If "N/A", skip to question 83**)
76	Running water, soap, and paper towels are needed for handwashing. [29 CFR 1910.130(d)(2)(iv); BMBL V 2009; Radford University Chemical Hygiene Plan]
77	Biohazard signs shall be posted outside of all labs handling biohazardous materials. [BMBL V 2009, Section VI, Page 106; Radford University Chemical Hygiene Plan]

78	Lab coats, gowns, or scrubs shall be used in labs handling biohazardous materials. [BMBL V 2009; Radford University Chemical Hygiene Plan]
79	Decontaminate work surfaces after completion of work and after any spill or splash of potentially infectious material with appropriate disinfectant. Decontaminate all cultures, stocks, and other potentially infectious materials before disposal using an effective method. Laboratory equipment should be routinely decontaminated, as well as, after spills, splashes, or other potential contamination. Spills involving infectious materials must be contained, decontaminated, and cleaned up by staff properly trained and equipped to work with infectious material. Equipment must be decontaminated before repair, maintenance, or removal from the laboratory. [BMBL V 2009, App B Page 326; Radford University Chemical Hygiene Plan]
80	Are biohazard warnings on freezers, refrigerators, storage units, and other types of equipment? [29 CFR 1910.1030(g)(1)(i)(A); BMBL V 2009, App B Page 386; Radford University Chemical Hygiene Plan]
81	Vacuum lines should be protected with HEPA filters, or their equivalent. [BMBL V 2009; Radford University Chemical Hygiene Plan]
82	Biological safety cabinets shall be certified every 12 months. [BMBL V 2009, App A Page 290; Radford University Chemical Hygiene Plan]
Biohazardous Waste/Regulated Medical Waste	
83	Regulated medical waste/biohazardous waste or "sharps" generated in this area? (**If "N/A", skip to question 86**)
84	Biohazardous BSL-1 and/or BSL-2 and/or ABSL waste shall be autoclaved in a timely manner. [BMBL V 2009; Radford University Chemical Hygiene Plan]
85	Use an approved sharps container for collection of sharps. [29 CFR 1910.1030; Radford University Chemical Hygiene Plan]
Radiation Safety	
86	Is radioactive material or radiation producing equipment used in this lab? (**If "N/A", skip to question 93**)
87	If radioactive material or radiation producing equipment is present a proper sign must be posted on the lab door. [12VAC5-481; Radford University Chemical Hygiene Plan; Radford University Radiation Safety Program]
88	Lab personnel utilizing radioactive material or radiation producing equipment must be trained and registered with EHS. [12VAC5-481; Radford University Chemical Hygiene Plan; Radford University Radiation Safety Program]
89	The radioactive material use area must be marked properly. [12VAC5-481; Radford University Chemical Hygiene Plan; Radford University Radiation Safety Program]
90	Radioactive materials shall be locked up when not in use. [12VAC5-481; Radford University Chemical Hygiene Plan; Radford University Radiation Safety Program]
91	If utilizing a GM meter is necessary, ensure it is calibrated. [12VAC5-481; Radford University Chemical Hygiene Plan; Radford University Radiation Safety Program]
92	Required Virginia Department of Health (VDH) Radiological postings must be present in the lab. [12VAC5-481; Radford University Chemical Hygiene Plan; Radford University Radiation Safety Program]
Radioactive Waste	
93	Radioactive waste is generated in this area? (**If "N/A", skip to question 95**)
94	Radioactive waste containers must be properly labeled. [12VAC5-481; Radford University Chemical Hygiene Plan; Radford University Hazardous Waste Guidebook; Radford University Radiation Safety Program]
Cryogenic Materials	
95	Cryogenic materials used in this area? (**If "N/A", skip to question 100**)
96	Personal protective equipment (i.e. gloves, goggles, faceshield) shall be used to avoid skin/face contact. [29 CFR 1910.132; 29 CFR 1910.133; 29 CFR 1910.136; Prudent Practices 2011 Page 175-176; Radford University Chemical Hygiene Plan]

97	Ensure adequate ventilation where cryogenic materials are used. [29 CFR 1910.1450; Radford University Chemical Hygiene Plan]
98	Do not use Tygon® Tubing or plastic tubing. They may split or shatter when cooled by the liquid flowing through it and could cause injury to personnel. [29 CFR 1910.101; NFPA 55.8.13.2; Radford University Chemical Hygiene Plan]
99	Ensure pressure relief for cryogenic cylinder is not compromised. [NFPA 55.8.2.5]
Compressed Gases	
100	Compressed gases used/stored in this area? (If “N/A”, the self-inspection is complete.)
101	Properly secure compressed gas cylinder(s) with a device designed for such use. [NFPA 45.11.1.5.1; NFPA 45 Annex F.17]
102	Cylinders shall have labels that are legible and that clearly indicate if the cylinder is “Full”, “In-Use”, or “Empty”. [CGA P-1; Radford University Chemical Hygiene Plan]
103	Incompatible gas cylinders in storage must be segregated (e.g. flammable and oxidizing gas cylinders must be separated by a distance of either 20 feet or a 5 foot high, ½ hour rated non-combustible wall). [29 CFR 1910.253(b)(4)(iii); Radford University Chemical Hygiene Plan; NFPA 45]
104	Cylinder valves closed and valve caps in place when cylinders not in use? [29 CFR 1910.253(b)(5)(ii)(G); Radford University Chemical Hygiene Plan; NFPA 45]
105	Highly toxic gas cylinders shall be stored in a gas cabinet, ventilated enclosure, or fume hood. [29 CFR 1910.1450; Radford University Chemical Hygiene Plan; NFPA 45]

Appendix L – Laboratory Risk Assessment

LABORATORY RISK ASSESSMENT

A Laboratory Risk Assessment provides a framework for risk assessment complimenting the process researchers already use to answer scientific questions.

This tool provides a format for researchers to systematically identify and control hazards to reduce risk of injuries and incidents. Conduct a risk assessment prior to conducting an experiment for the first time.

The risk assessment process involves rating the risk of the experiment from “low” to “unacceptable” risk. Consult with your PI/supervisor and EHS if your risk rating is “high” or “unacceptable” to redesign the experiment and/or implement additional controls to reduce risk.

Procedure:	
PI / Lab Group:	
Department:	**Building / Location:**
Form Completed By:	**Start Date:**

PHASE 1: EXPLORE

Identify your research question and approach. What question are you trying to answer? What are you trying to measure or learn? What is your hypothesis? What approach or method will you use to answer your question? Are there alternative approaches?

Research Question(s)

Approach(s) or Method

Identify the general hazards (check all that apply). Perform background research to identify known risks of the reagents, reactions, or processes. Review protocols, Safety Data Sheets (SDSs), and safety information for hazardous chemicals, agents, or processes. Review accident histories within your laboratory/department.

Hazardous Agents

Physical Hazards of Chemicals

☐ Compressed gases

☐ Cryogens

☐ Explosives

☐ Flammables

☐ Organic peroxides

☐ Oxidizers

☐ Peroxide formers

☐ Pyrophorics

☐ Self-heating substances

☐ Self-reactive substances

☐ Substances which, in contact with water, emit flammable or toxic gases

Health Hazards of Chemicals

☐ Acute toxicity

☐ Carcinogens

☐ Eye damage/ irritation

☐ Germ cell mutagens

☐ Nanomaterials

☐ Reproductive toxins

☐ Respiratory or skin sensitization

☐ Simple asphyxiant

☐ Skin corrosion/ irritation

☐ Specific target organ toxicity

☐ Hazards not otherwise classified

Ionizing Radiation

☐ Irradiator

☐ Radionuclide

☐ Radionuclide sealed source

☐ X-ray machine

Non-Ionizing Radiation

☐ Lasers, Class 3 or 4

☐ Lasers, Class 2

☐ Magnetic fields (e.g., NMR, MRI)

☐ RF/microwaves

☐ UV lamps

Biohazards

☐ BSL-2 Biological agents

☐ BBP - Human cells/blood

☐ NHPs/cells/blood

☐ Exempt rDNA

☐ Non-exempt rDNA

☐ Animal work

☐ Zoonotic agents

☐ Other (list):

Hazardous Conditions or Processes

Reaction Hazards

☐ Explosive

☐ Exothermic, with potential for fire, excessive heat, or runaway reaction

☐ Endothermic, with potential for freezing solvents decreased solubility or heterogeneous mixtures

☐ Gases produced

☐ Hazardous reaction intermediates/products

☐ Hazardous side reactions

Hazardous Processes

☐ Generation of air contaminants (gases, aerosols, or particulates)

☐ Heating chemicals

☐ Large mass or volume

☐ Pressure > atmospheric

☐ Pressure < atmospheric

☐ Scale-up of reaction

Other Hazards

☐ Hand/power tools

☐ Moving equipment/parts

☐ Electrical

☐ Noise > 80 dBA

☐ Heat/hot surfaces

☐ Ergonomic hazards

☐ Needles/sharps

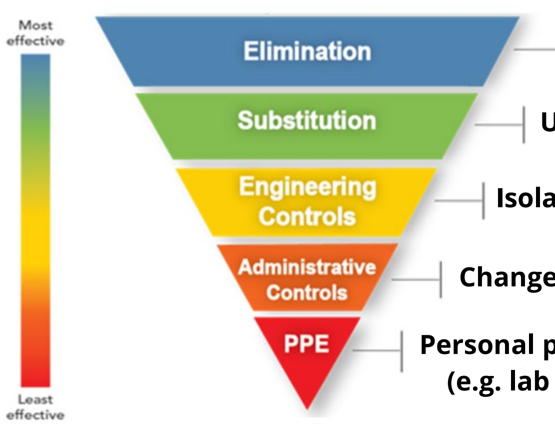
☐ Other (list):

PHASE 2: PLAN

Outline the Procedure. List the steps or tasks for your procedure and the hazard/potential consequences of each. Include set-up and clean-up steps or tasks. Define the hazard controls to minimize the risk of each step using the hierarchy of controls starting with the most effective (i.e., elimination, substitution, engineering controls, administrative controls, and personal protective equipment). List the hazard control measure you would use for each step or task (e.g., work in a fume hood, wear face shield and goggles).

Steps or Tasks	Hazard	Hazard Control Measure(s)

HIERARCHY OF CONTROLS



Eliminate use of chemical or hazard

Use a less hazardous chemical, concentration, or process

Isolate people from hazard (e.g. ventilation, barriers)

Change the way people work (e.g. training, work policies, SOPs)

Personal protective equipment (e.g. lab coat, appropriate gloves, goggles)

A hierarchy of controls should be applied starting with the most effective controls (i.e., elimination and substitution) at the top of the graphic and moving down. While personal protective equipment (PPE) should always be used, it should be considered the last line of defense from potential hazards.

Select the appropriate PPE and safety supplies for the procedure (check all that apply).

Laboratory PPE/Safety Equipment

☒ Appropriate street clothing (long pants, closed shoes)

☐ Disposable Gloves - indicate type:

____

☐ Other Gloves - indicate type:

____

☐ Safety glasses

☐ Safety goggles

☐ Face shield and googles

☐ Lab coat

☐ Flame-resistant lab coat

☐ Fire extinguisher

☐ Emergency shower/eyewash station

☐ First aid kit

☐ Spill kit

☐ Specialized medical supplies (e.g. calcium gluconate for hydrofluoric acid and amyl nitrite for cyanides

☐ Other (list):

Identify the appropriate training (check all that apply). Identify the general safety and procedure based/specific training appropriate for your procedure.

General Safety Training

General/Chemical Safety

☐ Lab Safety

☐ Hazard Communication

☐ Compressed Gas Safety

☐ Fume Hood Training

☐ Autoclave Training

☐ Cryogenics Safety

Biosafety

☐ Bloodborne Pathogens

☐ Biosafety Training

☐ Biosafety Cabinet Training

☐ Lab Acquire Infections

Radiation Safety

☐ Radiation Safety

☐ Laser Safety

Respiratory Protection Safety

☐ Respiratory Protection Training

Job Specific Training

☒ Lab/job-specific training

☐ Lab SOP(s) to review (list):

☐ Emergency plans or field evacuation plans

☐ Equipment SOP(s) to review (list):

☐ Other (list):

PHASE 3: CHALLENGE

Question your methods. What have you missed and who can advise you? Challenge your hazard control measures by asking "What if…?" questions. "What if" questions should challenge you to find the gaps in your knowledge or logic. Include possible accident scenarios. Factors to consider are human error, equipment failures, and deviations from the planned/expected parameters (e.g., temperature, pressure, time, flow rate, and scale/concentration). Update your plan to include any new controls required to address these possibilities.

What If Analysis
What if…? Examples: there is a loss of cooling? …valves/stopcocks are left open/closed? …there is unexpected over-pressurization? …a spill occurs? …the laser is misaligned? …weather conditions change?
Then… there may be a runaway reaction. …there may be an unexpected splash potential. …the reaction vessel may fail. …there may be a dermal exposure. …there may be an eye injury. …routes may be inaccessible.
What if…?
Then…
What if…?
Then…
What if…?
Then…
What if…?
Then…
What if…?
Then…
What if…?
Then…
What if…?
Then…

Assign a risk rating to the experiment. Based on your procedure outline and the what if analysis, determine the risk rating for the experiment or procedure.

Risk Rating: ____________________

1The Risk Rating is subjective. The primary goal is for researchers to think about risk, and differentiate unacceptable and high-level risk steps from those with a lower level risk. This will help drive additional consultation and control measures where needed.

Likelihood of Incident Occurrence	Severity of Consequences – Personnel Safety			
	No injuries	Minor Injury	Significant Injury	Life threatening
Very Likely	Low	High *	Unacceptable **	Unacceptable **
Likely	Low	Medium	High *	Unacceptable **
Possible	Low	Medium	High *	High *
Rare	Low	Low	Medium	High *

Revise plan if the risk rating is too high. Are these risks acceptable? Use this table to determine the action to take based on the risk rating. What are the highest risk steps? What more can you do to control the risks? Return to planning and use the hierarchy of controls to design a safer experiment.

Hazard Risk Level	Action
Unacceptable **	**STOP!** Additional controls needed to reduce risk. **Consult with PI.**
High *	Additional controls recommended to reduce risk. **Consult with PI.**
Medium	Ensure you are following best practices. Consult with peers, PI, and EH&S as needed.
Low	Perform work within controls

PI/Supervisor Approval:

____

***Signature for High** risk ratings. If needed, contact EHS (540-831-7790) for recommendations.

NOTE: **Unacceptable risk-rated experiments **should not proceed**. Introduce further controls to reduce risk. Contact EHS (540-831-7790) for recommendations and best practices.

PHASE 4: ASSESS

Perform a trial run. How you can test your experimental design? Can you do a dry run of the procedure without hazardous chemicals/reagents/gases to familiarize yourself with equipment and demonstrate your ability to manipulate the experimental apparatus? Can you run the procedure with a less hazardous material? Can you test your experimental design at a smaller scale? If your procedure requires multiple people, would a tabletop exercise be useful?

Trial Run
Trial Run Procedure / Date:
Did the trial go as expected? Yes ☐ No ☐
Experimental design changes needed (if any):

Perform and evaluate. Run your procedure using the appropriate controls you've identified. Evaluate controls and hazards as you work. Analyze the controls and process you used by answering the following questions. If changes to controls are needed, update your risk assessment tool and re-evaluate any time you revise your process (e.g. changes in scale, reagent, equipment, or conditions that might increase the hazard/risk). Share your assessment with your PI/colleagues for the next iteration of the experiment.

Evaluate Your Procedure
What went well?
Did the controls perform as expected?
Did anything unexpected occur?
Did a hazard manifest itself that was not previously identified?
Were there any close-calls or near misses that indicate areas of needed improvement?
Did something go exceptionally well that others could learn from?
I plan to evolve my procedure by…

Procedure Risk Assessment is Complete	
Form Completed By:	
Signature:	**Date:**
PI / Supervisor Signature:	

Appendix M – Alternatives for Laboratory Work With Open Flames

Recommended Alternatives for Laboratory Work with Open Flames

Are open flames in laboratories necessary?

Open flames have been used for many types of work and experimental procedures. Depending on your laboratory work, there may be alternatives to open flames that minimize the risks. As a best practice, we discourage the use of open flames in laboratories and instead encourage using alternative methods that do not require open flames. When work with open flames cannot be avoided, follow safe practices.

➢ **Open flame risks**

- Using open flames near flammable solvents or other combustible materials may cause flash fires, explosion, rapid spread of fire, and generate toxic combustion products. An example of what could happen can be found at https://ehs.stanford.edu/reference/ethanol-improper-sterilization-fire-risk-lessons-learned.
- Faulty or leaking Bunsen burners or hoses can cause highly flammable gas to escape.
- Open flames in biological safety cabinets creates turbulence that disrupts the pattern of HEPA-filtered air being supplied to the work surface, contaminating your work.

➢ **Laboratory work with recommended open flame alternatives**

No open flames needed and less environmental impact compared to natural gas usage

Laboratory Work	Alternatives	Pros	Cons
Sterilization	Autoclave	- Rapidly microbicidal - Penetrates medical packing - Rapid cycle time	- Deleterious for heat sensitive instruments - Microsurgical instruments may be damaged by repeated exposure - May leave instruments wet, causing them to rust - Potential for burns
	Sterile disposables	- Pre-sterilized and designed for single use - No risk of cross contamination and no need for flaming	- Creates waste
	Glass bead sterilizer	- Ideal for sterilizing surgical instruments with dry heat using glass beads at 233 °C - Can sterilize submerged portion of surgical instrument in 15 seconds - Replacement glass beads can be purchased separately - No gas line or open flame needed	- Only sterilizes surgical instruments

Laboratory Work	Alternatives	Pros	Cons
Yeast or bacterial colony work	Disposable spreaders/pickers/loops	- No heat/flame sterilization needed	- Creates waste
	Bacti-cinerator	- Sterilizes loops and needles by infrared heat - Heat is contained in deep ceramic tube to protect laboratory personnel - Completes sterilization in 5-7 seconds at 1500 °F (815°C)	- Types of items able to be sterilized are limited
	Autoclavable reusables	- Reusable items reduce waste - One-time purchase	- Microsurgical instruments can damaged by repeated autoclaving - Autoclave may leave instruments wet, causing them to rust - Higher risk of cross contamination
Drawing/pulling pipettes	Pre-pulled glass pipettes	- Less physical work - Less risk of glass injury - More consistency with pulled pipettes	- May be more expensive than making your own
Histology	Slide-warming tray	- Provides even heat transfer - Able to warm up multiple slides - Precise temperature control	- Slide-warming tray costs $400-$500
	Alternative stains or methods	- Can obtain better results without heat (no shrinkage, etc.) - May require more research to find	- Alternative stains costs may vary - Alternative stain chemicals may be more hazardous (e.g. methanol) - Slides take more time to air dry without heat
Drying glassware for water-sensitive chemistry	Oven overnight followed by cooling in a desiccator	- Less risk of injury or equipment damage	- Takes more time to dry
Heating flasks, beakers, crucibles, etc.	Hot plates - Can heat larger items	- Some hot plates have magnetic stir function with heating	- Older models of hot plates can cause runaway heating and fires
Heating smaller flasks, test tubes, smaller beakers, crucibles, etc.	Electric Bunsen burner	- Vented housing keeps base cool enough to hold during operation - Burner consumes only 400W of power - No gas line or open flame needed	- Items able to be heated are limited by size

➢ **If the use of open flame is unavoidable,** have an SOP in place to ensure equipment or gas is shut off between uses; have an emergency shut-off valve that is accessible to the user; if possible, use equipment that has a dimmer switch; **f**ollow safe practices, and **c**ontact EHS for an evaluation.

Appendix N – Decontamination Certificate

Version 12-2016

LAB EQUIPMENT DECONTAMINATION FORM

< PLEASE COMPLETE & DISPLAY THIS FORM ON EQUIPMENT >

OWNER / CUSTODIAN OF EQUIPMENT:	BUILDING /ROOM LOCATION:
EQUIPMENT MODEL NAME OR #:	UNIT SERIAL #:
EQUIPMENT DESCRIPTION:	
RESPONSIBLE PERSON TO BE AVAILABLE ON DATE OF SERVICE FOR QUESTIONS, ETC.: (name) (room/office #) (phone #)	

***IMPORTANT:** ALL EQUIPMENT SURFACES (INCL. TOP, SIDES, BACK) AND AREAS BEHIND AND UNDER THE UNIT MUST BE 1) CLEANED AND FREE OF DIRT, LAB DEBRIS, RESIDUE, ETC. AND 2) DISINFECTED/ DECONTAMINATED IF USED WITH HAZARDOUS MATERIALS. <u>SEE INSTRUCTIONS ON BACK OF FORM.</u>*

☐ BIOLOGICAL MATERIALS ☐ N/A

This unit was disinfected by ____(name) at __________________ (phone #) on ______________ (date) <u>prior</u> to service call or move.

Disinfection agents/methods used:

☐ RADIOACTIVE MATERIALS ☐ N/A

This unit was surveyed by ____(name) at _____________________ (phone #) on ______________ (date) and found to be clean <u>prior</u> to service call or move, including WIPE TEST for radioactive contamination.

Radiation-clearing agents/methods used:

☐ HAZARDOUS CHEMICALS ☐ N/A

This unit was cleaned by ____(name) at _____________________ (phone #) on ______________ (date) and was found to be residue-free <u>prior</u> to service call or move.

Chemical deactivation agents/methods used:

☐ HAZARD-FREE

To the best of my knowledge, I certify that this lab has not used this unit with biological agents, chemicals or radioactive materials, and that it was cleaned with detergent on________________(date) <u>prior</u> to service call or move.

____________________________________(name) ___________________ (phone #)

Instructions for Lab Personnel

1. **USE THIS FORM WHEN:**
   - Lab equipment needs to be certified or serviced by technicians, or by Facilities staff.
   - Lab equipment requires relocation or transport by VT movers, hired movers or VT Surplus.

2. **ACTIONS TO TAKE:**
   - Clean all dirty equipment surfaces that you can access with a detergent solution.
   - Disinfect/ decontaminate accessible inner and outer surfaces according to hazards present.
   - Clean and disinfect/decontaminate the area around the unit, if needed.

3. **WHEN YOU CAN'T MOVE HEAVY EQUIPMENT TO CLEAN AROUND IT:**
   - Be present when service providers/movers arrive and ask them to reposition the unit.
   - Clean/decon equipment surfaces and floor area that become accessible after unit is moved.

4. **COMPLETING THE FORM**
   - Fill out all required sections (1st block) and all applicable sections (2nd block) of this form after cleaning/decontamination is complete.
   - Attach completed form to the equipment, *and keep a copy with your equipment's service records.*

5. **PROCEDURES FOR SPECIFIC HAZARDS:**

   Chemicals -- Deactivate all hazardous chemicals by appropriate methods, esp. mutagens, corrosives, toxics, mercury or other metals.

   Biological Agents -- Use an appropriate disinfectant for the full contact time.

   Radioactive Materials -- Decontaminate using the appropriate methods. *Equipment must be wipe tested by the person performing the decontamination, and found free of radioactive contamination.*

6. **IMPORTANT:**
   - Equipment lacking a completed, attached form will not be serviced or transported.
   - In addition, equipment displaying a Decontamination Form will not be serviced or transported if it is found to be in a questionable state of cleanliness. Service providers/movers can suspend their activity until such time as the unit and/or the area around the unit has been sufficiently cleaned and decontaminated/disinfected.

Instructions for Service Providers/Movers/Surplus Property

1. When moving equipment:
   - Put on PPE and reposition large or heavy units, if necessary, so lab workers can finish cleaning.
   - Check that Decontamination Form for the equipment is present and completely filled out.
   - Check that equipment, equipment location, & your work area are clean and free of hazards before moving the equipment.
   - Keep the Decon Form and attach it to your work order documents or Surplus Property Report.
   - Wear appropriate PPE when handling/ moving equipment (minimum: disposable gloves).

2. Report any problems to your supervisor and/or the responsible party listed on the form; do not proceed with the work order until the situation has been corrected.

3. In the unlikely event that tools or moving equipment come into direct contact with hazardous materials in the lab, ask lab personnel to apply appropriate disinfecting/decontaminating agents.

Appendix O – Supplemental Laboratory Safety Plan

Laboratory Safety Plan

Introduction

A laboratory safety plan is a document that describes the general rules of conduct and other information useful in helping to prevent laboratory incidents and to appropriately respond to any incidents that may occur. A laboratory safety plan is appropriate for those labs where chemical usage is minimal to non-existent. For labs where chemical usage is higher, a Chemical Hygiene Plan should be developed and used in place of a lab safety plan, in compliance with OSHA's Laboratory Standard (29 CFR 1910.1450).

At Radford University, laboratory personnel are responsible for the preparation of their own lab specific Lab Safety Plan. The plan may cover one or more rooms/laboratories associated with a work group or laboratory curse and should consider all health and safety issues involved with that lab's work.

This Lab Safety Plan is a template that can be used by any Radford University laboratory where chemical use is minimal to non-existent. Filling in the specific information for your laboratory will complete this plan. The plan must then be reviewed by and made readily available to all lab personnel. The plan should be reviewed annually to ensure the continuing accuracy of the plan. This review may be done by the Principal Investigator, Instructor of Record, or another appropriately designated person.

Laboratory Information

Laboratory Unit:

Instructor of Record or Principal Investigator:
Office Location:
Work Phone Number:
Alternate Phone Number:

Department Chair:
Office Location:
Work Phone Number:
Alternate Phone Number:

General Laboratory Safety Rules

The following rules should be observed at all times to minimize the risk of accidental injury to yourself and/or others.

1. Appropriate clothing is required to work in this laboratory. Appropriate clothing for this lab is:

2. Appropriate Personal protective equipment (PPE) maybe required for some work in this lab. PPE will be described in a section below.

3. No eating, drinking, chewing gum, or applying cosmetics is allowed in the laboratory. Long hair should be pulled back.

4. Do not work with lab equipment unless you have reviewed the safety information regarding that equipment. In addition, read your laboratory procedure carefully *before* beginning any part of the experimental procedure.

5. Do not perform unauthorized experiments or make modifications to the procedure of an experiment without your instructor's or Principal Investigator's permission.

6. No horseplay is allowed in the lab.

7. Deliberate mishandling of laboratory equipment is strictly forbidden and may be harmful or fatal.

8. Do not sit on the lab benches.

9. Experiments in progress are not to be left unattended.

10. Mouth suction should never be used to pipet, start a siphon, or for any other purpose.

11. Report all incidents to your lab instructor or Principal Investigator.

12. Ensure that your lab area remains as clean as the work allows.

Specific Laboratory Rules

Personal Protective Equipment

The following personal protective equipment (PPE) is required in this laboratory:

Control Measures

First Aid Kit is located

Chemical Spill Kit is located

Emergency eyewash station(s) is/are located

Emergency Shower is located

Fire Extinguisher(s) is/are located

Waste Disposal

Regular Trash: This can be placed in the trashcans in the laboratory.

Broken Glass: This is to be placed in the broken glass box which is located

Sharps: These are to be placed in a Sharps container which is located

Hazardous Materials: These are to be disposed of according to the directions of your Lab Instructor or Principal Investigator.

Emergency Response

Evacuation Alarm: In the event of a building evacuation, turn off all sources of heat and suspend all experiments in progress and exit the building according to the evacuation route located near the lab exit(s). All persons evacuating this lab shall assemble at the evacuation assembly point designated for this building.

Fire: If a fire occurs in the lab, do not attempt to extinguish it yourself if you are not trained in the proper use of an extinguisher. Inform the lab instructor/Principal Investigator. If the fire cannot be safely extinguished, evacuate the lab and activate the nearest fire alarm.

Broken glass/chemical spills: Inform the lab instructor or Principal Investigator and follow their directions.

Injuries: Inform the lab instructor immediately or Principal Investigator immediately and follow their directions.

Hazard Communication Addendum

Note: Only include this if your lab uses chemicals

General Introduction

A Hazard Communication plan is a written program developed to detail how hazards are communicated in an area and how the personnel working in that area can protect themselves from those hazards. It fulfills the intention of OSHA's Hazard Communication Standard (29 CFR 1910.1200) by providing workers and students with information to help them make knowledgeable decisions about chemical hazards in their area. Employees and students have the right to know and understand the hazards they are working with, and the right to be protected from those hazards.

The administration of Radford University is committed to preventing accidents and ensuring the safety and health of its employees and students. Radford will comply with all applicable federal and state health and safety rules and provide a safe, healthful environment for all their employees and students. This written hazard communication plan is available at the following location for review by all area personnel:

Identifying hazardous chemicals

A list is included with this plan that identifies all hazardous chemicals with a potential for exposure in this area. Detailed information about the physical, health, and other hazards of each chemical is included in a Safety Data Sheet [SDS]; the product identifier (name, CAS #, etc.) for each chemical on the list matches and can be easily cross-referenced with the product identifier on its label and on its Safety Data Sheet.

☐ List of hazardous chemicals included

☐ Safety Data Sheets available

Identifying containers of hazardous chemicals

All hazardous chemical containers used at this area will be labeled with either the original manufacturer's label --that includes a product identifier, an appropriate signal word, hazard statement(s), pictogram(s), precautionary statement(s) and the name, address, and telephone number of the chemical manufacturer, importer, or other responsible party -- OR a label with the appropriate label elements just described; OR workplace labeling that includes the product identifier and words pictures, symbols, or a combination thereof that provide at least general information regarding the hazards of the chemicals.

It is the responsibility of all personnel working in the area to ensure that all containers are appropriately labeled. Workplace labels must be legible and in English. Environmental Health & Safety personnel will also check for proper labeling during audits of the area.

Keeping Safety Data Sheets

Safety Data Sheets are readily available to all personnel working in this area. Employees can review Safety Data Sheets for all hazardous chemicals used in this area.

If a Safety Data Sheet is not immediately available for a hazardous chemical, employees can obtain the required information by looking online in CHIMERA. They may also call Environmental Health & Safety at 831-7790 for assistance.

Training employees about chemical hazards

Before they start their work or are exposed to new hazardous chemicals, workers must attend a hazard communication training that covers the following topics:

- An overview of the requirements of OSHA's Hazard Communication Standard.
- The various routes of chemical exposure and the types of exposures.
- The types of hazards that chemicals present.
- The types of labeling systems currently in use.
- How to understand and use the information on labels and in (Material) Safety Data Sheets.
- The types of personal protective equipment that can be used to reduce exposures.
- The steps to take in responding to a chemical spill.
- Emergency procedures to follow if a chemical exposure occurs.

This training is provided by Environmental Health and Safety and is required to be completed on an annual basis.

Accuracy, Annual Review and Updates

I affirm that this Laboratory Safety Plan is accurate and that it provides information for the health and safety of personnel in this area.

Instructor/Principal Investigator

Signature	Printed Name	Date

EH&S Contact Information

Main Phone: 540-831-7790

ehs@radford.edu

Appendix P – Autoclave Standard Operating Procedures

Procedures for Decontamination of Biohazard Waste by Autoclaving

Purpose:

Biohazardous waste material and sharps containers generated in research and teaching laboratories are required to be rendered non-infectious in an autoclave(s) where validations are performed and disposed of using the appropriate waste streams.

The procedures below serve as guidelines to help autoclave users ensure safe and effective processing.

1. **Select appropriate containers or bags for collecting materials to be autoclaved. Collection areas and/or bags must be labeled with the symbol.**

✸ **For biohazardous dry solid materials:**

a. Collect in polypropylene AUTOCLAVE bags.

b. DO NOT use the red bags that come with the Regulated Medical Waste (RMW) boxes for initial waste collection. They are not meant to be autoclaved.

c. Ensure that bags are free of sharp objects that may puncture bags. Autoclave bags are tear resistant, but can be punctured or burst in the autoclave.

d. Fill bags only 2/3 full.

e. Ensure adequate steam penetration by creating an opening of at least one inch in the bag's closed top.

f. On autoclaves which have no Prevacuum cycle, water can be carefully added to bags of waste run on Solids/Gravity cycle if needed to achieve effective decontamination. (Steam created inside the bag during processing aids in reaching appropriate temperature.)

☑ **POLYPROPYLENE AUTOCLAVE BAG**

⊗ **SHARPS PENETRATING BAG**

☑ **CLOSURE**

⊗ **CLOSURE**

✸ **<u>For biohazardous sharps:</u>**

a. Collect in commercially available Sharps containers with lids or closures. Containers must not be tightly sealed shut AND MUST NOT BE OVERFILLED.

⊗ **OVERFILLED**

✸ **<u>For biohazardous liquids:</u>**

Laboratories are encouraged to treat biohazardous liquids with household bleach (10% final volume) for 30 minutes followed by drain disposal.

Alternatively, steam sterilize in a validated autoclave using the liquid cycle.

Liquids treated with Bleach must never be autoclaved.

a. Never autoclave plastic materials of uncertain heat stability. Collect liquid in glassware or plasticware that is suitable for autoclaving.

b. Do not fill containers more than 2/3 full.

c. Make sure that caps are loose or use vented closures.

d. Never put sealed containers in an autoclave. They can explode. Large bottles with narrow necks may also explode or boil over if filled too full of liquid.

e. Never put materials containing solvents, corrosives or radioactive materials in the autoclave (e.g., phenol, chloroform, pyridine, or bleach).

☑ **PROPER CLOSURES**

⊗ **NO PRESSURIZED VESSELS**

2. Place waste bags or containers with liquids in secondary containers.

a. Make sure your plastic secondary container is suitable for autoclaving. Polyethylene or HDPE cannot be autoclaved.

b. Polypropylene, polycarbonate or stainless steel pans are typically used for secondary containment. See Nalgene Labware's Autoclaving Web page for additional plastic considerations.

c. Select a container with the lowest sides possible for the autoclave. This will promote penetration of steam and will collect any leakage or overflow of liquids.

d. Make sure pan contains the entire volume of waste—no spilling over sides.

e. Leave space between items/bags to allow steam circulation.

f. Safely transport the material to the autoclave.

☑ **STAINLESS STEEL**

☑ **NALGENE PAN**

⊗ **OVERFILLED PAN**

3. Load the autoclave.

a. Review the Standard Operating Procedures (SOP) for the autoclave unit. Training must be provided for any new autoclave operators.

b. Place a piece of autoclave tape on the container. For bags place the tape in the shape of an "X" on the outside of the bag overtop of the biohazard symbol. Black stripes appearing on the tape only give a visual verification that the material has been processed and shuld not be the color change should not be interpreted as indication of adequacy of sterilization cycles.

c. In a validated autoclave place the load + its secondary container in the autoclave chamber for processing.
- DO NOT OVERFILL THE CHAMBER!
- Load should not touch chamber walls
- DOOR should be clear of obstructions before closing

d. Whenever possible, autoclave the load immediately after preparation. Do not leave unprocessed items in the autoclave overnight.

e. If the autoclave is in use, store waste, in a secondary container, in a designated holding area, and decontaminate at the earliest possible time.

☑ **AUTOCLAVE TAPE**

⊗ **OVERFILLED CHAMBER**

4. Choose an appropriate cycle.

CYCLE TYPE & TYPICAL PARAMETERS	RECOMMENDED FOR:
LIQUIDS **STERILIZE TEMP = 121° C** **STERILIZE TIME = 30-60 min.** **COOL TIME =40 min.** **RUN TIME = 70-100 min.**	• Type I borosilicate glass containers with vented closures; 2/3 full only • Liquid Media • Nonflammable liquids • Aqueous solutions • Liquid biowaste
	NOT RECOMMENDED FOR DRY ITEMS THAT <u>DON'T REQUIRE</u> A SLOW EXHAUST
SOLIDS / GRAVITY **STERILIZE TEMP = 121° C** **STERILIZE TIME = 30 to 40 min.** **DRY TIME =0 to 30 min.** **RUN TIME =45 to 80 min.**	• Glassware: -Type I borosilicate - empty & inverted - no tight or impermeable closures • Dry hard items, either unwrapped or in porous wrap • Metal items with porous parts • Other porous materials
	NOT RECOMMENDED FOR LIQUIDS OR MEDIA THAT <u>REQUIRE</u> A SLOW EXHAUST
PRE-VACUUM **STERILIZE TEMP121° C** **STERILIZE TIME = 30 to 45 min.** **COOL TIME = 2 to 5 min.** **RUN TIME 40 to 55 min.**	• Glassware that must be sterilized upright &/or can trap air • Wrapped dry items that can trap air • Pipette tip boxes • Sharps decontamination (in collection containers) • Biohazard waste decontamination (in autoclave bags; can be wet & dry tubes, plates, etc.)
	NOT RECOMMENDED FOR LIQUIDS OR MEDIA, LIGHTER WEIGHT PLASTIC CONTAINERS OR DRY ITEMS WHICH WILL COLLAPSE IN A VACUUM

☑ **LIQUID CYCLE**

⊗ **LIQUID RUN ON SOLIDS CYCLE—**

(NOTE BOIL-OVER IN CHAMBER FLOOR PLUS NO SECONDARY CONTAINER)

☑ **PREVAC CYCLE**

5. **Please note this important information:**

   a. For both DRY and LIQUID biohazardous waste materials, cycle times must be set for a minimum of 30 minutes @ 121ºC, 15 psi.

   b. LARGER VOLUMES OF LIQUIDS AND LARGER LOADS OF SOLIDS REQUIRE LONGER STERILIZATION TIMES.

   c. LIQUIDS MUST BE AUTOCLAVED WITH SLOW EXHAUST.

6. **Fill out the autoclave use log (link) and be aware of required cycle times. Record your name, date, time, cycle to be run, etc. The results of the load verification results must also be recorded on this log.**

7. **Always employ the following safety guidelines when the autoclave cycle is finished:**

   a. Wear personal protection equipment:
   - Lab coat
   - Eye protection (when removing load)
   - Closed-toe shoes
   - Heat-resistant gloves to remove items, especially hot glassware

   b. Never open an autoclave unless the chamber pressure = 0.

   c. Open the door cautiously. Stand behind the door or beside the unit and slowly crack it open no more than ½". Allow all steam to escape by waiting at least 10 minutes before unloading the material. CAUTION: Material will still be HOT!

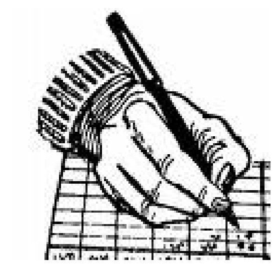
   d. Let liquids stand 10–20 minutes after the autoclave is opened. Superheated liquids can boil over and damage the autoclave and cause personal injury.

   e. Do not override autoclave's built-in safety control features under any circumstances. If problem occurs, contact the responsible technician.

RECOMMENDED STERILIZATION TIMES PER VOLUME FOR LIQUID CYCLES

Volume of Liquid in One Container	Minimum Recommended Sterilize Time at 121° C
75 ml	25 minutes
250 ml	30 minutes
500 ml	40 minutes
1000 ml	45 minutes
1500 ml	50 minutes
2000 ml	55 minutes
>2000 ml	55 + 10 min. / L

☑ **SIGN AUTOCLAVE USE LOG**



☑ **USE REQUIRED PPE**

8. Properly dispose of materials that have been successfully autoclaved.

a. Once cooled, place a sticker over the biohazard symbol that states ...

☑ **REGULATED MEDICAL WASTE**

b. Discard BSL-1 and BSL-2 decontaminated waste into the regular trash.

c. Place ALL Sharps containers into Regulated Medical Waste boxes lined with red biohazard bags.

d. Decontaminated biohazardous liquids may be poured down the drain.

NOTE: The stripes on autoclave indicator tape changing from light to dark does not ensure that decontamination conditions were successfully met, but serves only as a visual indicator of processed (heat-exposed) versus non-processed items.

seal the treated waste in an orange plastic bag and securely attach a tag or label with the following message in indelible ink and legible print of a 21-point or greater typeface:

"The generator certifies that this waste has been treated in accordance with the Virginia Regulated Medical Waste Management Regulations and is no longer regulated medical waste.

Treated: (include date treatment performed)

Generator: (include name, address and telephone number of generator)."

9. Perform required verification testing for your autoclave.

☑ **BIOLOGICAL INDICATOR**

a. Use Biological Indicator (BI) testing for:

- Verifying proper function of newly installed autoclaves
- A monthly check on proper function for all other autoclaves used to decontaminate waste

b. When the heat-resistant bacterial spores *(Geobacillus stearothermophilus)* in the BI vial are killed, definitive verification for decontamination was achieved by the autoclave.

c. Each specific cycle (type, time, temperature, etc.) used to decontaminate biohazardous waste must be verified with BI testing.

d. Label the BI with pertinent information (date, autoclave tested, location in chamber, etc.)

e. Place BI in the waste load in one of the following ways:
- Challenge test packs are placed with a waste load (such as between 2 bags of waste).
- BI vials (no packs) are positioned <u>within</u> a load, such as inside a Sharps container or bag of waste, to encounter the greatest challenge to steam penetration.
- For more thorough testing, additional vials can be placed in critical loads.

f. BI vials used alone can be taped to the same extenders used for CI strips to facilitate placement and avoid direct exposure to waste.

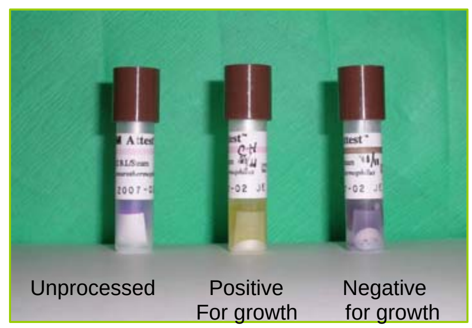
g. Upon completion of the cycle, follow BI manufacturer's instructions for activating and incubating test vials and positive control. Observe vials at specified intervals (such as 24 to 48 hours) for a color change indicating bacterial growth. If growth occurs, the autoclave tested has not met appropriate operating parameters.

h. Results must be recorded on the Biological Indicator Testing log.

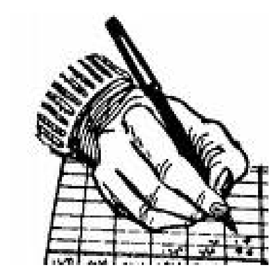
i. See the EHSS website to download SOP for Biological Indicators (BI).

☑ **B.I. INCUBATOR**

BI TEST RESULTS



☑ **RECORD IN BI STERILITY TESTING LOG**



BI Failures:

- All BI testing failures must be reported immediately to the technician responsible for the autoclave, who will investigate and take corrective action.
- Users of the autoclave also must be informed of any failure that may have affected runs processed in the autoclave at or near the time of testing.
- The autoclave in question must be taken out of service for decontamination of waste until the problem is found and proper function is restored as verified by repeat BI testing.

☑ **SIGN ON OUT-OF-SERVICE AUTOCLAVE**

BI verification testing should also be performed:

- After a sterilizer has been repaired
- As required for research needs

☑ **UTILITIES SIDE OF AUTOCLAVE**

11. Keep autoclaves in good repair with preventive maintenance.

a. The responsible technician, the autoclave’s manufacturer, or the autoclave’s sales /service representative can provide more information.

b. If you suspect there is a problem with your autoclave’s performance, contact the responsible technician for assistance.

References

1. Le, R.N., et al (2005), Autoclave Testing in a University Setting. *Applied Biosafety*, 10(4), 248-252.

2. Centers for Disease Control and Prevention, Oral Health Resources "Sterilization – Monitoring FAQs," April 2005. www.cdc.gov/oralhealth/infectioncontrol/faq/sterilization_monitoring.htm

3. University of Ottawa Environmental Health and Safety Service, A Guideline for the Safe Use of Autoclaves, 9 July 2003, http://www.uottawa.ca/services/ehss/docs/autoclave.pdf

4. 3M™ Technical Product Profile: 3M™ ATTEST™ Biological Monitoring System, 1994.

Appendix Q – Glossary of Terms

Appendix Q – Glossary of Terms

ACGIH - The American Conference of Governmental Industrial Hygienists is a voluntary membership organization of professional industrial hygiene personnel in governmental or educational institutions. The ACGIH develops and publishes recommended occupational exposure limits each year called Threshold Limit Values (TLVs) for hundreds of chemicals, physical agents, and biological exposure indices.

ACID – A compound that releases hydrogen ions in the presence of solvents or water. Acids react with bases to form salts and water.

ACTION LEVEL - A concentration designated in Title 8, California Code of Regulations for a specific substance, calculated as an eight (8)-hour time weighted average, which initiates certain required activities such as exposure monitoring and medical surveillance.

ACUTE HAZARDOUS WASTE (aka "P-Waste")- chemicals listed in 40 CFR §261.33

ACUTE TOXICITY – A substance that causes injury because of a short term exposure, usually in minutes or hours.

AEROSOL - Liquid droplets or solid particles dispersed in air that are of fine enough size (less than 100 micrometers) to remain dispersed for a period of time.

ASPHYXIANT - A chemical (gas or vapor) that can cause death or unconsciousness by suffocation. Simple asphyxiants, such as nitrogen, either use up or displace oxygen in the air. They become especially dangerous in confined or enclosed spaces. Chemical asphyxiants, such as carbon monoxide and hydrogen sulfide, interfere with the body's ability to absorb or transport oxygen to the tissues.

AUTO-IGNITION TEMPERATURE – The lowest temperature at which a flammable gas mixture will ignite from its own heat source without the necessity of a spark or flame.

BENIGN – A tumor that does not metastasize.

BLOOD TOXIN – Chemicals that damage blood cells or decrease the ability of the blood cells to deliver oxygen.

BOILING POINT – The temperature at which the vapor pressure of a liquid and the atmospheric pressure is the same.

BRONCHITIS – Inflammation of the trachea (windpipe) and its branches.

CANCER – Cancer is characterized by uncontrolled growth of abnormal cells. These cells are destructive and often capable of migrating to new sites to form secondary growths**.**

CANISTER – A container filled with sorbents that removes gases and vapors drawn through the device.

CARCINOGEN - A cancer-producing substance or physical agent in animals or humans. A chemical is considered a carcinogen or potential carcinogen if it is so identified in any of the following:
National Toxicology Program, "Annual Report of Carcinogens" (latest edition)
International Agency for Research on Cancer, "Monographs" (latest edition)
OSHA, 29 CFR 1910, Subpart Z, Toxic and Hazardous Substances

CAUSTIC – A chemical that is strongly irritating or corrosive.

"C" OR CEILING - A description usually seen in connection with a published exposure limit. It refers to the concentration that should not be exceeded, even for an instant. It may be written as TLV-C or Threshold Limit Value - Ceiling. (See also Threshold Limit Value).

CFR - Code of Federal Regulations

CHEMICAL HYGIENE OFFICER - An employee who is designated by the employer and who is qualified by training or experience to provide technical guidance in the development and implementation of the provisions of the Chemical Hygiene Plan.

CHEMICAL HYGIENE PLAN - A written program developed and implemented by the employer which sets forth procedures, equipment, personal protective equipment, and work practices that (1) are capable of protecting employees from the health hazards presented by hazardous chemicals used in that particular workplace and (2) meets the requirements of OSHA regulation 29 CFR 1910.1450.

CHEMICAL NAME - The scientific designation of a chemical in accordance with the nomenclature system developed by the International Union of Pure and Applied Chemistry (IUPAC) or the Chemical Abstracts Service (CAS) rules of nomenclature, or a name which will clearly identify the chemical for the purpose of conducting a hazard evaluation.

COMBUSTIBLE LIQUID - Any liquid having a flashpoint at or above 100°F (37.8°C) but below 200°F (93.3°C) except any mixture having components with flashpoints of 200°F or higher, the total volume of which make up 99% or more of the total volume of the mixture.

COMPRESSED GAS - A gas or mixture of gases having, in a container, an absolute pressure exceeding 40 psi at 70oF (21.1°C), or; a gas or mixture of gases having, in a container, an absolute pressure exceeding 104 psi at 130°F (54.4°C) regardless of the pressure at 70oF (21.1°C), or; a liquid having a vapor pressure exceeding 40 psi at 100°F (37.8°C) as determined by ASTM D-323-72.

COMMON NAME - Any designation or identification such as code name, code number, trade name, brand name, or generic name used to identify a chemical other than by its chemical name.

CONTAINER - Any bag, barrel, bottle, box, can, cylinder, drum, reaction vessel, storage tank, or the like that contains a hazardous chemical. For purposes of this section, pipes or piping systems, and engines fuel tanks or other operating systems in a vehicle are not considered to be containers.

CORROSIVE - A substance that, according to the DOT, causes visible destruction or permanent changes in human skin tissue at the site of contact or is highly corrosive to steel.

CHRONIC TOXICITY – A substance that causes injury because of long term (months or years) exposure or causes injury after months or years following an acute exposure.

CRYOGENIC LIQUIDS – Liquified gases which are handled at very low temperatures, typically below -150 F.

DENSITY – The mass of a substance divided by its volume**.**

DERMATITIS – Inflammation of the skin.

DESICCANT – A substance that absorbs water.

DESIGNATED AREA - An area which has been established and posted with signage for work involving hazards (e.g., "select carcinogens," reproductive toxins, or substances which have a high degree of acute toxicity). A designated area may be the entire laboratory, an area of a laboratory, or a device such as a laboratory hood.

DUCT – A conduit that air travels through.

DYSPNEA – Shortness of breath or difficulty in breathing.

ECZEMA – Skin disease or disorder.

EDEMA – Swelling of body tissue from excess water.

EMBRYO – The stage of gestation from conception to the end of the third month.

EMBRYOTOXIC – Substances that act during pregnancy to cause adverse effects on the fetus.

EMERGENCY - Any potential occurrence, such as, but not limited to, equipment failure, rupture of containers, or failure of control equipment which could result in an uncontrolled release of a hazardous chemical into the workplace.

EPCRA - Emergency Planning and Community Right-To-Know Act (Title III or SARA)

EPIDEMIOLOGY – Study of the cause of diseases in human populations.

ERYTHEMA – Reddening of the skin.

EXHAUST VENTILATION – The removal of air from an area by mechanical means.

EXPLOSIVE - A chemical that causes a sudden, almost instantaneous release of pressure, gas, and heat when subjected to a sudden shock, pressure, or high temperature.

FACE VELOCITY – Air velocity at the opening of a hood.

FETUS – The stage of gestation from the end of the fourth month to birth.

FLAMMABLE - A chemical that falls into one of the following categories:
Flammable aerosol - an aerosol that, when tested by the method described in 16 CFR 1500.45, yields a flame projection exceeding 18 inches at full valve opening, or a flashback (a flame extending back to the valve) at any degree of valve opening;
Flammable gas - a gas that, at ambient temperature and pressure, forms a flammable mixture with air at a concentration of 13% by volume or less; or a gas that, at ambient temperature and pressure, forms a range of flammable mixtures with air wider than 12% by volume, regardless of the lower limit;
Flammable liquid - any liquid having a flashpoint below 100°F (37.8°C), except any mixture having components with flashpoints of 100°F (37.8°C) or higher, the total of which make up 99% or more of the total volume of the mixture; or
Flammable solid - a solid, other than a blasting agent or explosive as defined in1910.109(a), that is liable to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or which can be ignited readily and, when ignited, burns so vigorously and persistently as to create a serious hazard. A chemical shall be considered to be a flammable solid if, when tested by the method described in 16 CFR 1500.44, it ignites and burns with a self-sustained flame at a greater than one- tenth of an inch per second along its major axis.

FLASHPOINT - The minimum temperature at which a liquid gives off a vapor in sufficient concentration to ignite in the presence of an ignition source or when tested as follows:
Tagliabue Closed Tester (See American National Standard Method of Test for Flashpoint by Tag Closed Tested, Z11.24-1979 (ASTM D-56-79) for liquids with a viscosity of less than 45 Saybolt Universal Seconds (SUS) at 100oF (37.8°C) or that contain suspended solids and do not have a tendency to form a surface film under test;

Pensky-Martens Closed Tester (See American National Standard Method of Test for Flashpoint by Pensky-Martens Closed Tester, Z11.7-1979 (ASTM D-73-79) for liquids with a viscosity equal to or greater than 45 SUS at 100oF (37.8°C), or that contain suspended solids, or that have a tendency to form a surface film under test; or, Setaflash Closed Tester (See American National Standard Method of Test for Flashpoint of Setaflash Closed Tester (ASTM D-3278-78)). Organic peroxides, which undergo auto accelerating thermal decomposition, are excluded from any flashpoint determination methods specified above.

FUME – Minute solid particles dispersed in the air because of heating a solid.

GAS – State of matter characterized by very low density and viscosity.

GENERAL VENTILATION - Also known as general exhaust ventilation, this is a system of ventilation consisting of either natural or mechanically induced fresh air movements to mix with and dilute contaminants in the workroom air. This is not the recommended type of ventilation to control contaminants that are highly toxic, when there may be corrosion problems from the contaminant, when the worker is close to where the contaminant is being generated, and where fire or explosion hazards are generated close to sources of ignition. (See Local Exhaust Ventilation)

GLOBALLY HARMONIZED SYSTEM (GHS) - The GHS is a system for standardizing and harmonizing the classification and labeling of chemicals. It is a logical and comprehensive approach to: defining health, physical and environmental hazards of chemicals; creating classification processes that use available data on chemicals for comparison with the defined hazard criteria; and communicating hazard information, as well as protective measures, on labels and Safety Data Sheets (SDS).

GLOVE BOX – A sealed enclosure in which all operations are carried out through long impervious gloves sealed to the box.

HAZARD ASSESSMENT - A formal procedure undertaken by the supervisor in which occupational hazards for all employees are described per procedure or task, and by affected body part(s) or organ(s), and which is documented and posted in the workplace with all personal protective equipment requirements.

HAZARD WARNING - Any words, pictures, symbols or combination thereof appearing on a label or other appropriate form of warning which convey the hazards of the chemical(s) in the container(s).

HAZARDOUS MATERIAL (DOT) - A substance or material capable of posing an unreasonable risk to health, safety, and property when transported including, but not limited to, compressed gas, combustible liquid, corrosive material, cryogenic liquid, flammable solid, irritating material, material poisonous by inhalation, magnetic material, organic peroxide, oxidizer, poisonous material, pyrophoric liquid, radioactive material, spontaneously combustible material, an water-reactive material.

HAZARDOUS CHEMICAL - A chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees. The term "health hazard" includes chemicals that are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents that act on the hematopoietic system, and agents which damage the lungs, skin, eyes or mucous membranes. A chemical is also considered hazardous if it is listed in any of the following:
OSHA, 29 CFR 1910, Subpart Z, Toxic and Hazardous Substances;
"Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment," ACGIH (latest edition);
"The Registry of Toxic Effects of Chemical Substances," NIOSH (latest edition);

HEALTH HAZARD – A chemical for which there is statistically significant evidence based on at least one scientific study that acute or chronic health effects may occur in exposed individuals. Health hazards include chemicals that are carcinogens, mutagens, teratogens, corrosives, toxic and highly toxic agents, irritants, and sensitizers.

HEMATO – Referring to the blood.

HEMATOPOIETIC TOXINS – Chemicals that interfere with the production of red blood cells.

HEPA FILTER – High efficiency particulate air filter. Removes 99.97% of particles with a diameter greater than 0.3 microns.

HEPATOXINS – Chemicals that damage the liver.

HIGHLY TOXIC - A substance falling within any of the following categories:
A substance that has a median lethal dose (LD50) of 50 milligrams or less per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each;
A substance that has a median lethal dose (LD50) of 200 milligrams or less per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between two and three kilograms each; or
A substance that has a median lethal concentration (LC50) in air of 200 parts per million by volume or less of gas or vapor, or 2 milligrams per liter or less of mist, fume, or dust, when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

HUMAN CARCINOGEN – A substance that has been shown by statistically significant epidemiological evidence to cause cancer in humans.

HYDROCARBON – Organic compounds consisting solely of hydrogen and carbon.

IARC - International Agency for Research on Cancer.

IGNITABLE - A solid, liquid or compressed gas waste that has a flashpoint of less than 140°F. Ignitable material may be regulated by the EPA as a hazardous waste as well.

INCOMPATIBLE - The term applies to two substances to indicate that one material cannot be mixed with the other without the possibility of a dangerous reaction.

INORGANIC – Compounds from a source other than animal or vegetable that generally do not contain carbon.

IRRITANT - A substance which, by contact in sufficient concentration for a sufficient period of time, will cause an inflammatory response or reaction of the eye, skin, nose or respiratory system. The contact may be a single exposure or multiple exposures. Some primary irritants: chromic acid, nitric acid, sodium hydroxide, calcium chloride, amines, metallic salts, chlorinated hydrocarbons, ketones and alcohols.

ISCHEMIA – Loss of blood supply to a part of the body.

LABEL - Any written, printed or graphic material displayed on or affixed to containers of chemicals, both hazardous and non-hazardous.

LABORATORY- A facility or room where potentially hazardous chemicals, biological agents or sources of energy (i.e. lasers, high voltage, radiation, etc.) are used for scientific experimentation, research, or education.

LABORATORY TYPE HOOD - A device located in a laboratory, enclosed on five sides with a movable sash or fixed partial enclosure on the remaining side; constructed and maintained to draw air from the laboratory and to prevent or minimize the escape of air contaminants into the laboratory; and allows chemical manipulations to be conducted in the enclosure without insertion of any portion of the employee's body other than hands and arms.

LABORATORY USE OF HAZARDOUS CHEMICALS - Handling or use of such chemicals in which all of the following conditions are met:
Chemical manipulations are carried out on a "laboratory scale";
Multiple chemical procedures or chemicals are used;
The procedures involved are not part of a production process nor in any way simulate a production process; and
"Protective laboratory practices and equipment" are available and in common use to minimize the potential for employee exposure to hazardous chemicals.

LC50 – The air concentration of a chemical that causes the death of 50% of the test animals.

LD50 - Lethal dose needed to kill 50% of the test population.

LOCAL EXHAUST VENTILATION (Also known as exhaust ventilation) – A ventilation system that captures and removes the contaminants at the point they are being produced before they escape into the workroom air. The system consists of hoods, ductwork, a fan, and possibly an air- cleaning device. Advantages of local exhaust ventilation over general ventilation include: it removes the contaminant rather than dilutes it, requires less airflow and, thus, is more economical over the long term; and the system can be used to conserve or reclaim valuable materials; however, the system must be properly designed with the correctly shaped and placed hoods, and correctly sized fans and ductwork.

LOWER FLAMMABILITY LIMIT – The minimum concentration of the vapor in air that will sustain the spread of a flame.

LSRs – Lab Safety Rules

MAKEUP AIR – Clean, tempered outdoor air that replaces air removed by exhaust ventilation.

MEDICAL CONSULTATION - A consultation which takes place between an employee and a licensed physician for the purpose of determining what medical examinations or procedures, if any, are appropriate in cases where a significant exposure to a hazardous chemical may have taken place.

MIXTURE - Any combination of two or more chemicals if the combination is not, in whole or in part, the result of a chemical reaction.

MUCOUS MEMBRANES – Lining of the hollow organs of the body such as the nose, mouth, stomach, intestines, and bronchial tubes.

MUTAGEN - Anything that can cause a change (or mutation) in the genetic material of a living cell.

NARCOSIS – Loss of consciousness.

NECROSIS – Death of body tissues.

NEOPLASM – A new growth that may be benign or malignant.

NEPHROTOXINS – Chemicals that produce kidney damage.

NEUROTOXINS – Chemicals that produce their primary effect on the central nervous system.

NFPA - The National Fire Protection Association; a voluntary membership organization whose aims are to promote and improve fire protection and prevention. NFPA has published 16 volumes of codes known as the National Fire Codes. Within these codes is Standard No. 705, "Identification of the Fire Hazards of Materials". This is a system that rates the hazard of a material during a fire. These hazards are divided into health, flammability, and reactivity hazards and appear in a well-known diamond system using from zero through four to indicate severity of the hazard. Zero indicates no special hazard and four indicates severe hazard.

NIOSH - The National Institute for Occupational Safety and Health; a federal agency that among its various responsibilities trains occupational health and safety professionals, conducts research on health and safety concerns, and tests and certifies respirators for workplace use.

NTP - National Toxicology Program

ODOR THRESHOLD - The minimum concentration of a substance at which a majority of test subjects can detect and identify the substance's characteristic odor.

OSHA – Occupational Safety and Health Administration

OXIDIZER - Is a substance that gives up oxygen easily to stimulate combustion of organic material.

PERMISSIBLE EXPOSURE LIMIT (PEL) - An exposure, inhalation or dermal permissible exposure limit specified in 8 CCR 5155. PELs may be a time-weighted average (TWA) exposure limit (8- hour), a 15-minute short-term limit (STEL), or a ceiling (C).

PERSONAL PROTECTIVE EQUIPMENT (PPE)- Any devices or clothing worn by the worker to protect against hazards in the environment. Examples are respirators, gloves, and chemical splash goggles.

PHYSICAL HAZARD - A chemical for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive), or water-reactive.

PLENUM – A space filled with air as opposed to a vacuum.

POISON – A chemical with an oral LD50 of 50 mg/kg or less.

PYROPHORIC - A chemical that will spontaneously ignite in the air at a temperature of 130oF (54.4oC) or below.

RCRA - Resource Conservation and Recovery Act

REACTIVITY - A substance's susceptibility to undergoing a chemical reaction or change that may result in dangerous side effects, such as explosion, burning, and corrosive or toxic emissions. The conditions that cause the reaction, such as heat, other chemicals, and dropping, will usually be specified as "Conditions to Avoid" when a chemical's reactivity is discussed on an SDS.

REPRODUCTIVE TOXINS - Chemicals which affect the reproductive capabilities including chromosomal damage (mutations) and effects on fetuses (teratogenesis).

RESPIRATOR - A device which is designed to protect the wearer from inhaling harmful contaminants.

RESPIRATORY HAZARD - A particular concentration of an airborne contaminant that, when it enters the body by way of the respiratory system or by being breathed into the lungs, results in some body function impairment.
Responsible party is defined as any individual employed by the College.

SAFETY CAN – Designed to safely relieve internal pressure when exposed to a fire. Has a spring-closing lid and a flame arrestor in the spout.

SAFETY DATA SHEET (SDS) - Written or printed material concerning a hazardous chemical which is prepared in accordance with paragraph (g) of 29 CFR 1910.1200. Formerly known as Material Safety Data Sheet (MSDS)

SARA- Superfund Amendments and Reauthorization Act of 1986

SELECT CARCINOGENS - Any substance which meets one of the following:
It is regulated by OSHA as a carcinogen; or
It is listed under the category, "known to be carcinogens," in the Annual Report on Carcinogens published by the National Toxicology Program (NTP) (latest edition);or
It is listed under Group 1 ("carcinogen to humans") by the International Agency for Research on Cancer Monographs (IARC)(latest editions); or
It is listed in either Group 2A or 2B by IARC or under the category, "reasonably anticipated to be carcinogens" by NTP.

SENSITIZER - A substance that may cause no reaction in a person during initial exposures, but afterwards, further exposures will cause an allergic response to the substance.

SHORT-TERM EXPOSURE LIMIT - Represented as STEL or TLV-STEL, this is the maximum concentration to which workers can be exposed for a short period of time (15 minutes) for only four times throughout the day with at least one hour between exposures. Also the daily TLV-TWA must not be exceeded.

SIC - Standard Industrial Code.

SIGNIFICANT HAZARD is any hazard, which left untreated, will result in injury or harm to life or property.

SIGNIFICANT SPILL is any hazard, which left untreated, will result in injury or harm to life or property.

SOLVENT - A substance, commonly water, but in industry often an organic compound, which dissolves another substance.

SORBENT – A material that removes toxic gases and vapors from air inhaled through a respirator.

SPECIFIC GRAVITY – The mass of a substance divided by the mass of an equal volume of water.

SYNERGISM – Substances combining to cause an effect that is greater than the sum of the parts.

TERATOGENIC – A substance that may produce a malformation of the embryo or fetus.

THRESHOLD LIMIT VALUE (TLV) - Airborne concentration of substances devised by the ACGIH that represents conditions under which it is believed that nearly all workers may be exposed day after day with no adverse effect. TLVs are advisory exposure guidelines, not legal standards, that are based on evidence from industrial experience, animal studies, or human studies when they exist. There are three different types of TLVs: Time-Weighted Average (TLV-TWA), Short-Term Exposure Limit (TLV-STEL), and Ceiling (TLV-C). (See also PEL).

TOXICITY - A relative property of a material to exert a poisonous effect on humans or animals and a description of the effect and the conditions or concentration under which the effect takes place.

VAPOR - The gaseous form of substances which are normally in the liquid or solid state (at normal room temperature and pressure). Vapors evaporate into the air from liquids such as solvents. Solvents with lower boiling points will evaporate faster.

UNIVERSAL WASTE- items and conditions listed in 6 NYCRR 374-3. Normally things like batteries, lamps, ballasts etc.

UPPER FLAMMABILITY LIMIT –

VAPOR PRESSURE – The pressure of a vapor in equilibrium with its liquid or solid. The higher the vapor pressure the greater the volatility.

VAPORS – The gaseous form of a material that is normally in the solid or liquid state.

VISCOCITY – The internal friction or resistance to flow in a liquid or gas.

VOLATILE – The ability of a liquid to vaporize. A highly volatile liquid, such as gasoline, has a high vapor pressure and will vaporize easily.

WATER-REACTIVE – A chemical that will react with water to release gas that is either flammable or presents a health hazard.