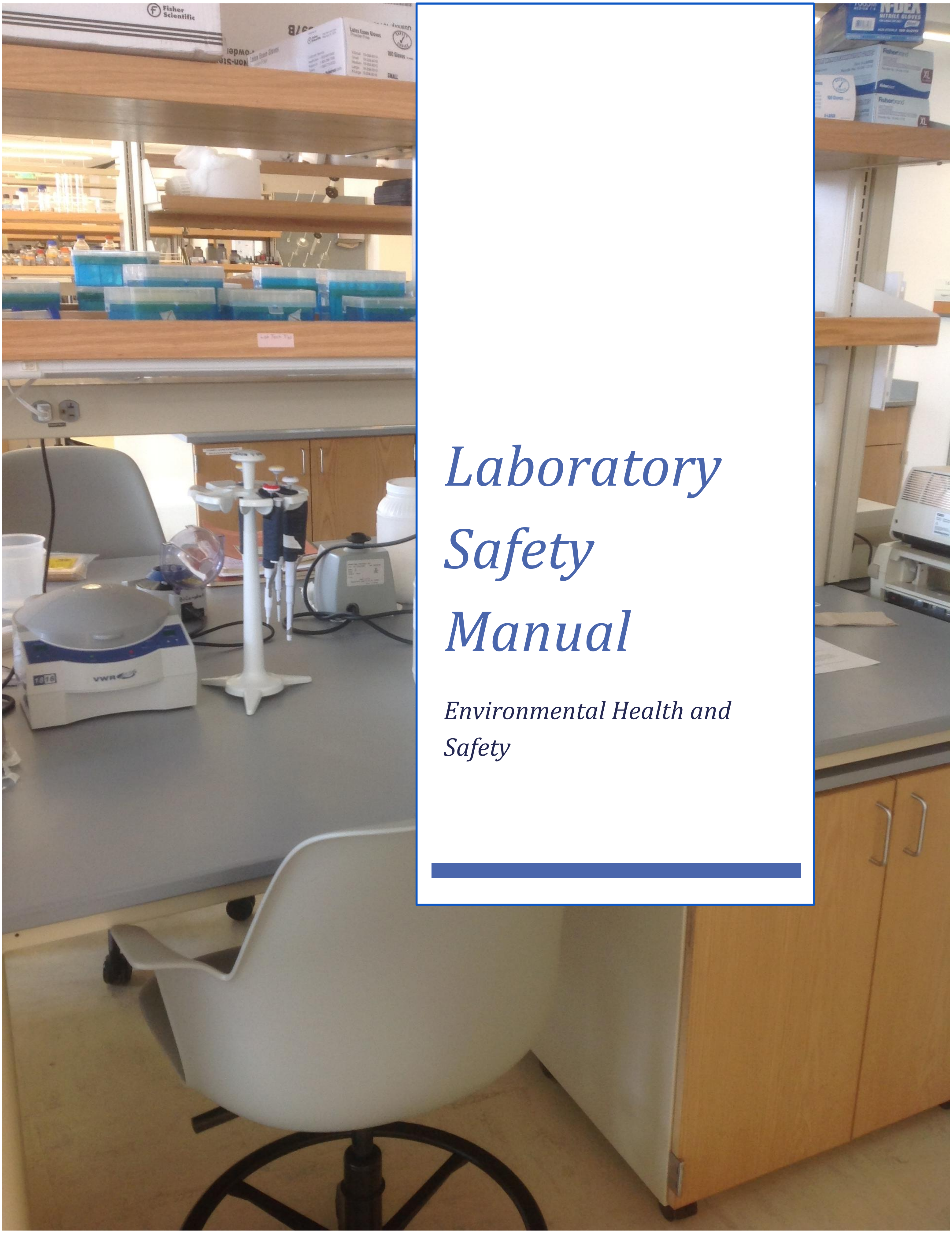


Laboratory Safety Manual

Environmental Health and Safety

Executive Summary

The purpose of this manual is to provide guidance for personnel on how to work safely in laboratories. Laboratories are expected to be in compliance with this manual in the areas that are applicable. Where the guidance provided in this manual is not used, written documentation should be given showing that the procedure or arrangement used in lieu of the guidance given in this manual will provide a situation that is either as safe or safer than the guidance given in this manual.

This manual applies to all areas that are classified as laboratories and the personnel that work within laboratories. This guidance is not meant to apply to areas outside of laboratories; for those areas, refer to safety manuals specifically written for those areas. This manual is intended to provide general guidance for common laboratory procedures. Laboratories should have standard operating procedures for hazardous procedures and chemicals that are unique to their lab or for any highly hazardous procedure or chemical. For assistance in determining whether or not a procedure or chemical is highly hazardous, contact the director of EHS.

There are a number of regulations and guidelines concerning laboratory safety. The primary regulation is the Occupational Safety and Health Administration (OSHA) Lab Standard (29CFR1910.1450); however, this is not the only source of requirements for working safely in the laboratory. Other sources include the rest of the OSHA regulations for General Industry (particularly those that deal with personal protective equipment, engineering controls and hazardous material storage), Environmental Protection Agency (EPA) and Tennessee Department of Environment and Conservation (TDEC) Hazardous Waste Regulations, Department of Transportation (DOT) regulations and International Air Transport Association (IATA) requirements for shipping of hazardous materials, CDC guidelines for use of biological materials in labs (Biosafety in Microbiological and Biomedical Laboratories or BMBL), American National Standards Institute (ANSI) guidelines for safe use of lasers, the Department of Energy and the Tennessee Department of Environment and Conservation regulations for radiation use among others.

The OSHA Lab Standard addresses the use of chemicals and other substances on a laboratory scale. The lab standard requires the development of a Chemical Hygiene Plan. The University of Memphis does have a Chemical Hygiene Plan that can be found on the Environmental Health and Safety (EHS) website. The Chemical Hygiene Plan addresses all of the requirements of the Lab Standard; adopting a Chemical Hygiene Plan reduces the regulatory burden on laboratories in regards to many of the other requirements of Subpart Z of the OSHA regulations.

Contents

Chapter 1: Roles and Responsibilities

Safety in the laboratory is a responsibility that is shared by faculty, staff and students. General roles and responsibilities for all faculty, staff and students regarding safety are defined in the university-wide EHS Policy found on the university policy website. Responsibilities specific to laboratory safety are described below.

1.1 Principal Investigator/Responsible Faculty

The Principal Investigator (PI) is the person in charge of a research lab. Responsible faculty is a faculty member that has primary use of a teaching lab or is responsible for a teaching lab. PI and responsible faculty have the following responsibilities:

- Ensure that the staff and students know and follow the chemical hygiene rules and project-specific protocols,
- Ensure that appropriate personal protective equipment (PPE) is available and in working order,
- Ensure that staff and students know the location of the chemical hygiene plan,
- Ensure that staff and students know where to find a safety data sheet (SDS) for the substances with which they may come in contact,
- Ensure that all SDSs that are sent with chemicals shipments from the supplier are kept,
- Ensure that staff and students have completed all appropriate training,
- Provide an inventory of all hazardous chemicals to EHS annually before May 31 and
- Ensure chemical fume hood is operating properly on a monthly basis

1.2 Environmental Health and Safety

While day to day compliance with regulations within the laboratory is the responsibility of the lab occupants, EHS also has a responsibility to help ensure the safety of all workers and students that are present in laboratories. To that end, these are the responsibilities of EHS with regard to lab safety:

- Develop and implement appropriate chemical safety practices,
- Promulgate current legal requirements concerning regulated substances,
- Help determine the level of protective apparel and equipment required based on the hazards within the laboratory,
- Review and update all plans regarding laboratory and chemical safety on a regular basis,
- Respond to researcher queries regarding new procedures and/or chemicals,
- Monitor new procedures to determine the appropriate level of protection,
- Ensure employee exposures do not exceed permitted exposure limits (PELs),
- Monitor exposure if there is suspicion of levels of exposure in excess of established PELs and follow all requirements in regards to employee notification and records,
- Suspend work in a laboratory until if exposure levels to a substance are exceeded until such time as measures are taken to reduce exposure levels to less than the PELs and

- Provide training upon request regarding laboratory safety to all students and employees that work in laboratories.

1.3 Facility Manager

Not all buildings that have laboratories have a facility manager. The responsibilities of a facility manager may be accomplished by the faculty in charge of a lab, a department designee (such as a department safety coordinator) and, in the case of regular inspections, EHS. The responsibilities of the facility manager are as follows:

- Monitor procurement, use and disposal of chemicals used in the lab,
- Ensure that facilities and training for any material being ordered are adequate and
- Perform regular formal laboratory safety inspections as well as routine inspections of emergency equipment.

1.4 Staff and Students

While those listed above have the responsibility of providing a safe laboratory environment and ensuring that equipment, procedures and processes are in place to help keep laboratory workers safe, staff and students play a role in their own safety. Their responsibilities include:

- Plan and conduct each laboratory operation in accordance with this manual, the chemical hygiene plan and project-specific protocols,
- Develop and maintain good personal laboratory safety habits,
- Review the SDS of a chemical before working with it and
- Never remove or deface the label on a container containing a hazardous substance.

Chapter 2: General Laboratory Rules

The general rules for working safely in the laboratory are addressed in the university Chemical Hygiene Plan. They are also posted here for convenience. While most of these rules are explained in more detail throughout this manual, the general rules for laboratory safety are as follows:

- Avoid “routine” exposure. Do not smell or taste chemicals. Use a hood if the TLV (available on the SDS) of a substance is <50 ppm.
- Do not apply cosmetics, eat, drink, smoke or chew in laboratories.
- Do not store or handle food or beverages in laboratories.
- Use appropriate PPE. At a minimum, all persons, including visitors, when in a laboratory in which chemicals are in use or a chemical process is in progress, shall wear eye or face protection.
- Avoid inappropriate apparel (loose clothing, sandals, shorts, etc.)
- Mouth pipetting is prohibited.

- Do not work alone in the building; do not work alone in the laboratory if the procedures being conducted are hazardous. Post an appropriate sign on the door and leave the lights on whenever an ongoing operation is left unattended.
- Deposit hazardous waste in an appropriately labeled, closed container; waste characterization, is initiated by the generator and confirmed by EHS. Do not discharge laboratory-generated waste to the sewer without written permission from EHS.
- In the event of a spill, the priority of actions shall be: personnel decontamination, spill containment, cleanup.
- Keep laboratories clean and uncluttered. Label all containers containing chemicals.
- If a substance is produced in the lab for use outside of the lab by another user, then the facility manager must comply with the Hazard Communication standard for that substance.
- Particularly Hazardous Substances (carcinogens, reproductive toxins and acute toxins) and Major Physical Hazards shall be handled per specific protocols (SOPs) approved by EHS.
- All manipulation of free nanoparticles MUST be performed in a HEPA-filtered bag in/out chemical fume hood, exhausted glove box, biological safety cabinet or an exhausted enclosure specifically designed for handling nanoparticles. Contamination of the exhaust system must be avoided in order to protect maintenance personnel; a bag in/out HEPA filter MUST be in place between the work enclosure and the building's ductwork.

Chapter 3: Laboratory Attire

Laboratory attire is distinct from personal protective equipment (PPE) in that it is the expected clothing to be worn anytime entering the lab with few exceptions. While PPE is hazard specific, laboratory attire is universal. While PIs are responsible for providing PPE for workers and students, it is the responsibility of those working in the lab to show up attired properly.

The requirements for laboratory attire are based on government regulations, industry best practices and benchmarks set by other colleges and universities. Deviations from the attire requirements must be approved by the director of Environmental Health and Safety in writing.

Listed below is the required attire for all people entering a laboratory:

- Long pants or skirts that cover the ankles
- Closed-toe shoes
- Long hair tied back
- No scarves or other loose, hanging items

Required laboratory attire is expected to be worn year-round, regardless of the outside temperature. Long pants can be replaced with scrubs; it is at the discretion of the PI to purchase scrubs for lab workers in lieu of long pants. Spare pants may be kept at the lab entrance for workers that are wearing shorts to place over their legs before entering the lab. The same can be done for closed-toe shoes.

Chapter 4: Engineering Controls and Safety Equipment

Engineering controls are physical modifications to a process or equipment to prevent the exposure of workers to harmful substances or conditions. Engineering controls are used where feasible to protect workers from hazards before resorting to personal protective equipment. Safety equipment refers to items that will be used in the event of an emergency.

Engineering controls, for the purposes of this manual will be divided into two categories; ventilation and containment devices and other engineering controls. Engineering controls specific to specialized equipment (such as lasers, centrifuges, etc.) within the laboratory should be described in Standard Operating Procedures for that piece of equipment.

4.1 Ventilation Equipment and Containment Devices

Ventilation equipment and containment devices are present in laboratories to protect either the worker from the hazards posed by the items used inside of them (such as chemicals in a fume hood) or to protect the product being used or the procedure being done in them from dust or microbes in the air (such as tissue culture in a clean bench or semiconductor work in a clean room). Many devices will be discussed in this section, but most attention will be given to items that keep workers safe.

4.1.1 Chemical Fume Hoods

The purpose of a chemical fume hood is to protect a worker using a chemical with the hood from the harmful vapors generated by the chemicals. A motor runs a fan above the ductwork attached the hood to pull air across the chemical hood work surface toward the back of the hood and up the exhaust. The vapors are exhausted out of the building where they become dilute to the point of no longer being harmful. Below are a picture and a diagram of a chemical fume hood.

Figure 1: Picture of a typical chemical fume hood

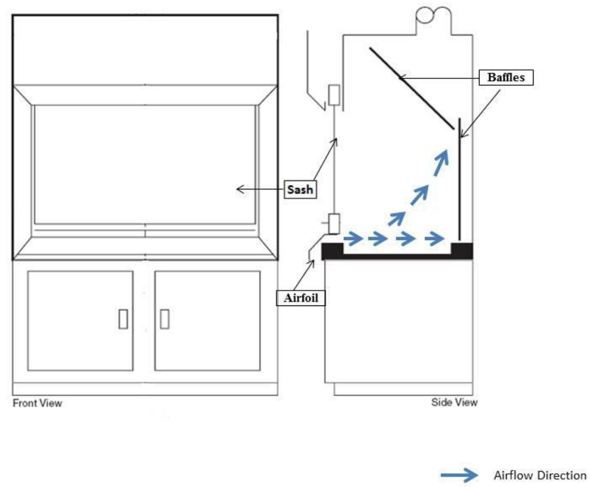


Figure 2: Standard chemical fume hood diagram front and side view

Here are the rules for working in a chemical fume hood:

- Chemical fume hoods are not to be used as storage. A hood is a working surface; only chemicals that are currently being used should be in the hood.
- The working surface of the hood should be as clear as possible to allow for adequate airflow across the work surface; large equipment within the hood should be raised off the work surface.
- The baffles of the hood shall not be obstructed. Items should be at least 6 inches away from the rear of the hood.
- Work should not be performed in the hood with the sash raised above the indicated position. The sash may be raised higher than the indicated position for experiment setup, but must be 18” or less from the work surface while hazardous work is being performed.
- Keeping the sash as low as possible reduces the amount of chemical vapors that can escape from the hood. Air within the chemical fume hood, because of turbulence, creates a vortex of air in the upper portion (as pictured below). Hazardous vapors can be present in that vortex and are likely to escape if the hood sash is fully open.
- If a hood is suspected of not functioning properly, immediately cease activity and report it to a supervisor. The supervisor should then contact EHS for evaluation of the hood.
- Never use a hood that has a sign on it indicating that it has failed inspection.

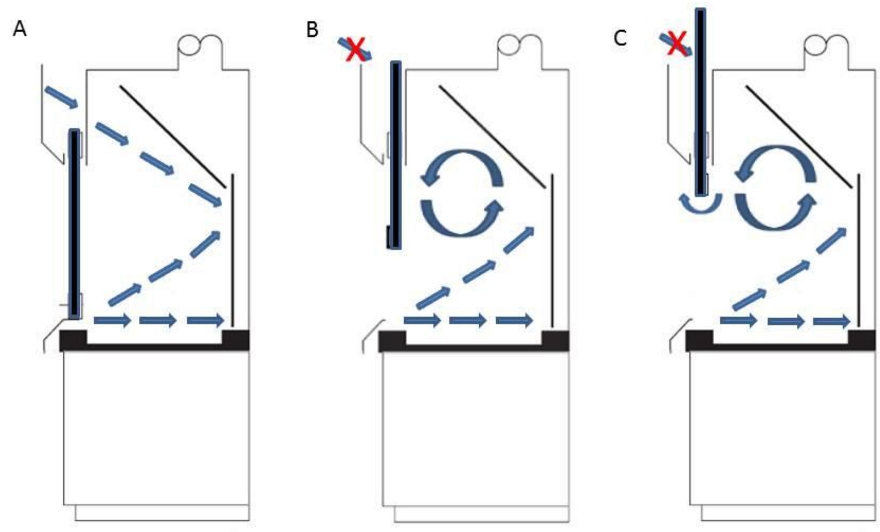


Figure 3: Airflow direction in a chemical fume hood. Airflow direction is indicated by blue arrows. Sash is the solids black vertical line. **A**- *Sash Closed*. When the sash of the hood is closed, air flows under the air foil below the sash and through the bypass above the sash. Because of directional airflow through the bypass, there is less probability of a vortex being created in the upper portion of the hood. **B**-*Sash Partially Open*. Because the sash is partially open there is no directional airflow in the upper portion of the hood. Some air is reflected by the baffles back toward the front of the hood; however, if the sash is low enough, that air is redirected toward the back of the hood and stays contained. **C**- *Sash Fully Open*. With the sash fully open, there is not a barrier to direct air that is moving from the back of the fume hood toward the front, thus air (and potentially hazardous vapors if hazardous materials are in use) can escape potentially exposing the hood user to hazardous vapors.

- Having the sash as low as possible also protects the user from physical hazards such as breaking glass or elevated temperatures.
- Keep hazardous chemicals at least 6 inches away from the sash as well. This will help reduce the likelihood of hazardous chemical vapor escape.

A chemical fume hood should have an operating face velocity of at least 90-150 linear feet per minute of air flow.

- EHS will annually confirm that chemical fume hoods are operating at this capacity.
- Hoods not operating at this level shall be marked as unsafe and shall not be used until it is repaired and retested by EHS.
- Some exceptions to the face velocity requirement will be made for hoods that are not used for hazardous situations (for example, for simple heat or non-hazardous odor dissipation)

Other conditions that will reduce the effectiveness of a chemical fume hood and that should be avoided when the hood is in use are:

- Heavy foot traffic near the hood while in use,
- Doors being opened and closed in the lab while the hood is in use,

- Swift, jerking movements in and out of the hood (slow, fluid movements help prevent additional turbulence and thus reduce hazardous vapor escape)
- Other air-moving devices such as fans being used near the hood and
- Overcrowding of the hood with equipment, chemicals, etc.

In buildings that have variable air volume HVAC systems (like ABI), keeping the hood sash closed when not in use may save energy.

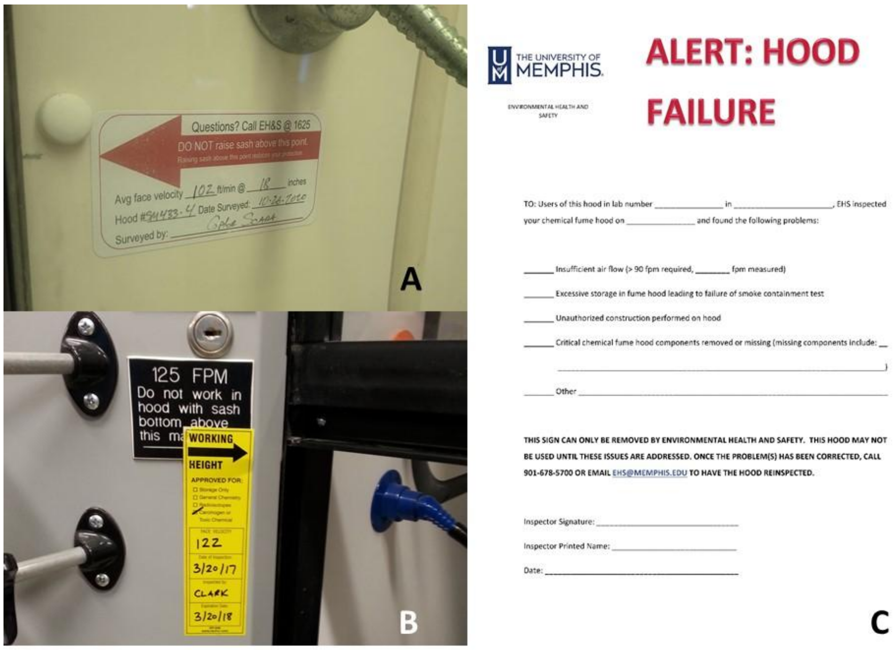


Figure 4: Chemical fume hood approval. A and B-*Chemical fume hood passes inspection.* If this either sticker shown is present and the current date is within the range specified on the sticker, then the chemical fume hood is approved for use. **C-***Chemical fume hood failure.* If this sign is present it means that the chemical fume hood has failed inspection. Do not use a chemical fume hood that has this sign on it and do not remove the sign! Notify building management or place a Physical Plant work order to have the hood examined for repairs. When the hood has been repaired, contact EHS to have it retested.

4.1.2 Biological Safety Cabinets

The purpose of a biological safety cabinet (BSC) is primarily to protect the user from biohazardous materials and secondarily to protect the materials being manipulated within the biological safety cabinet from contaminants in the laboratory air. All BSCs are equipped with at least one HEPA filter, which has the ability to filter all hazardous biological agents and prevent their release into the environment. There are three classes of biological safety cabinets; the class of BSC used depends on the application.

Figure 5: Biological Safety Cabinet (Class II)

4.1.2.1 Rules for Biological Safety Cabinets

Here are the rules for working in a biological safety cabinet:

- Hazardous chemicals may not be used in BSCs. BSCs do not filter out hazardous chemical vapors and do not exhaust the chemicals away from the lab; the air from a BSC is most often vented back into the lab. While a BSC will remove harmful biological agents, it will not remove hazardous chemical vapors.
- Biological safety cabinets in which hazardous biological agents are used must be certified on an annual basis by a NSF 49 certified technician.
- BSCs must be disinfected and all waste removed after each use to ensure that the cabinet is both safe and clean for the next user.
- BSCs where hazardous biological agents are used must be marked with a biohazard symbol.
- Open flames shall not be used in a biological safety cabinet. Because many BSCs recirculate the air within, and open flame can lead to a recirculation of both increased temperature air and leaking gas resulting in a fire or explosion.
- Clean benches (laminar flow hoods) are not BSCs and must not be used with biological hazards.
- For additional guidance regarding biological safety cabinets, see the university Biological Safety Manual.

4.1.2.2 Types of Biological Safety Cabinets

The category of biological safety cabinet used in a laboratory depends on the application. There are three classes of biological safety cabinets and several types within at least one class (class II). Airflow patterns and containment attributes vary within the classes and types. Most BSCs fall into class II and thus the most detail is given on this class in the Biological Safety Manual.

4.1.2.2.1 Class I

Class I biological safety cabinets are very similar to chemical fume hoods. They protect the user from harmful biological agents just as a chemical fume hood protects the user from harmful chemical agents. However, because harmful biological agents have the ability to reproduce (unlike chemicals) they cannot be released to the environment. All BSCs are equipped with a HEPA filter to capture these microbes.

Unlike other biological safety cabinets, class I BSCs do not protect the items being used within from contamination. Thus, class I BSCs should not be used when the product being manipulated needs to be protected from environmental contamination. The environment within this class of BSC is not sterile. Below is a diagram of a class I BSC:

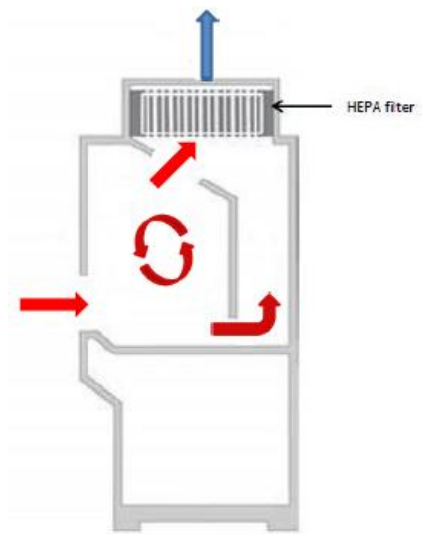


Figure 6: Class I Biological Safety Cabinet. Notice the airflow pattern (indicated by arrows) is very similar to that of a chemical fume hood. Red indicates unfiltered air, blue is filtered air

4.1.2.2.2 Class II

Class II biological safety cabinets offer the same level of personal protection and environmental protection but offer the added benefit of protecting the product being used within. There are several different types of Class II BSCs (details on each type are given in the Biological Safety Manual), but in general, room air is immediately pulled down at the entrance to the cabinet through a grate or grille and then filtered through a HEPA filter before being blown back down onto the work surface. Some of the air blown back down onto the surface is recirculated; the rest is exhausted through a separate HEPA filter. When properly used, a class II BSC provides a sterile environment to perform microbiological work. Below is a diagram of a class II BSC:

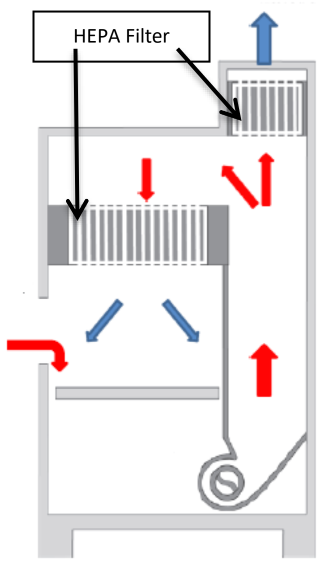


Figure 7: Class II Biological Safety Cabinet. This device is equipped with two HEPA filters. In many types, some of the air is recirculated while some of it is exhausted. Red arrows indicate unfiltered air, blue arrows indicate filtered air.

4.1.2.2.3 Class III

Class III biological safety cabinets are a type of glove box known as a negative pressure glove box. Glove boxes will be discussed in a subsequent section. These types of BSC are often called isolators and offer protection to the user, environment and the product within.

4.1.2.2.4 Clean Benches or Laminar Flow hoods

Many times, biological safety cabinets are incorrectly called laminar flow hoods. Laminar flow means flow in one direction. While BSCs have airflow in several different directions, clean benches truly demonstrate laminar flow. These devices offer product protection but do not protect the environment or the user. Thus they are not suitable for use with biological hazards. However, if used properly, these devices can provide a sterile environment in which to perform non-hazardous microbiological work. Below there are pictures and diagrams of these devices.

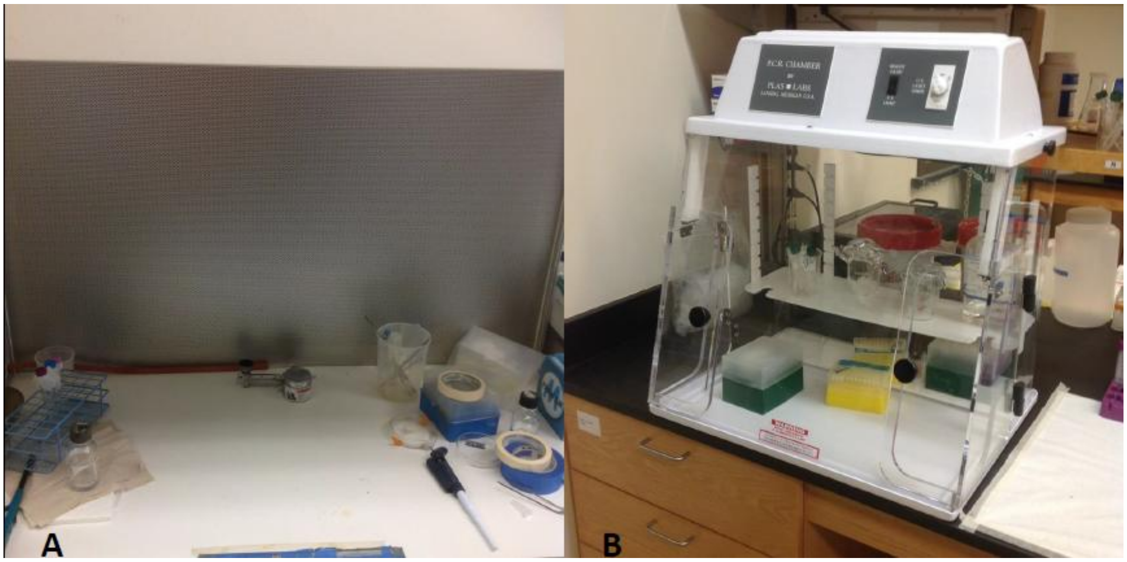


Figure 8: Horizontal clean bench and vertical clean bench. A-*Horizontal clean bench.* A horizontal clean bench (also known as a laminar flow hood or tissue culture hood) has a motor that blows HEPA-filtered air across the work surface toward the user. This keeps room contaminants out of the work area. **B-***Vertical clean bench***.** A vertical clean bench (also known as a PCR hood) has a motor mounted on top of the device where air is HEPA-filtered and blown down toward the work surface keeping room contaminants out of the device. In both devices, any hazards inside the device would be blown onto the user, thus hazardous material are not allowed to be used in them.

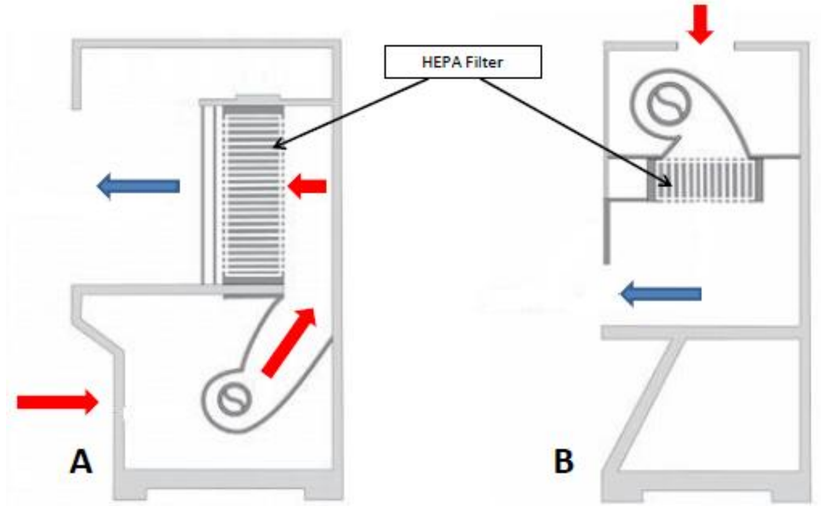


Figure 9: Clean bench diagram. A-*Horizontal clean bench and* **B-***Vertical clean bench.* Airflow is indicated by arrows; red indicates unfiltered air, blue indicates filtered air.

4.1.3 Glove Boxes and Glove Bags

Glove boxes come in many different varieties. Some are used strictly to protect materials from the environment and thus are not safety devices at all. Others are for protecting the user from very hazardous materials. In general, there are two types of glove boxes; there are those that are under negative pressure and those that are under positive pressure. There are also devices called glove bags that are used to provide an environment free of oxygen to manipulate certain types of microorganisms. All three will be discussed below.

4.1.3.1 Negative Pressure Glove Box

Figure 10: Negative Pressure Glove Box. Note the direction that the gloves are facing.

Negative pressure glove boxes are glove boxes that are attached to the exhaust system of a building to maintain a negative pressure within. They function much like a fume hood or biological safety cabinet in that they pull air away from the user. The air coming into them may or may not be HEPA filtered, depending on whether or not it is important to protect the product. The exhaust is HEPA filtered if biological agents are being used within. In general, negative pressure glove boxes are not used unless the product being used within is very highly hazardous to the user. These devices must not be installed and used without first consulting with EHS.

Negative pressure glove boxes can easily be identified by the direction the gloves are pointing when the device is on but not in use. Gloves are sucked into a negative pressure glove box. Certification of these devices must be handled according to manufacturer's instructions and the standards/guidelines of the American Glovebox Society should be consulted. Below is a picture of a typical negative pressure glove box.

4.1.3.2 Positive Pressure Glove Box

Positive pressure glove boxes are glove boxes that are kept under pressure either by compressed air or an inert gas. Sometimes these devices are used strictly to protect the chemicals within from moisture or air to prevent degradation; other times these are used to protect materials that might otherwise react violently with air or water from the standard atmosphere. EHS is only concerned with these types of glove boxes when they are being used as a safety device. When these are being used as a safety device, they should be equipped with alarms to indicate a loss of containment as the atmosphere within is leaked into the lab when containment is breached.

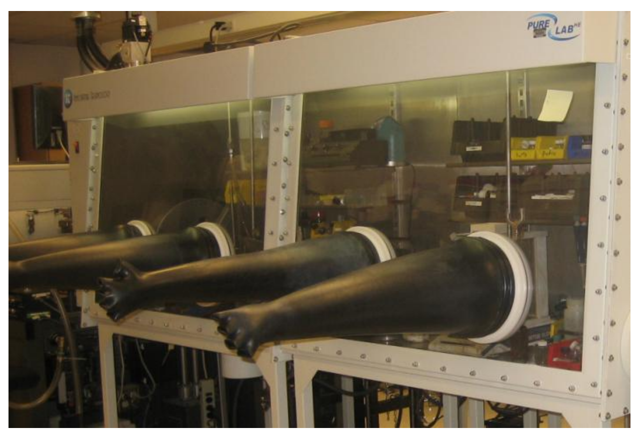


Figure 11: Positive Pressure Glove Box. Note the direction that the gloves are facing.

Positive pressure glove boxes can easily be identified by the direction the gloves are pointing when the device is on but not in use. Gloves are pushed out of a positive pressure glove box because of the pressure within. Certification of these devices must be handled according to manufacturer's instructions and the standards/guidelines of the American Glovebox Society should be consulted.

4.1.3.3 Glove Bags

Glove bags are a special type of isolation device that allows the growth of microorganisms that cannot thrive in environments that contain oxygen. While glove bags are not themselves safety devices, they do present safety hazards in that the atmosphere within them usually contains a certain percentage of hydrogen, a highly flammable gas. Pure hydrogen must never be used to establish or to maintain an anaerobic chamber; a mixture of gases should be used. Mixtures with a concentration of hydrogen greater than 4% can present and explosive mixture within the chamber. Below is a picture of a typical glove bag.

Figure 12: Glove Bag. Materials are placed in the airlock on the far right; the airlock is purged with an atmosphere free of oxygen. Once the purge is complete, materials are then taken into the main chamber. Note the percentage of hydrogen in this bag is 4% according to the gauge.

4.1.4 Other Ventilation/Containment Devices

There are many other types of ventilation equipment and containment devices that are not discussed in as much detail here because they are not as common or require less explanation. Some of them are meant to dissipate vapors or heat, while others are meant to protect the materials within them from contamination. These devices, if being used for safety purposes, require testing on an annual basis according to manufacturer's instructions and must be approved by EHS. A detailed operating procedure for the device, including its limitations, must be developed by a knowledgeable individual and the procedure must be reviewed by all who will use or be affected by the use of the device. Evidence that the device protects the user to the level required, including calculations and measurements, should be documented. Some examples of other exhaust devices include:

- Canopy hoods
- Snorkels
- Compressed gas exhaust cabinets
- Dust collectors
- Clean rooms

4.1.5 More Information

The requirements for laboratory ventilation devices, including more details for shutdown, are contained in the Laboratory Ventilation Device Program available on the EHS website. This program describes the testing/certification, placement, purchase and decommissioning of laboratory ventilation devices. The plan should be reviewed before any changes to laboratory ventilation devices, including installation or removal, are performed.

4.2 Safety Showers and Eyewashes

One of the most important pieces of safety equipment in the laboratory is the safety shower and eyewash. In some instances, these two units are plumbed together, in others they are in separate locations. Eyewashes are intended to flush chemicals or other substances that get into the eyes of lab workers while safety showers are intended to remove hazardous materials from the skin or clothing of a person contaminated. It is important to make sure that all lab workers know where the safety shower and eyewash are in the laboratory and how to use them.

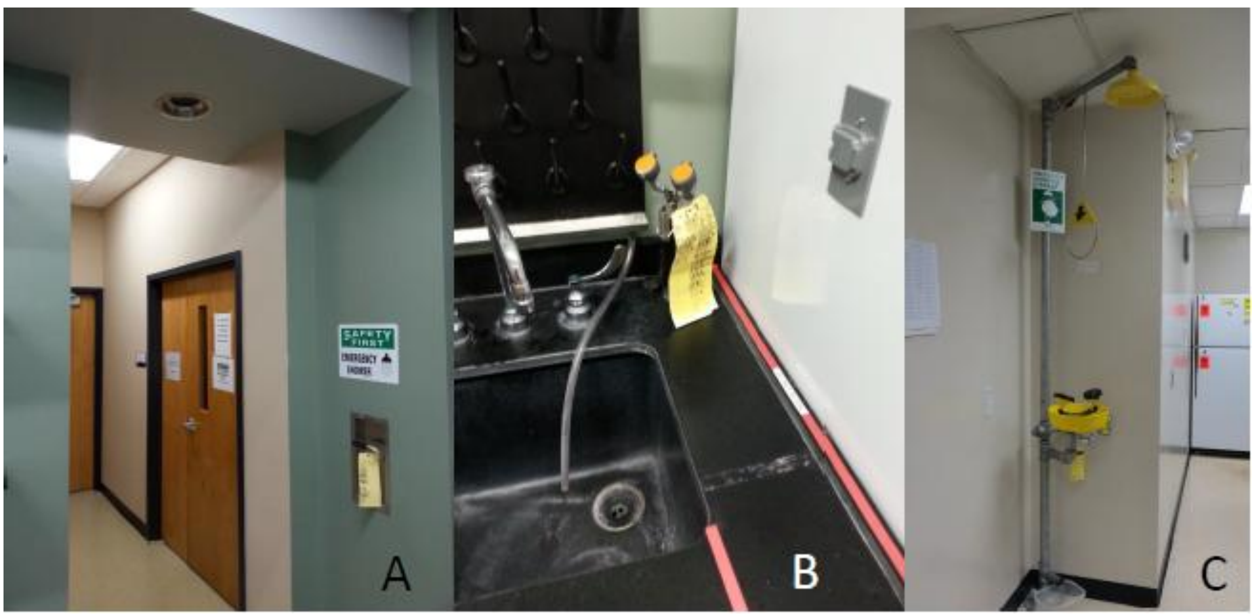


Figure 13: A-*Safety Shower.* In this instance, the safety shower is in a separate location from the eyewash in the ceiling. **B-***Eyewash.* In some laboratories on campus, the eyewashes are located on a lab sink. In many cases, the eyewash doubles as a drench hose and can also be used for washing hazardous materials off skin and clothing. **C-***Combination Unit.* Some laboratories have a combination safety shower/eyewash unit.

Anyone that gets a hazardous material on their skin, on their clothing or in their eyes must not hesitate to use the safety shower or eyewash as appropriate. Most safety showers do not have a drain; thus, the floor will be wet if it has to be used. For this reason, it is very important to keep electrical equipment and any item that should not get wet as far away from a safety shower as possible. In addition to this, there are some rules regarding safety showers and eyewashes:

- Eyewashes are required in any area where corrosive materials are used. The path to the eyewash shall not be impeded by doors, equipment or any other obstruction.

- All eyewashes should be flushed weekly for at least 30 seconds by a lab user or someone else assigned by the department. The result of this test should be recorded either on a tag attached to the eyewash or in a logbook displayed prominently in the lab.
- All safety showers are tested monthly by Environmental Health and Safety.
- Eyewashes and safety showers must be able to be operated in a hands-free mode meaning that once the valve is activated, it must be shutoff intentionally (not automatically shut off).
- The time required to reach an eyewash shall not exceed 10 seconds under normal circumstances.
- When using the safety shower or eyewash, the minimum recommended time of use is 15 minutes.
- When flushing the eyes, the affected individual should hold the eyelids open and roll the affected eyeball while under the flow of water.

Figure 14: What qualifies as an obstructed safety shower or eyewash? A-*Obviously obstructed combination unit.* Storing items in front of a safety shower or eyewash is an obvious violation of lab safety procedures. **B-***Subtle obstruction of eyewash.* Anything that can impede access to an eyewash or a safety shower is a violation of lab safety procedures. While picture B does not seem serious, a lab worker that cannot see due to having hazard materials in their eyes could have trouble accessing the drench hose in this case. The red outline area on this sink may not have anything placed in it.

4.3 Fire-Related Safety Equipment

There are several types of fire-related safety equipment in or near the laboratory. This lab safety manual is not intended to inform lab users of all the fire safety requirements (that is accomplished thought fire safety training and the fire prevention plan); however, a few fire safety items, such as fire extinguishers, sprinklers and fire alarms will be discussed here.

4.3.1 Fire Extinguishers

Fire extinguishers in the laboratory can be a valuable safety tool; however, failure to use them properly or to interpret the circumstances under which they should be used can have severe consequences. Detailed rules for the access to and use of fire extinguishers is given in the fire extinguisher and safety training on the Fire Safety webpage, but a brief list of rules is given below:

- Fire extinguishers must be available wherever flammable materials are stored. This means most labs.
- Fire extinguishers must not be obstructed or hidden from view.
- Fire extinguishers should only be used by individuals that have completed Fire Safety training.
- There are a limited set of conditions under which a person may fight a fire with a fire extinguisher:
    - The local authorities must be contacted first. This means the fire alarm must be pulled or someone has to call 911. The person making contact with the authorities can be a different person than the one using the fire extinguisher.
    - The fire must be small. Anything larger than approximately 3 ft. x 3 ft. is too big to fight.
    - Chemicals must not be involved in the fire. Chemicals can emit dangerous by-products when burning. Unless you are 100% sure that the chemicals will not have toxic products of combustion (by being familiar with the Safety Data Sheet for the chemical), do not attempt to extinguish the fire.
    - If you do not feel comfortable fighting a fire, even if it fits the criteria listed above, do not attempt to extinguish it.
- Fire extinguishers must be inspected on a monthly basis and must have annual recertification. This service is provided by a local contractor, but it is the job of lab workers to confirm that the service is being provided.

Figure 15: Fire Extinguishers. A-*Accessible fire extinguisher.* This fire extinguisher is free of obstructions and plainly visible. **B-***Obstructed fire extinguisher.* A cart is blocking this extinguisher; this would be considered a safety violation. **C**-*Hidden fire extinguisher*. It is important to make sure fire extinguishers are not only unobstructed, but also clearly visible. While this extinguisher is accessible, it is not easily seen.

4.3.2 Sprinklers

Sprinklers are present in most labs. Sprinklers are intended to release water to cool the environment in the event of a fire thereby potentially decreasing the impact and severity of a fire. For sprinklers to work properly, certain rules must be followed:

- Never tamper with or disable sprinkler heads. Not only does this make the laboratory less safe, it also has the potential to flood your lab!
- Do not hang items from sprinkler heads. They are not designed to bear any load.
- Do not store any items within 18” of a sprinkler head. Anything closer than this will change the water dispersal pattern of the sprinkler thus limiting their effectiveness.
- Do not store combustible items within 18” of the ceiling. If items catch fire within 18” of the ceiling, the water from the sprinkler head may not be able to reach that item to help extinguish the fire.

4.3.3 Fire Alarms

Fire alarms are required in all lab buildings. One of the first things a lab worker should do before beginning work in a lab is to determine the location of fire alarm pull stations. This will ensure preparedness in the event of an emergency rather than scrambling when the emergency occurs. Fire alarms can always be found within 5 feet of the exit from a building, but there are likely to be pull stations closer to your lab. Make sure to know the location of fire alarms and ensure that those areas do not become obstructed from access or view. For more information, see the university fire prevention plan.

Chapter 5: Administrative Controls

Administrative controls are controls that change the way work is done to make it safer to the most workers. This may mean limiting access to certain areas, changing the timing of work and/or altering work procedures. Examples of administrative controls in the laboratory include: signs, training, standard operating procedures (SOPs), inspections and general housekeeping. Some administrative controls are explained in more detail below.

5.1 Signs

Warning signs are a very important administrative control. Their purpose is to discourage individuals from entering places where hazards are present when they are not authorized to enter. There are several different types of signs that may be used in laboratories. Each will be discussed below.

5.1.1 General Laboratory Information Sign

The general information laboratory sign gives the person reading information on all the different types of hazards present in the lab, the contact information for the people responsible for the lab, the requirements for entry to the lab and other safety information. These signs are provided by EHS and developed based on information given by the lab users. The sign is required to be posted outside of every laboratory so that before entering individuals can be apprised of the hazards they may encounter in the lab.

The top section of this sign indicates that only individuals authorized to be in the laboratory are allowed to enter. The dot on the top right of the sign indicates to custodians whether or not they are allowed to enter. A green dot indicates that they may enter unescorted at any time. A yellow dot indicates that they may enter if they are escorted by a lab user. A red dot indicates that custodians are prohibited from entering. The red box shows emergency contact information and the green box shows the Environmental Health and Safety department contact information. Laboratory contact information is found at the very bottom of the page (not pictured).

Each of the three symbols toward the middle right of figure 16 indicated a particular type of hazard. The black symbol on the orange background is the biohazard symbol, the black symbol on the yellow background is the radiation symbol and the yellow symbol on the white background indicates the presence of lasers in the laboratory. If these hazards are not present in the lab, these squares will be blank. Each of these symbols will be discussed in more detail later. The gray shaded section contains the chemical hazards present in the lab. The diamond shaped pictograms in this section symbolize different types of chemical hazards. Their meaning will be discussed in the chemical hazards section of this manual.

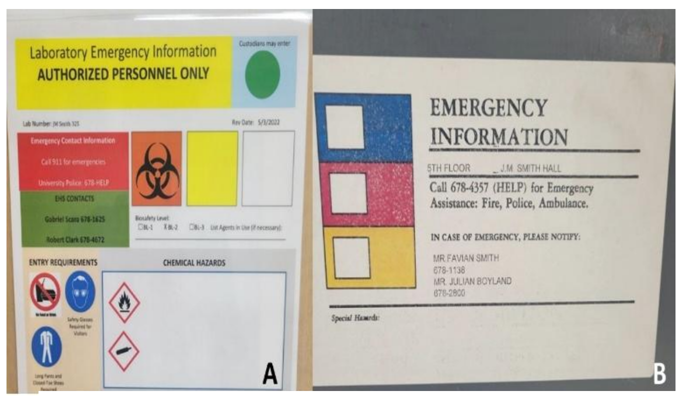


Figure 16: A-New Lab Sign. Information given on this sign includes: the existence of biohazards, radioactive materials or lasers (colored boxes), whether or not custodians are allowed to enter (the dot color and message at top), the chemical hazards present (indicated by pictograms), the entry requirements and contact information. The contact information for the lab is not pictured but is present on the full sign. **B-Old Area Signs.** These are still present on some labs but are being phased out.

Lastly, the beige shaded section informs individuals of the requirements for entry to the lab. No food or drink is permitted in any laboratory. Safety glasses are required for visitors as a visitor will not know what processes may be occurring in the lab prior to their entry. Safety glasses may be removed if the visitor is escorted by a lab user and no processes that require eye protection are being performed. Long pants and closed-toe shoes are required before entering the lab. Additional personal protective equipment (or PPE, which is discussed in a later chapter) may be required before entry depending on the hazard. Special laboratories may require medical screening or vaccination prior to entry.

5.1.2 Biohazard Symbol

The biohazard symbol on the general laboratory information sign indicates the presence of biological hazards in a laboratory. This symbol may also be present on a separate sign in certain circumstances. The biohazard symbol is also displayed on equipment and containers that contain biohazardous agents.

A biohazardous agent is any agent that has the potential to cause disease in humans. Anything that has come into contact with such agents is also considered a biohazard. Work with these types of agents must be done in a laboratory that is classified as Biosafety Level 2 (BSL-2). More information on the types of agents that are biohazards can be found in the Biosafety Manual and the Exposure Control Plan.

Figure 17: The biohazard symbol

5.1.3 Radiation Symbol

The radiation symbol on the general laboratory information sign indicates the presence of radioactive materials in a laboratory. Additional signage containing the radiation symbol is also present on the entrances to labs where radioactive materials are used. The radiation symbol is also displayed on equipment and containers that contain radioactive materials. The presence of the radiation symbol outside of a lab where radioactive materials are used specifies the presence of a sealed source of radiation inside a piece of equipment. As long as the equipment is not tampered with, there is no possibility of exposure to radiation in such cases.

Figure 18: The radiation symbol

A radioactive material is any substance that emits high energy particles or waves capable of causing ionization nearby materials to which the particles and waves come into contact. Radioactive materials that are not in sealed sources are only permitted to be used in labs designated for such work and that work is reviewed by the Radiation and Laser Safety Committee. Additional information on radiological hazards is given later in this manual. Even more information on the hazards associated with radiation and the procedures required for handling radioactive materials can be found in the Radiation Safety Manual.

5.1.4 Laser Symbol

The laser symbol on the general laboratory information sign indicates the presence of lasers in a laboratory. Additional signage containing the laser symbol may also present on the entrances to labs where lasers are used, depending on the power of the lasers being used. The laser symbol is also displayed on equipment that contains lasers.

Figure 19: The laser symbol

Lasers are classified based on the power of the laser that they emit. Most lasers require nothing more than a sign indicating their presence; however, labs that have lasers that are class IIIb or class IV are required to comply with the guidance given in the Laser Safety Manual. Works with these types of lasers is reviewed by the Radiation and Laser Safety Committee. For more information on work with lasers consult the Laser Safety Manual.

5.1.5 Other Signs

There are other signs and labels that may be encountered in the laboratory. Chemical bottles must be labeled with their contents. Specific labels are required for hazardous waste generated in the laboratory (see the Hazardous Waste Management Plan and the Laboratory Management Plan for more details). Chemical fume hoods and other ventilation devices may have signs indicating they have failed inspection or labels indicating only certain materials may be used in them. Pay attention to these signs as they may contain vital safety information!

Figure 20: Examples of Other Signs. **A-***No Food or Drink Sign*. This sign is present on refrigerators, freezers, microwaves, etc. in the laboratory to ensure that equipment used for research is not used in the preparation or storage of food. **B-***Chemical Fume Hood Failure Sign*. This sign will be present when a chemical fume hood has failed inspection. The hood may not be used until the problems have been corrected.

5.2 Training

Since not all hazards can be removed from the laboratory, it is important to train personnel how to work with and around hazards. Training is also required by certain regulatory entities. Environmental Health and Safety training for laboratories falls into three categories: Laboratory Safety, Environmental Compliance and Other. Documentation of all training should be kept by the individual responsible for the lab; this may also be maintained by EHS.

Training can be accomplished in several different ways. First, online training modules can be found at the EHS website for certain subjects. Eventually, all online training will be available on the EHS website; currently, some of the training is found on Blackboard. Another option is attending live training. EHS offers live training modules for most of the trainings listed. A schedule of upcoming training can be accessed by contacting EHS. Environmental Health and Safety will also bring training to your department or your lab at the request of faculty or lab managers.

While general training is developed and delivered by EHS, it is the responsibility of faculty and lab managers to give all lab workers on-the-job training specific to the area in which the individual will be working. Our EHS staff is trained and stays up to date on lab safety, but people that work in the lab every day are best suited to point out the specific hazards in their lab environment. This on the job training should be documented and the records kept in the lab. This training should be done before a person begins work in the lab; all other trainings should be accomplished in the first 30 days if possible.

5.2.1 Laboratory Safety Training

Laboratory safety training can itself be divided into several categories, mainly to limit the training requirements for lab workers. There are some lab training modules that are required only in certain types of laboratories and thus are not included in the general lab safety training. The main three training modules regarding laboratory safety are General Lab Safety, Biological Safety and Radiation Safety.

5.2.1.1 General Laboratory Safety

General laboratory safety training is the broadest and thus the lengthiest training. This training covers most of the contents of this manual and generally follows the subject matter in the order laid out in this manual. The subjects covered include:

- Roles and responsibilities of all lab users
- Laboratory attire
- Engineering controls and safety equipment (fume hoods, safety showers, etc.)
- Administrative controls (signs, SOPs, inspections)
- Personal protective equipment
- Chemical safety
- Hazardous material shipping and disposal (covered briefly)
- Physical hazards

- Biological and radiological hazards (covered briefly)

Any subject that is covered in a separate training module will only be covered briefly in this training. While lab workers need to be aware of all the potential hazards they may encounter in a laboratory, it is the intent of EHS to only require training that is pertinent to the lab worker.

5.2.1.2 Biological Safety

Biological safety training is required for anyone that works in a laboratory that has microorganisms that are capable of causing human disease or anyone that works in a lab that uses human body fluids, tissues or cell lines. This training is also recommended for anyone that works with any biological materials in the laboratory. Biological safety training covers follows the guidance given in the Biosafety Manual and covers the following topics:

- Roles and responsibilities of lab users
- Definition of biohazards
- Infection control
- Principles of containment and laboratory equipment
- Biosafety level criteria
- Animal and plant biosafety
- Select agents and biosecurity
- Emergency response
- Biological waste disposal (covered briefly)
- Transport and shipping of biohazards (covered briefly)

Any subject that is covered in a separate training module will only be covered briefly in this training. While lab workers need to be aware of all the potential hazards they may encounter in a laboratory, it is the intent of EHS to only require training that is pertinent to the lab worker.

5.2.1.3 Radiation Safety

Because the number of people that work with radioactive materials is limited, radiation safety training does not have a dedicated online training module. Users of radiation must complete a safety module that was developed by the Tennessee Department of Environment and Conservation and is available upon request from EHS. This module must be completed prior to beginning work with radiation. Once completed, an in-person refresher training must be completed annual. EHS contacts each department that must complete the training prior to the due date to schedule.

5.2.2 Environmental Compliance Training

Environmental compliance training is required by specific environmental regulations in either the Federal Code of Regulations or by one or more state regulations. While some portions of this training may incorporate safety principles, the main goal of the trainings (and the regulations that require the training) is to protect the environment. Some of these modules are only required to be taken once;

others may need to be done on a recurring basis. Hazardous waste disposal training, biological waste disposal training and stormwater awareness training are included in this category.

5.2.2.1 Hazardous Waste Disposal

Hazardous waste disposal is regulated by the Environmental Protection Agency at the federal level and by the Tennessee Department of Environment and Conservation at the state level. Both of these agencies require training when a hazardous waste generator (like the University of Memphis) generates a certain amount of hazardous waste. Because University of Memphis is a university, there are special regulations that make the management of waste from the university easier. More detail will be given on this in a later chapter.

There are two separate hazardous waste disposal training modules and the module individuals are required to take depends on where they work. Lab workers must take the hazardous waste disposal training for laboratories. Topics covered in this training include:

- Definition of hazardous waste
- Generator status of University of Memphis
- Instructions for the labeling and filling of hazardous waste containers
- Instructions for having hazardous waste removed from the laboratory
- How to respond to hazardous waste emergencies

This training is only intended to cover the management and disposal of chemical wastes. Other types of waste (biological and radiological) are covered in different training modules.

5.2.2.2 Biological Waste Disposal

Biological waste disposal is regulated by the Tennessee Department of Environment and Conservation. While the agency itself does not require generator training, the university does require this training if you work in a laboratory to ensure compliance with the regulations. The regulations only apply to waste that is defined as *medical waste* by the regulations. The rules for biological waste disposal are not intuitive, thus the requirement for training. Topics covered in this training include:

- Different types of biological waste
- Definition of medical waste
- Treatment methods for medical waste
- Requirements for treating medical waste in the laboratory
- Guidelines for spill cleanup and emergencies

5.2.3 Other Training

Several trainings are lumped into this category because they do not fit neatly into another category. This category includes hazardous materials shipping training, bloodborne pathogens training, fire safety training and on-the-job training. Only fire safety and on-the-job training are required for all lab workers;

hazardous materials shipping and bloodborne pathogens training are only required under certain conditions.

5.2.3.1 Hazardous Materials Shipping

Hazardous materials shipping training is required for anyone that ships hazardous materials. This training is unique in that it is not currently provided by EHS. There is a Hazardous Materials Shipping Program that applies to the university. To ship hazardous materials, an employee has to have completed the modules specified in the program based on what types of hazardous materials he or she is shipping. Once the prescribed training module(s) is (are) completed, a copy of the completion certificate is sent to EHS. EHS then presents a certificate to the employee permitting them to ship the hazardous materials specified by the training that they have taken. The certification is only good for 2 years if shipping by air and 3 years if shipping exclusively by ground.

Some individuals may be shipping hazardous materials without realizing it. It is important that all employees that ship be aware of the types of materials that could be potentially classified as hazardous materials. Items that may require training before shipping include:

- Anything shipped on **dry ice**
- Biological samples
- Preserved specimens
- Chemicals
- Human derived products

If there is any doubt about whether or not training is required, please contact EHS to confirm. For more information, please consult the Hazardous Materials Shipping Program on the EHS website.

5.2.3.2 Bloodborne Pathogens

Bloodborne pathogens are infectious microorganisms that are present in human blood and in other human derived materials. OSHA requires training for anyone that works with these materials. Labs that use these materials must comply with the university's Exposure Control Plan, available on the EHS website. Items used in the lab that would require bloodborne pathogens training include:

- Unfixed human or non-human primate cells, tissues or cultures
- Human or non-human primate blood or other body fluids
- Unfixed human or non-human primate anatomical parts

5.2.3.3 Fire Safety

Fire safety training is required for all employees, including those that work in laboratories. It is very important that all employees on campus understand their role in fire safety. Fire safety training can currently be found on the Fire Safety website. Topics covered include:

- Personal fire safety
- Fire extinguisher use and selection
- Evacuation

5.2.3.4 On-the-Job Training

While this is the last training listed in this section of the manual, it is the most important. On-the-job training is required prior to a new lab worker beginning work in the laboratory. This training needs to be documented. On-the-job training includes review of all pertinent laboratory standard operating procedures (SOPs) and training on general laboratory procedures. On-the-job training documentation should be provided to laboratory inspectors upon request.

5.3 Standard Operating Procedures

The OSHA Laboratory Standard requires that the chemical hygiene plan for a laboratory include specific measures to ensure protection of workers. One of the ways to meet this requirement is to develop standard operating procedures (SOPs), particularly those that pertain to the use of hazardous chemicals. While the chemical hygiene plan and the lab safety manual can be used as the guidance documents for general hazardous chemical categories (such as flammables, corrosives, etc.), SOPs must be developed for particularly hazardous chemicals. Review of these SOPs should be completed on an annual basis and must be reviewed by any new laboratory employee prior to beginning work with chemicals.

EHS will help in the development of SOPs for hazardous materials if needed by providing templates. At a minimum, SOPs should include:

- Special hazards of the chemical
- Use of engineering controls
- Required PPE
- Spill response procedure
- Waste disposal procedure
- Decontamination procedure

SOPs are not limited to hazardous chemical use. Equipment and devices in the lab may require SOPs to ensure safe use. Some examples include: Lasers, autoclaves, cryogenic liquids, high-voltage equipment and compressed gas cylinders. These SOPs may point to other documents available in the laboratory (such as equipment users' manuals) so long as the location of those documents is noted in the SOP.

It is the responsibility of the faculty in charge of the lab to ensure that SOPs that incorporate health and safety considerations are developed for working with hazardous chemicals in their laboratories. Further, they are responsible for ensuring that PPE and engineering controls specified in the SOPs are adequate to prevent overexposure to hazardous substances. The person in charge of the lab must ensure that everyone working in the laboratory (employees and students) have reviewed and understand these SOPs.

5.4 Inspections

Laboratories, like other hazardous work areas, are regulated by OSHA, EPA, TDEC, NIH and many other government regulatory agencies. To help promote compliance with the multitude of safety regulations, EHS performs annual inspections of all laboratory areas. These inspections take several different forms: from monthly inspections for hazardous waste satellite accumulation areas to general lab inspection. The purpose of the inspection is not to be punitive; instead EHS intends to the greatest extent possible, to assist labs in complying with all applicable federal, state and local regulations and, most importantly, EHS desires to help keep all lab workers safe and healthy!

Inspections for specialty areas such as hazardous waste and fire safety are described in more detail in those areas on the EHS website. General laboratory inspections have a dedicated webpage with all the materials to help labs be successful in passing laboratory inspections. Items on the webpage include:

- Self-inspection checklist (an exact copy of the lab inspection checklist EHS uses)
- Inspection cheat sheet (a detailed explanation of how each item on the list is graded)
- SOP and memos associated with laboratory inspections
- Staff training rubric that shows all required training for a lab based on the hazards
- Specialty chemical lists (a list of chemicals that have special requirements for handling)
- Online safety manuals and documents
- Chemical storage diagram

Currently, general laboratory inspections are scheduled; there are no surprise inspections. A memo is sent to every lab in the building, notifying them that laboratory inspections will be happening during a specified date range. If the lab does not contact EHS with a time to conduct the inspection, EHS will still conduct the inspection unaccompanied. If a lab fails to pass the first inspection, the follow-up inspection will happen during a different specified range of dates, normally within two weeks of the initial inspection, but will not be scheduled. Failure to pass the inspection does have consequences; see the lab inspection webpage for more detail.

5.5 General Housekeeping

There is a strong correlation between the cleanliness and orderliness of a laboratory and the level of safety within that laboratory. Good housekeeping creates a safer workplace and great care should be given to keeping a laboratory in good order. A clean and well organized laboratory is also more efficient.

In general, benchtops should be well organized and relatively clear when not in use. All chemical bottles must be labeled. Aisles must be kept clear to ensure easy egress from the lab in the event of an emergency. Safety equipment such as safety shower, eyewashes and fire extinguishers must not be obstructed. Chemical fume hoods should be kept clear when not in use; they should not be used for storage. Below are some examples of good housekeeping and poor housekeeping in laboratories.

Figure 21: Several examples of poor housekeeping. Bench space, aisles/exits and chemical; fume hoods should remain relatively clear.

Figure 22: Several examples of good housekeeping. While these spaces are obviously occupied and in regular use, they are still clear of clutter and obstructions.

Chapter 6: Personal Protective Equipment

Personal protective equipment (PPE) should be considered as the last line of defense in protecting laboratory personnel against chemical hazards. PPE should only be used when engineering controls and administrative controls are either inadequate or not feasible to protect laboratory personnel from chemical hazards. PPE is not a substitute for good engineering controls, administrative controls or work practices; however, PPE should be used in conjunction with all of these controls to ensure the health and safety of all university faculty, staff and students.

The OSHA personal protective equipment standard requires the following:

- Hazard assessment of each work area
- PPE selection based on assessment
- Training on PPE
- Certification of the hazard assessment
- PPE must be provided by the employer at no cost to the employee
- PPE must be regularly inspected for contamination, cracks, leaks, etc.

EHS has completed a general hazard assessment for each area of campus; however, it is the responsibility of each principal investigator or responsible faculty to ensure that the appropriate PPE for each task. Don't forget that there are also requirements for attire to be worn in the lab (see chapter 3) In general, the following PPE should be worn in the laboratory:

- Eye or face protection when materials that may injure the eye are being used
- Lab coats when materials that may injure the skin are being used
- Gloves whenever chemicals are being used. Gloves must be compatible with the chemicals that are being used.
- Other PPE may be required based on the hazard assessment

A table is available on the EHS website that is a template for conducting a hazard assessment in the laboratory. Each task is listed on the table along with the required PPE. This table should be available in the laboratory for all workers to access and for lab inspectors to check. In the absence of this assessment, the expected PPE in the lab at all times is safety glasses (or goggles or face shield), lab coat and gloves.

Training for PPE in labs is accomplished through the general laboratory safety training available on the EHS website. This training covers each type of PPE and guides lab workers on how to select the appropriate PPE. Specialty PPE may require additional training and can be included in on-the-job training. See the Personal Protective Equipment on the EHS program for more details.

6.1 Eye and Face Protection

Figure 23: Face Shield. Face shields are used when there are severe splash hazards. Only face shields that have chin guards should be used.

Eye and face protection takes many forms, depending on the task being performed. The required eye protection for using a laser, for example, is much different than that used for simple chemical splash protection. All eye and face protection, unless specified, must comply with consensus standard ANSI Z87.1. Each type of eyewear is described below.

Safety glasses fit the face like normal glasses. They can have metal or plastic frames and have impact-resistant lenses. They must either have side shields or the lenses must wrap around to protect the periphery of the eye. They must comply with ANSI Z87.1. Prescription glasses do not count as safety glasses, thus safety glasses must be worn over prescription glasses if safety glasses are necessary. Prescription glasses that are also safety glasses may be purchased from your eye doctor. **Figure 24B** shows an example of safety glasses.

Splash goggles are tight fitting eye protection that completely covers the eyes and the facial area around the eyes. Chemicals that splash on the skin will not be able to drip down into the eyes if splash goggles are worn. These provide protection from impact just as safety glasses do, but they protect the eye from chemical splashes much better than mere safety glasses. Like safety glasses, splash goggles must comply with ANSI Z87.1. **Figure 24A** shows and example of splash goggles.

Face shields are face protection that extend from the eyebrows to below the chin and across the width of the workers face. Face shields protect from major splash hazards and are often used in conjunction with splash goggles when there is a high probability of hazardous splashes or sprays. Face shields may also be used for UV protection, but they must be approved by the manufacturer for this use. Face shields must also comply with ANSI Z87.1 to be appropriate for use in the laboratory.

The picture below shows how to tell if eye protection is, in fact, Z87.1 compliant. The table below the picture describes the type of eyewear appropriate according to the task being performed. While the table may be used as a guideline, remember that the ultimate responsibility for the determination of appropriate PPE lies with the person in charge of the lab.

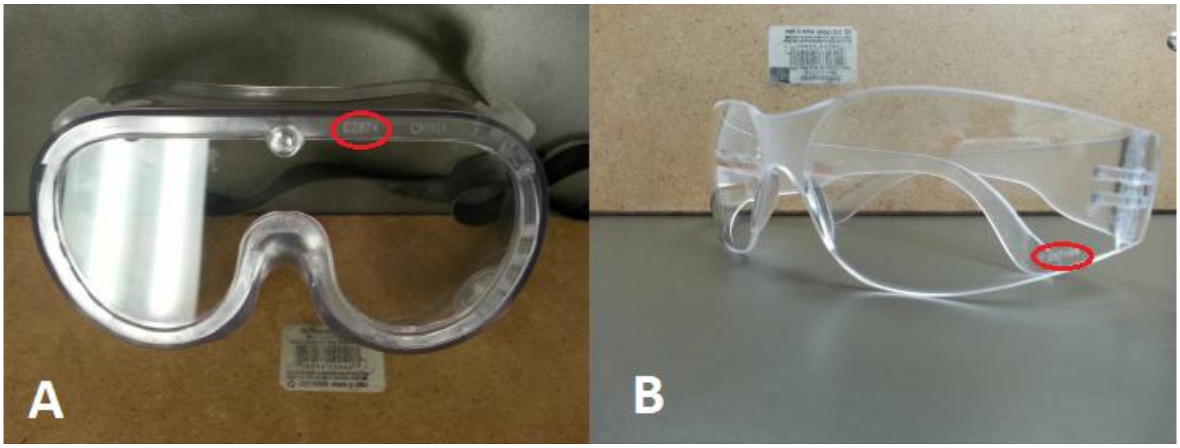


Figure 24: ANSI Z87.1 compliant eyewear. A-*Splash goggles.* The red oval encircles the indication on these splash goggles that they comply with the appropriate consensus standard. Goggles that lack this indication do not comply with OSHA. **B**-*Safety glasses*. These safety glasses also comply with ANSI Z87.1 and are thus OSHA compliant as indicated by the stamp on the glasses encircled in red. Eyewear that lacks this stamp on the lenses or on the temples (the part of the glasses that extends over the ear) is not OSHA compliant.

Eye and Face Protection Chart		
Category	**Type of Eye or Face Protection Needed**	**Additional Notes**
Chemicals		
Hazardous dry chemicals and small amounts of hazardous liquid chemicals	Safety glasses	Required whether working on the open bench or in a chemical fume hood
Hazardous chemicals that are a splash hazard	Splash goggles	Required whether working on the open bench or in a chemical fume hood
Cryogenic liquids	Splash goggles and face shield	
Highly reactive or explosive materials	Splash goggles and face shield	
Pyrophoric solids or liquids	Splash goggles	
Biological Materials		
Potentially infectious materials	Safety glasses or face shield	Eye protection may not be required when using a biological safety cabinet. See Biosafety Manual for details
Radiation		
Unsealed radioactive materials	Safety glasses	
Ultraviolet light	Face shield with UV protection	
Lasers	Depends on wavelenght and power of laser used	See Laser Safety Manual
Physical Hazards		
Soldering or working with spattering hot material	Safety glasses or splash goggles	
Particulate or dust generated	Safety glasses	
Glassware under pressure	Safety glasses	
Cutting or connecting glass tubing	Safety glasses	
Changing or connecting compressed gas cylinders	Safety glasses	
Use of compressed air for cleaning	Safety glasses	Use of compressed air for cleaning equipment only; it should not be used for cleaning personnel
Welding, brazing or cutting metal	See PPE program or welding hazard assessment	

Figure 25: Eye and Face Protection Chart. This is a guide that explains what type of eye and face protection to use in the lab based on the task.

Eye and face protection should be cleaned on a regular basis to prevent buildup of grime and microorganisms. They should also be cleaned whenever vision through them becomes compromised. Alcohol-based wipes can be used for this purpose as well as simple soap and water. Consult the manufacturer's instructions for cleaning instructions. Eyewear should also be regularly examined for damage. Lastly, make sure to remove gloves and wash hands, if necessary, before removing eyewear to prevent potential exposure of the eyes to hazardous substances that may be on gloves or hands.

6.2 Hand Protection

Much like eye and face protection, the type of hand protection needed depends on the task being performed. Gloves, the primary form of hand protection, vary more than any other type of PPE because the hands are the area of the body most exposed to hazards. The hands can be exposed to physical hazards and chemical hazards.

Physical hazards that the hands can encounter in the lab include sharps, cold temperature and high temperatures. When using sharps, consideration should be given to using cut-resistant gloves. When working with cryogenic liquids (such as liquid nitrogen or liquid oxygen), cryogenic gloves should be used. When removing items from the autoclave or oven, heat-resistant gloves should be used to prevent burns. These types of gloves may also be used for removing or handling items that have been heated on a hot plate. Hot hands (see figure) may also be used for this purpose but should not be used for removing items from an autoclave. These are not the only physical hazards presented to the hands in the laboratory, but they are the most common. For details on the gloves required for each task, refer to your lab's hazards assessment.

Figure 27: Gloves for physical hazards. A-*Cut-resistant gloves.* Cut resistant gloves should be used for tasks involving sharps such as syringes, razor blades and scalpels. These gloves a fairly flexible and do offer some dexterity. **B-***Cryogenic gloves.* These gloves should be used with cryogenic liquids when possible. **C-***Autoclave gloves.* While these gloves are called autoclave gloves, they may be used for handling hot items from ovens and hot plates as well.

Figure 26: Hot Hands. Hot hands are used for handling somewhat hot objects that have been heated on hot plates. They must not be used for removing items from the autoclave.

The most common reason gloves are used in the lab is to protect the hands from chemicals. There are many different types of materials from which chemical resistant gloves can be made. The most common material seen in the lab is nitrile-butadiene rubber (commonly referred to as Nitrile or Solvex). This is a very good multi-purpose glove that is resistant to most chemicals such as acids, bases and non-halogenated solvents. They are not suitable for use with halogenated solvents, acetone or benzene among other chemicals. There are other glove materials that are resistant to the other chemicals; consulting a chemical resistance guide before using a glove for protection against chemicals is a wise course of action. Links to these guides are given later in this section and are available on the EHS website.

Figure 28: Process for removing gloves.

Latex gloves are frequently found in labs but should be avoided for several reasons. First, latex allergies are common. Even if you are not allergic, your coworker may be. Second, latex gloves are poor protection from most solvents. Last, it is most difficult to identify tears and pinholes on latex gloves because of their color.

With most chemicals, it is difficult to tell if your gloves are contaminated. It is best to assume that gloves are contaminated when it is time to remove them. If chemical contamination can be seen, it is best to wipe it off before removing gloves. Once gross contamination is removed, follow the instructions given below to remove gloves:

1) Grasp the outside of one glove above below the top of your wrist (below meaning toward your fingers) being careful not to touch your bare skin.
2) Peel off the first glove away from your body from your wrist toward your fingertips turning the glove inside out.
3) You may discard the removed glove or continue to hold the removed glove in your other gloved hand.
4) With your ungloved hand, take off the second glove by inserting your finger (or fingers) inside the glove near your wrist being careful not to touch the outside of your glove with your bare fingers. If this is not possible, you may use the inside of the glove you removed to pinch the second glove below the wrist and remove it.
5) Turn the second glove inside out as well. Once both gloves are removed, dispose of them properly.
6) Wash your hands once you have removed your gloves!

Standard nitrile gloves, the most commonly used glove, are meant to be one time use gloves. They are not to be washed and reused as this degrades the ability of these gloves to protect. Once standard nitrile gloves are removed, they must be disposed. Thicker gloves, such as Solvex, PVA, PVC, etc. are intended to be used multiple times. These gloves can be cleaned and reused per manufacturer's instructions. These gloves are generally easier to remove than standard nitrile gloves.

Figure 29: Gloves for chemical hazards. A-*Standard nitrile gloves.* These are the most common laboratory gloves and they are suitable for use with most chemicals. They are unsuitable for use with halogenated solvents, acetone, phenol or benzene. For complete compatibility discussion, see manufacturer's chemical resistance guide. **B-***Solvex gloves.* These gloves are made of the same material as nitrile; they are just thicker and longer. This thickness reduces dexterity but increases protection. **C-***Polyvinyl alcohol (PVA) gloves.* PVA gloves are should be used when large amounts of halogenated solvents (like chloroform) are going to be used. These gloves have limited dexterity and are expensive (~$30 per pair). **D-***Polyvinyl chloride (PVC) gloves.* PVC gloves tend to be more susceptible to chemical breakthrough than nitrile, but there are a few chemicals for which they are more protective than nitrile (like phenol). **E-***Laminate film gloves.* These gloves are resistant to almost every chemical; however, they have very limited dexterity. They should be used as a last resort in a laboratory setting but are good for used in chemical spill cleanup kits.

There are more different types of chemical resistant gloves than those listed above. Below is a list of chemical resistance guides from different glove companies. These links are also available on the EHS website.

- Ansell Chemical Resistance Guide: https://cdn.mscdirect.com/global/media/pdf/search/ansell/ansell-chemical-glove-resistance-guide.pdf
- ChemRest Glove Protection Guide: https://www.showagroup.com/wp-content/uploads/2021/06/ChemRest-catalog-EN-US.pdf
- Fisher Chemical Resistance Guide: https://www.fishersci.com/content/dam/fishersci/en_US/documents/programs/scientific/brochures-and-catalogs/guides/ansell-chemical-resistance.pdf
- Cole-Parmer Safety Glove Compatibility Guide: https://www.coleparmer.com/safety-glove-chemical-compatibility

- VWR Glove Chemical Resistance Chart: https://digitalassets.avantorsciences.com/adaptivemedia/rendition?id=b47d969521239fc3e6845f1fb1ffa1bb0d5d73f9&vid=1da9834a105c45208ef170fe93c3a1813b78fa65&prid=original&clid=SAPDAM

Chemical gloves must not be worn outside of the lab. Even new gloves must be taken off before leaving the lab. Touching doorknobs, elevator buttons or other items commonly touched by the public increases the likelihood of spreading contamination. Even wearing clean gloves in such areas gives an inappropriate impression about the safety culture of the laboratory.

6.3 Lab Coats

The hands are not the only places where skin is exposed that may need to be protected. Arms and personal clothing are also exposed and, depending on the materials being used, may need to be protected. Lab coats are worn for this purpose. In the absence of a laboratory hazards assessment, a lab coat is expected to be worn at all times in the laboratory.

Just like other types of PPE, the type of lab coat used is based on the task that is being performed. In most cases, a standard cotton or polyester lab coat will work. However, when working with pyrophoric chemicals or explosion hazards, those types of coats may not be appropriate. Disposable lab coats can also be used. The laboratory hazard assessment and the safety information available for the hazardous materials that are being used in the lab should be consulted before selecting a lab coat.

Lab coats also need to be cleaned regularly. Fluid resistant lab coats are easy to clean with the appropriate disinfectant in the lab. Lab coats that have biohazardous contamination must be disinfected by being autoclaved, laundered with 10% bleach (10% is the total concentration of bleach including the wash water that is added to the washing machine; only used washing machines designated for lab coats. Home washing machines are not appropriate) or spray disinfected (if the lab coat is fluid resistant). Contaminated lab coats that are being removed from the lab for cleaning must be in a closeable bag or container and must be labeled appropriately. Disposable lab coats should be disposed of properly if they become contaminated; they are not to be washed and reused. Special lab coats (like Nomex coats that are fire resistant) may have special laundering requirements; make sure to follow all manufacturers' instructions when laundering any lab coat.

Figure 30: Different types of lab coats. The most common type of lab coats found in the lab is standard cotton lab coats. Here are some examples of alternatives to those coats. **A**-*Fluid-resistant lab coat.* This coat does not absorb liquids; it repels them. It is suitable for working with liquid chemicals and is easy to disinfect. **B**-*Disposable lab coat.* This lab coat is meant for short-term use and may be suitable for a teaching lab. Once it is gets contaminated, it must be disposed. **C**-*Fire-resistant lab coat.* This type of coat must be used when working with materials that may spontaneously ignite. It is made from a fire-resistant material called Nomex.

Lab coats should not be worn outside of the lab. There are some labs where it is forbidden to remove the lab coat from the lab unless it is being taken to an area for decontamination. Lab coats are useful for protecting users from chemical and physical hazards in the lab, but they are inappropriate for public areas. If lab coats are taken out of the laboratory for laundering, they must be in sealed bags that are labeled appropriately.

6.4 Respiratory Protection

Respiratory protection is a heavily regulated type of personal protective equipment. Wearing a respirator presents physiological challenges to the worker and using a respirator should only be required when all other feasible controls have been used to reduce employee exposure to airborne contaminants. The university Respiratory Protection Program details the requirements for care and use of a respirator. Please note that even dust masks are considered respirators by OSHA and the procedures that are described below are required for them as well.

There are several steps required before respirator use is allowed. Purchasing a respirator and using it without following the procedures set forth in the respiratory protection program is prohibited. First, EHS should be consulted to determine whether the use of a respirator is necessary. Other controls should be attempted before deciding to allow respirator use. If it is determined that a respirator is necessary, the worker shall report to an occupational health professional (at the expense of the lab or department, not the worker) to be medically screened to determine if the worker is physically able to use a respirator (contact EHS for suggestions on occupation health professionals). Once the worker is medically cleared, the respirator may be ordered. Then the worker must be fit tested for the respirator; an outside contractor will need to conduct the fit testing (contact EHS for details).

If EHS determines that a respirator is not required and the worker still wishes to use a respirator, EHS must be consulted to provide the worker with the appropriate information on the risks of using a respirator. This and more information on the care and use of respirators are provided in the respiratory protection program. The types of respirators and the conditions under which they may be used are also discussed in the respiratory protection program.

Figure 31: Examples of respirators. A-*N95 dust masks.* These are several different types of dust masks that are all considered respirators by OSHA. **B-***Full-face air purifying respirators.* These respirators require cartridges that filter out different types of contaminants (dependent on the type of cartridge). They provide a higher level of protection than a simple dust mask. **C-***Powered air-purifying respirator (PAPR).* This hood attaches to a pump that filters air to remove contaminants. Unlike the other types of respirators, it is loose fitting. **D-***Self-contained breathing apparatus (SCBA).* This type of respirator isolates the breathing air into a tank. These types are not used in the laboratory, but are appropriate for many emergency response situations.

6.5 Other PPE

While the previous sections address the most common types of PPE found in the laboratory, there may be others that are required. Other examples of personal protective equipment include hearing protection, foot protection, head protection and other protective clothing. All of these are addressed in the university PPE program and if any of these are required in the laboratory, it must be documented in the laboratory hazard assessment. There are consensus standards and regulatory requirements for each of these types of PPE; consult EHS for details.

Chapter 7: Safe Use of Chemicals

Chemicals are the primary hazard in most labs, so a large portion of this manual provides information on working safety with chemicals. More specific information about the hazards of particular classes of chemicals is given in later chapters. Topics included in safe chemical use include:

- Routes of chemical exposure
- Methods for minimizing chemical exposure
- Chemical exposure limits and monitoring
- Methods for obtaining information on chemical hazards
- Chemical labeling
- Chemical storage and segregation guidelines

7.1 Routes of Chemical Exposure

Before discussing how to minimize exposure to chemicals, it is important to understand how chemicals can enter the body. The levels of protection from exposure to chemicals are based on reducing the likelihood of a chemical entering the body through one or more of these routes. Chemicals can enter the body through inhalation, ingestion, injection or absorption/contact. Understanding how a chemical with which you are working can enter the body can help you provide the maximum level of protection practicable for your health.

It is important to note if you suspect exposure to a chemical as soon as possible. Some chemical effects are immediate (acute), but others take time to develop (chronic). Identifying exposures as quickly as possible increases the likelihood of a full and complete recovery. Use of hazard controls such as PPE significantly reduces the probability of chemical exposure.

7.1.1 Inhalation

Exposure to chemicals through inhalation happens when the gas, vapor, aerosol or particulate of a chemical is inhaled into the lungs and nose. These contaminants can cause problems in the respiratory tract itself or be absorbed into the bloodstream in the lower lungs. Symptoms of exposure by inhalation vary based on the chemical, but typical symptoms include nose and throat irritation, coughing, difficulty breathing, headache, dizziness, disorientation and/or fainting. If you notice any of these symptoms, leave the immediate area to fresh air. If symptoms continue, seek medical attention. Then, report the incident to EHS to start the injury/illness report for workers compensation.

7.1.2 Ingestion

Chemical exposure through ingestion occurs by chemicals being absorbed through the digestive tract. This means that a chemical is eaten or drunk accidentally. While accidentally eating or drinking a chemical is unlikely, especially if good labeling and housekeeping practices are employed, indirectly ingesting a chemical can happen in the laboratory if chemical hygiene rules are not followed. Having food and drink in the lab where they can contact chemicals or absorb chemical vapors or dust from the air can result in exposure once the food and drink are consumed. Thus, food and drink are not allowed in the laboratory. Furthermore, failing to wash your hands after working in the lab can result in ingesting residues from your hands.

Symptoms of exposure to chemicals through ingestions vary based on the chemical; however, common symptoms are strange tastes in the mouth, nausea, stomach cramps, vomiting, problems swallowing or general malaise. If these symptoms occur and you believe it may be the result of ingesting a chemical, seek immediate medical attention. Then, report the incident to EHS to start the injury/illness report for workers compensation.

7.1.3 Injection

Chemical exposure through injection happens when a chemically contaminated item, such as a syringe or broken glass, punctures the skin causing the chemical to be deposited below the skin and potentially into the bloodstream. Handling sharps with bare hands, failing to examine glassware for cracks or chips and disposing of broken glass improperly are a few of the many ways in which an exposure by injection can occur. Guidance for working with sharps is included in chapter 11 of this manual.

If you are cut or injected by a sharp object, the injury needs to be reported to EHS whether or not you seek medical treatment. If the object that cut or stuck you is chemically contaminated, rinse the area thoroughly to remove as much chemical contamination as possible and then seek medical attention. Then, report the incident to EHS to start the injury/illness report for workers compensation.

7.1.4 Absorption/Contact

Exposure by absorption can take many forms. Some chemicals can be absorbed by the eyes being exposed to the chemical vapor or aerosol. Others can be absorbed through the skin. Some chemicals are harmful just by coming into contact with the skin or eyes. The use of PPE is the primary way to avoid exposure by this pathway.

Chemical exposure to the eyes occurs most of the time because of failure to use prescribed hazard controls like PPE. While symptoms of eye exposure vary based on the chemical, common symptoms include itching or burning, blurring of vision, general eye discomfort or blindness. If chemical exposure to the eye is suspected, immediately flush the exposed eye(s) in the laboratory eyewash station for at least 15 minutes. Use your fingers to hold open the affected eye(s) while flushing. After flushing the eye(s) for 15 minutes, seek medical attention. After this, report the incident to EHS to start the injury/illness report for workers compensation.

Because skin covers every part of the body, it is much more difficult to control chemical exposure to the skin. Appropriate use of safety procedures, PPE and other hazard controls will significantly reduce the probability of chemical exposure to the skin. While symptoms of skin exposure vary based on the chemical, common symptoms include redness, dryness, whitened skin, swelling, rashes, blisters, itching, burns and defatting. For small exposures to the skin, clean the affected area with soap and water for at least 15 minutes. If the symptoms persist, seek medical attention and then report the injury to EHS. If a large portion of the body is exposed, use the laboratory safety shower and flush the whole body for at least 15 minutes. After this, seek medical attention; then, report the incident to EHS to start the injury/illness report for workers compensation.

7.2 Minimizing Chemical Exposure

The organization of this manual is such that many of the control measures for minimizing chemical exposure are outlined in chapter 4-6. Other control measures are alluded to in various portions of this manual but are summarized here. The best way to protect laboratory personnel from chemical hazards is to minimize exposure to them. Chemical exposure can be best minimized by:

- Not using chemicals, if possible. This is not often practical, but it is often overlooked. Examine literature to be sure that the experiment being attempted has not been done before.
- Substituting less hazardous chemicals in experiments where possible.
- Using the smallest amount of a chemical possible for all experiments. This also saves money.
- Minimizing chemical exposures for all potential routes of entry using engineering controls (chapter 4), administrative controls (chapter 5) and personal protective equipment (chapter 6).
- Removing PPE prior to leaving the laboratory.
- Understanding the risks that all chemicals present by consulting this manual and the Safety Data Sheet (SDS) for the chemical.
- Planning experiments in advance, including measures for safely handling hazardous chemicals.
- Requesting exposure monitoring when there is a question as whether exposure limits are being exceeded.
- Promptly cleaning up chemical spills.
- Attempting experiments where large amounts of a chemical will be needed on a microscale prior to scaling up.
- Washing hands frequently and every time you leave the lab.

7.3 Information on Chemical Hazards

There are many different types of chemical hazards (most of which are discussed in chapters 8 and 9 of this manual), but these hazards can be lumped into two different categories. Chemicals can pose both physical and health hazards. A physical hazard is, according to OSHA, “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.” According to OSHA a health hazards is “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 which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic system and agents which damage the lungs, skin, eyes, or mucous membranes."

There are several different places to find chemical hazard information. This manual is one source as is the university Chemical Hygiene Plan. The manufacturer of the chemical provides information on the chemical label and on the Safety Data Sheet for the chemical. The laboratory door sign contains pictograms for the hazards associated with the chemicals in a laboratory. The National Fire Protection Association (NFPA) diamond is another quick reference. Department of Transportation (DOT) labels are another source of information that is often available on chemical packaging. There are multiple websites that discuss chemical safety as well. Some of the sources of information are discussed below.

7.3.1 Pictograms

Pictograms were developed as a part of the Globally Harmonized System to identify chemical hazards and have specific meaning according to OSHA. While pictograms themselves are not a source of information *per se*, they are present on many of the sources of information (lab door signs, chemical labels, safety data sheets, etc.) so understanding what they look like and what they mean are important. More detailed information on the types of chemicals that are identified by each pictogram is given in chapter 8 where chemical hazards are described extensively. Each pictogram is described below.

7.3.1.1 Skull and Crossbones

This pictogram is used exclusively for health hazards. It is used when a chemical is hazardous for one or more of the following reasons:

- It is an acute oral toxin,
- It is an acute dermal toxin or
- It is an acute inhalation toxin.

For more specific information on the use of this pictogram, see the university Hazard Communication Plan.

Figure 32: Skull and Crossbones Pictogram.

7.3.1.2 Test Tube and Hand

This pictogram is the only pictogram that is used for both health hazards and physical hazards. It is used when a chemical is hazardous for one or more of the following reasons:

- It is severely injurious to the eyes,
- It is severely corrosive to the skin or
- It is corrosive to metals.

For more specific information on the use of this pictogram, see the university Hazard Communication Plan.

Figure 33: Test Tube and Hand Pictogram.

7.3.1.3 Star on Chest

This pictogram is used exclusively for health hazards. It is used when a chemical is hazardous for one or more of the following reasons:

- It causes inhalation sensitization,
- It is germ cell mutagenic,
- It is carcinogenic,
- It is toxic to specific organs or
- It is a severe aspiration hazard.

Figure 34: Star on Chest Pictogram.

For more specific information on the use of this pictogram, see the university Hazard Communication Plan.

7.3.1.4 Exclamation Point

This pictogram is used exclusively for health hazards. It is used when a chemical is hazardous for one or more of the following reasons:

- It is mildly toxic by any exposure route (oral, dermal or inhalation),
- It is a mild skin corrosive,
- It can cause reversible eye damage,
- It causes dermal sensitization or
- It is mildly toxic to specific organs.

Figure 35: Exclamation Point Pictogram.

For more specific information on the use of this pictogram, see the university Hazard Communication Plan.

7.3.1.5 Exploding Bomb

This pictogram is used exclusively for physical hazards. It is used when a chemical is hazardous for one or more of the following reasons:

- It is explosive,
- It is self-reacting or
- It is an organic peroxide that can cause an explosion.

Figure 36: Exploding Bomb Pictogram.

For more specific information on the use of this pictogram, see the university Hazard Communication Plan.

7.3.1.6 Flame

This pictogram is used exclusively for physical hazards. It is used when a chemical is hazardous for one or more of the following reasons:

- It is flammable,
- It is mildly self-reacting,
- It is pyrophoric,
- It is self-heating,
- It emits flammable gases when in contact with water or
- It is an organic peroxide that can cause a fire.

Figure 37: Flame Pictogram.

For more specific information on the use of this pictogram, see the university Hazard Communication Plan.

7.3.1.7 Flaming Circle

This pictogram is used exclusively for physical hazards. It is used when a chemical is hazardous because it is an oxidizing solid, liquid or gas. For more specific information on the use of this pictogram, see the university Hazard Communication Plan.

Figure 38: Flaming Circle Pictogram.

7.3.1.8 Gas Cylinder

This pictogram is used exclusively for physical hazards. It is used when a chemical is hazardous because it is a gas stored under pressure. For more specific information on the use of this pictogram, see the university Hazard Communication Plan.

Figure 39: Gas Cylinder Pictogram.

7.3.1.9 Dead Fish and Tree

This pictogram is used for environmental hazards. This is important in terms of disposal of residues of chemical that bear this pictogram. For more specific information on the use of this pictogram, see the university Hazard Communication Plan.

Figure 40: Dead Fish and Tree Pictogram.

7.3.1.10 "W" with a Line through it

This symbol is not an official pictogram, but it is used on laboratory door signs and on some chemical labels. It means that the chemical present will react when exposed to water or moisture. Water reactive chemicals are discussed in chapter 8.

Figure 41: "W" with a Line through It Pictogram.

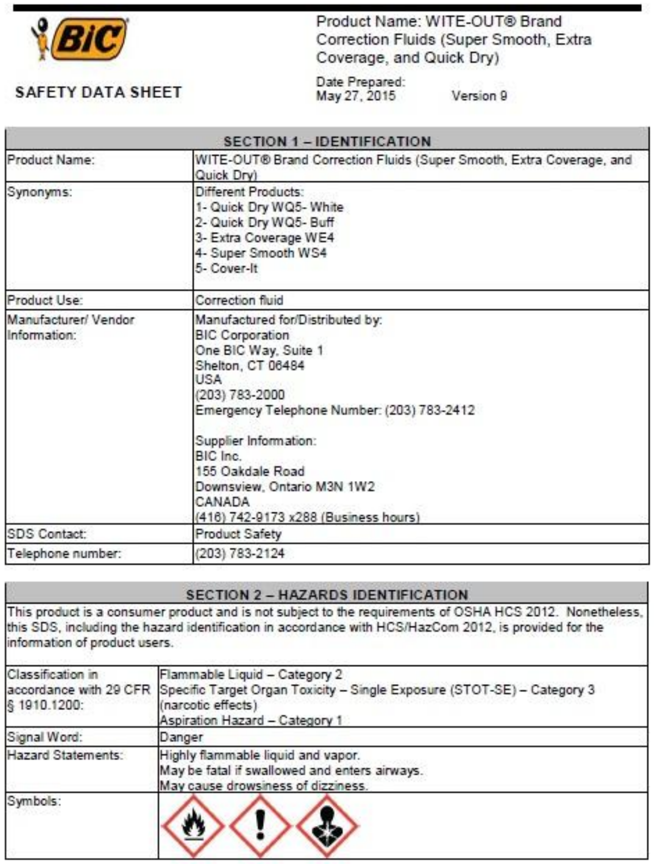
7.3.2 Chemical Label

A chemical label is the easiest and quickest way to get information about a chemical. Included on most chemical labels is information about the hazards of the chemical, instructions on emergency situations and instructions on safe storage conditions for the chemical. If the chemical is not in its original manufacturer's container, a secondary label must be on the container describing the chemical and the primary hazards associated with the material. Below is an example of a typical chemical label

Figure 42: Chemical label. This is a typical manufacturer's label for a chemical. Information on the hazards of the chemical is provided here.

7.3.3 Safety Data Sheet

The Safety Data Sheet (SDS) for a chemical has the most complete information available for that chemical. OSHA requires manufacturers of chemical substances to provide very specific information about the hazards associated with those substances on the Safety Data Sheet. Labs should maintain a database (electronic or hard copy) of SDSs for all chemicals in the laboratory. The SDSs are structured consistent with OSHA requirements; all SDSs have 16 sections. Details about SDSs are discussed in the university Hazard Communication Plan available on the EHS website, but examples of information given in a safety data sheet include: the physical and health hazards, exposure limits, safe storage and use, symptoms of exposure, physical and chemical characteristics. Below is an example of a typical safety data sheet.



SAFETY DATA SHEET

Product Name: WITE-OUT® Brand Correction Fluids (Super Smooth, Extra Coverage, and Quick Dry)

Date Prepared: May 27, 2015 Version 9

SECTION 1 – IDENTIFICATION	
Product Name:	WITE-OUT® Brand Correction Fluids (Super Smooth, Extra Coverage, and Quick Dry)
Synonyms:	Different Products: 1- Quick Dry WQ5- White 2- Quick Dry WQ5- Buff 3- Extra Coverage WE4 4- Super Smooth WS4 5- Cover-It
Product Use:	Correction fluid
Manufacturer/ Vendor Information:	Manufactured for/Distributed by: BIC Corporation One BIC Way, Suite 1 Shelton, CT 06484 USA (203) 783-2000 Emergency Telephone Number: (203) 783-2412 Supplier Information: BIC Inc. 155 Oakdale Road Downsview, Ontario M3N 1W2 CANADA (416) 742-9173 x288 (Business hours)
SDS Contact:	Product Safety
Telephone number:	(203) 783-2124

SECTION 2 – HAZARDS IDENTIFICATION	
This product is a consumer product and is not subject to the requirements of OSHA HCS 2012. Nonetheless, this SDS, including the hazard identification in accordance with HCS/HazCom 2012, is provided for the information of product users.	
Classification in accordance with 29 CFR § 1910.1200:	Flammable Liquid – Category 2 Specific Target Organ Toxicity – Single Exposure (STOT-SE) – Category 3 (narcotic effects) Aspiration Hazard – Category 1
Signal Word:	Danger
Hazard Statements:	Highly flammable liquid and vapor. May be fatal if swallowed and enters airways. May cause drowsiness of dizziness.
Symbols:	

Figure 43: Safety Data Sheet. This is the first page of a safety data sheet for Wite-Out. The first section gives the name of the material and the second section gives information on the hazards associated with the material. Information about the contents of other sections of a safety data sheet can be found in the Hazard Communication Plan on the EHS website.

7.3.4 National Fire Protection Association (NFPA) Diamond

Figure 44: NFPA Diamond

The National Fire Protection Association (NFPA) classifies chemicals based on their hazards and displays the information using the NFPA diamond. The diamond is divided into four sections. The left most section is blue and indicates the health hazard associated with the chemical. The red section is on the top and indicates the flammability of the chemical. The yellow section is on the right and gives information on the instability or reactivity of the chemical. Lastly, the white section is on the bottom and provides special information about the chemical. The "W" with the line through it discussed in the pictogram section originates from this diamond and is placed in the white section when a material is water reactive. The letters "OX" in the white section shows that the material is an oxidizer and the letters "SA" in this section indicate the material is a simple asphyxiant gas (a non-reactive, non-flammable gas that can be a health hazard by displacing oxygen in the immediate atmosphere but is otherwise safe).

The information provided in the blue, red and yellow sections is given numerically; each can range from 0 to 4. The hazard is more serious as the number increases; 0 meaning no hazard in that section and 4 meaning very hazardous for that section. The meanings of the numbers for each section are given below.

7.3.4.1 Health Hazards (Blue Section)

A summary of the meaning of the numbers 0 through 4 for this section are as follows:

- 0- No health hazard
- 1- Can cause significant irritation
- 2- Can cause temporary incapacitation or residual injury
- 3- Can cause serious or permanent injury
- 4- Can be lethal

7.3.4.2 Flammability Hazards (Red Section)

A summary of the meaning of the numbers 0 through 4 for this section are as follows:

- 0- Will not burn
- 1- Must be preheated before material can ignite
- 2- Must be heated or temperature of environment must be high to burn
- 3- Can be ignited at normal temperatures
- 4- Will vaporize and readily burns at normal temperatures

7.3.4.3 Reactivity/Instability Hazards (Yellow Section)

A summary of the meaning of the numbers 0 through 4 for this section are as follows:

- 0- Stable
- 1- Stable except at high temperatures
- 2- Violent chemical changes at high temperatures or pressures
- 3- May explode at high temperatures or if shocked
- 4- May explode at normal temperatures and pressures

7.3.5 Department of Transportation (DOT) Labels

The Department of Transportation (DOT) requires labels to be placed on packages that contain chemicals to communicate the hazards of those chemicals to anyone involved in their transport. This information is also provided so that emergency responders to incidents with these chemicals in transport can know what types of chemicals may be involved in the incident from a safe distance. Each of the nine hazard classes is shown below. Some hazard classes have subclasses called divisions. For a lot more information on hazardous materials in transport, refer to the university Hazardous Materials Shipping Plan. The DOT hazard classes are:

- Class 1: Explosives
- Class 2: Compressed gases
  - Division 2.1: Flammable gases
  - Division 2.2: Non-flammable, non-poisonous gases
  - Division 2.3: Gases that are poisonous by inhalation
- Class 3: Flammable liquids
- Class 4: Flammable solids
  - Division 4.1: Flammable solids
  - Division 4.2: Spontaneously combustible- includes pyrophorics and self-heating substances
  - Division 4.3: Dangerous when wet
- Class 5: Oxidizers
  - 5.1 Oxidizers
  - 5.2 Organic Peroxides
- Class 6: Poisonous materials and infectious substances
  - Division 6.1: Poisonous materials
  - Division 6.2: Infectious substances
- Class 7: Radioactive materials
- Class 8: Corrosives
- Class 9: Miscellaneous hazards

Figure 45: DOT Hazardous Materials Labels

7.3.6 Other References

There is a lot of information available for most laboratory chemicals and there is no limit to the number of resources you can use to ensure safe use of chemicals in the laboratory. Other departments at the university may have information in their safety manuals. Most universities maintain a laboratory safety manual and chemical safety information. EHS is continually adding resources to the EHS website that can be used. OSHA has a reference list for safe chemical use in the laboratory that can be found at this website: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10108. While EHS strives to provide as much information on chemical safety as possible, you are not limited to the information that EHS provides. If you find information that is not available on the EHS website that is useful, submit the source of information to EHS so that the resource can be added to the website for others to use.

7.4 Chemical Exposure Limits

The OSHA Laboratory Standard requires that laboratory employee exposures of OSHA Regulated Substances do not exceed the Permissible Exposure Limits as specified in 29 CFR Part 1010, subpart Z. The Permissible Exposure Limits (PEL) are based on the average concentration of a chemical to which workers can be exposed to over an 8-hour workday, 5 days per week, for a lifetime without receiving damaging effects. In some cases, chemicals can also have a Ceiling (C) limit, which is the maximum concentration that cannot be exceeded. OSHA has established PELs for over 500 chemicals.

Another measure of exposure limits are Threshold Limit Values (TLV) which are recommended occupational exposure limits published by the American Conference of Governmental Industrial Hygienists (ACGIH). Like PELs, TLVs are the average concentration of a chemical that a worker can be exposed to over an 8-hour workday, 5 days per week, over a lifetime without observing ill effects. TLVs also have Ceiling (C) limits, which are the maximum concentration a worker can be exposed to at any given time. The ACGIH has established TLVs for over 800 chemicals. Both PELs and TLVs can be found in SDSs. Another good resource for information is the National Institute for Occupational Health and Safety (NIOSH).

More specific information on chemical toxicity is given in chapter 8. In general, any chemical with a TLV or PEL of 50 ppm or lower must be used in a chemical fume hood. If use of a chemical fume hood is not feasible, then EHS must be consulted to explore alternatives. Respiratory protection may not be used *in lieu* of a fume hood unless circumstances make the use of a fume hood impossible.

7.5 Chemical Exposure Monitoring

Laboratory work practices and engineering controls in the lab are generally sufficient to protect the lab worker from exposure to chemicals above safe limits. However, certain circumstances may require the use of chemical exposure monitoring. EHS can evaluate the effectiveness of chemical exposure methods by performing air monitoring for particular chemicals.

If you believe there is a chance that you are receiving a chemical exposure in excess of safe limits, contact EHS. The primary evidence that you are being overexposed to a chemical is if you begin experiencing the symptoms of being exposed to the chemical. Signs and symptoms of exposure to a particular chemical are given on the chemical safety data sheet.

7.6 Chemical Labeling

Every chemical in a laboratory must be labeled. This ranges from chemicals in the original manufacturer’s container to media bottles that contain solutions. It includes carboys filled with water or buffers, test tubes, vials, beakers, flasks, squirt bottles and more. How a chemical is labeled guides lab workers on how to properly use the chemical and how to properly dispose of the chemical. Even if a bottle simply contains water, it must be labeled appropriately.

If possible, the label on a container must have the full chemical name and the hazard(s) associated with that chemical. For example, a bottle to which a small amount of ethanol has been transferred would have a label that reads: “Ethanol- Flammable”. It is also suggested that the date the chemical is transferred to a secondary container be placed on the label. Some containers may be too small to write out a full chemical name. In those cases, abbreviations may be used. Racks of tubes that contain the same or similar chemicals can have a label attached to the rack that describes the types of chemicals in the tubes and the hazards associated with the chemicals. Tags attached to containers can also be used *in lieu* of labels.

Figure 46: Chemical labeling. Even when there are large numbers of bottles, all of them must be labeled as in the picture.

7.7 Chemical Storage and Segregation

Improper chemical storage is the most frequent problem found in laboratory inspections. The proper storage of chemicals is the starting place for safe chemical use as how a chemical is stored gives a clue as to how a chemical should be used and the hazards associated with the chemical. A storage scheme is suggested at the end of this section, but first, the following guidelines should be followed regarding chemical storage:

- All chemical containers must be labeled (as discussed in the previous section).
- All chemical containers must remain closed unless they are in use.
- Chemicals on bench tops and in fume hoods must be kept to a minimum to prevent accidental spillage because of clutter and to ensure adequate airflow within the fume hood.
- Chemical storage cabinets should be used whenever possible. When a cabinet is not available, a shelf with a lip to prevent chemical bottles from sliding off should be used for storage.

- Larger containers of chemical should be stored behind smaller containers so that the maximum number of chemical labels possible can be read without moving containers.
- Hazardous chemicals and/or liquid chemicals must not be stored on the floor unless they are in a secondary container.
- Chemicals should have a date received placed on them so that users will know the age of the chemical they are using. This is especially true of chemicals that become hazardous when they expire.

Figure 47: Chemicals on Floor in Secondary Containment

- Chemicals should not be stored on high shelves. Large containers of chemical must be stored on lower shelves to help prevent injuries. No chemical that may injure the eye should be stored at eye level or above.

Figure 48: Improper Chemical Storage on a High Shelf. Chemicals should not be stored this high; especially chemicals in such large containers! The chemicals should be in the cabinets that in the picture have glassware stored in them.

- Segregate and store chemicals based first on their hazard classes, not simply in alphabetical order (see the scheme described later in this section).
- Do not store flammable chemicals in normal refrigerators or freezers. Store these items only in refrigerators or freezers designated for the storage of these types of chemicals by the manufacturer.
- Do not store corrosive materials in flammables cabinets. The corrosive vapors from these chemicals will compromise the integrity of these cabinets, rendering them no longer suitable for the storage of flammables.
- Observe storage limits given for certain types of chemicals given in the chemical hazards chapter (chapter 8) of this manual.

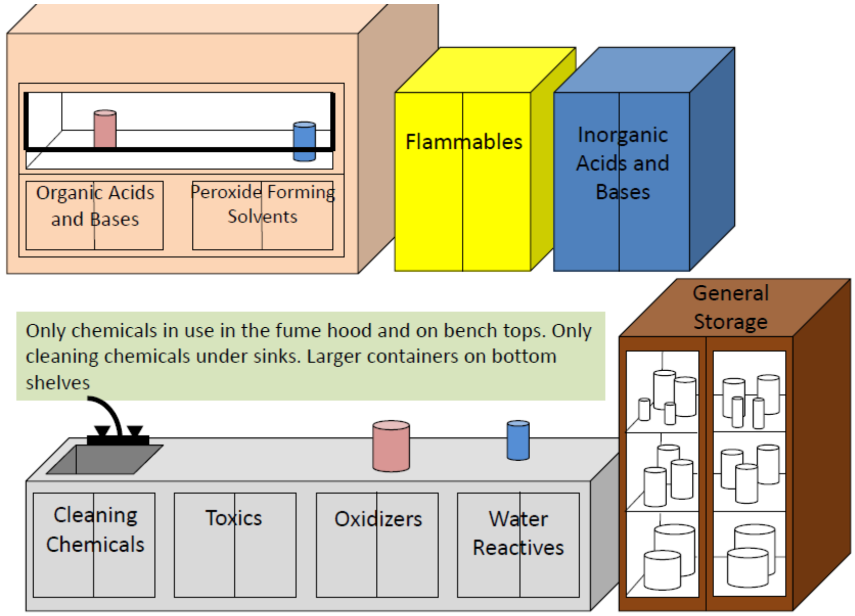


Figure 49: Chemical Storage Scheme. This is a suggested storage scheme. Not all labs have sufficient room to store chemicals in this manner but the general segregation of these chemical types should be observed. When incompatible materials are stored in the same cabinet, they must be separated by secondary containment (such as separate containment trays or pans).

7.8 Chemical Transport

Transport of chemicals off campus in a vehicle should not be attempted without permission from EHS. Transporting chemicals between laboratories or between buildings on campus should be done using the following guidelines to protect people and the environment:

- Put chemicals in secondary containment such as a carrying bucket.
- Add absorbent material (such as paper towels or vermiculite) to secondary containment when transporting liquids.
- Bring the PPE required to clean up a spill of the chemical being transported with you in case of a spill.
- Used wheeled carts with a lipped surface as opposed to hand carrying whenever possible.
- Never move compressed gases by hand. Use an approved cart.
- Avoid riding elevators with compressed gases or cryogenic liquids. Send these materials on the elevator unoccupied and have someone ready on the destination floor to receive the material.

Shipping chemicals from the main campus is prohibited without the proper training (see chapter 10).

7.9 Chemical Spills

Chemical spills can vary greatly in size. Spills will be covered in chapter 13 (Laboratory Emergency Preparedness).

Chapter 8: Chemical Hazards (General)

Chemicals can be classified into hazard classes based on the types of hazards that they pose. There are some classes of chemicals that are commonly found in laboratories and those types of chemicals are discussed in this chapter. This includes flammable liquids, flammable solids, corrosives, toxics (poisons), oxidizers, compressed gases and peroxide forming chemicals. Chemicals that are highly hazardous are less commonly found in labs and they are discussed in chapter 9. This includes acutely hazardous toxic chemicals, pyrophoric chemicals, water reactive chemicals, explosives and certain acids (hydrofluoric acid and perchloric acid). Special procedures must be developed for these types of chemicals as detailed in chapter 9.

For each type of hazardous chemical the definition is given at the beginning of the section. Then instructions for safe use of that hazardous chemical are given. This laboratory safety manual serves as the operating procedure for these types of chemicals so long as it has been reviewed by all lab personnel. Then, instructions are given on safe storage and segregation.

8.1 Flammable Liquids

Whether or not a liquid is flammable depends on its flash point. According to OSHA, the flash point of a chemical is "the minimum temperature at which a liquid gives off vapor within a test vessel in sufficient concentration to form an ignitable mixture with air near the surface of the liquid." The flash point of a liquid is given on the safety data sheet for the chemical. The Environmental Protection Agency (EPA), the Department of Transportation (DOT) and the Occupation Safety and Health Administration (OSHA) all have different flash point thresholds for the different categories of flammable materials; for the purposes of safe use and storage in the laboratory, the definition and thresholds given by OSHA are used.

	OSHA Definition of a Flammable Liquid			
Flash Point	<73.4˚F (23˚C)		< 140˚F (60˚C)	< 199.4˚F (93˚C)
Boiling Point	< 95˚F (35˚C)	> 95˚F (35˚C)		
Category	1	2	3	4

Figure 50: Flammable Liquid Definition. OSHA defines a flammable liquid as anything with a flash point below 199.4˚F (93˚C). OSHA further classifies flammable liquids based on their flash points and boiling points.

There are a few quick ways to determine if a chemical fits the flammable definition. If the label or SDS has a pictogram of a flame, then it is considered flammable. If the chemical has an NFPA diamond on the label and the flammability rating is 3 or 4, then it is considered flammable. The DOT class 3 label is another way to identify flammable liquids. Examples of typical flammable liquids include ethanol, hexane, ethyl acetate and acetonitrile. Many solvents are flammable liquids.

8.1.1 Safe Use

Here are the guidelines for using flammable liquids safety:

- Wear gloves when using or dispensing flammable liquids. Make sure the gloves being worn are compatible with the chemical being used by checking chemical resistance guides on the EHS website or the SDS for the chemical.
- Wear safety glasses when using and dispensing flammable liquids.
- Flammable liquids may also be corrosive or toxic so additional PPE may be required. Check the SDS or chemical label to be sure.
- Do not use flammable liquids near open flames. If heating is necessary, use water bath, steam baths or oil baths.
- When dispensing class 1 or 2 flammable liquids from large containers (such as 5 gallon pails or 55 gallon drums), make sure the container is grounded and bonded to the container to which you are dispensing to help prevent the buildup of static electricity that can ignite flammable vapors.

Figure 51: Appropriately Grounded and Bonded Containers.

8.1.2 Storage

Flammable liquids must be stored in the right types of containers and cabinets. Here are the guidelines for safe storage of flammable liquids:

- There are restrictions on the types of containers in which certain flammable liquids can be stored based on the flammability category (see table below). Plastic should be avoided when possible as plastic can buildup static electricity. A discharging spark can be several hundred degrees which can easily ignite a flammable vapor.

Container Type	Category 1	Category 2	Category 3	Category 4
Glass or approved plastic	1 pint	1 quart	1 gallon	1 gallon
Metal (other than drums)	1 gallon	5 gallons	5 gallons	5 gallons
Safety cans	2 gallons	5 gallons	5 gallons	5 gallons
Metal drums (DOT)	55 gallons	55 gallons	55 gallons	55 gallons

Figure 52: Maximum Allowable Size of Containers for Flammable Liquids. When transferring liquid to secondary containers, make sure to follow these guidelines. This includes the generation of waste.

- Flammable liquids should always be stored in cabinets designed for their storage. No more than 10 gallons may be outside of these cabinets in a lab at any one time. This amount includes hazardous waste!
- No more than 60 gallons of flammable liquids can be stored in any cabinet and no more than 3 cabinets may be kept in any lab.
- Items should not be stored on top of flammables cabinets.

Figure 53: Flammables cabinet. Flammables cabinets should be closed unless removing a chemical. Items should not be stored on top of them.

- Flammables may not be stored in normal refrigerators or freezers. Vapors of flammable liquids are heavier than air. Those vapors sink to the floor when the refrigerator or freezer is opened and have the chance of being ignited by electrical components on the bottom. If flammable liquids must be kept cold, they should be stored in properly rated flammable liquid storage refrigerator/freezer.

Figure 54: Laboratory Refrigerators and Freezers. A-*Standard refrigerator and freezer*. Any refrigerator that looks like it came from an appliance store is not approved for the storage of flammables. **B-***Improperly stored flammables.* Flammable materials must not be stored in standard refrigerators or freezers. **C and D-** *Flammable storage refrigerators and freezers.* These are readily identified by markings on front.

8.1.3 Incompatible Materials

No chemicals should be stored near chemicals with which they are incompatible. Flammable liquids should not be stored with any of the following materials:

- Oxidizers
- Pyrophorics
- Water-reactives
- Acids
- Bases
- Non-flammable toxics

8.2 Flammable Solids

Flammable solids are defined by OSHA as “a solid, other than a blasting agent or explosive, that is liable to cause fire through friction, absorption of moisture, spontaneous chemical change or retained heat from manufacturing or processing which can be ignited readily and when ignited, burn so vigorously and persistently to create a serious hazard.” The DOT subdivides flammable solids into three categories: normal flammable solids, pyrophorics and water-reactives. Pyrophorics and water reactives are discussed in chapter 9 as they are highly hazardous chemicals. Some examples of normal flammable solids are sodium dodecyl sulfate (SDS), sodium borohydride and phosphorus.

The same principles of use and storage that apply to storage of flammable liquids apply to normal flammable solids. They should be stored in flammable materials cabinets and kept away from the same materials shown in section 8.1.3.

There are a few quick ways to determine if a chemical fits the flammable definition. If the label or SDS has a pictogram of a flame, then it is considered flammable. If the chemical has an NFPA diamond on the label and the flammability rating is 3 or 4, then it is considered flammable. The DOT class 4 label is another way to identify flammable solids.

8.3 Corrosives

Corrosives are defined by OSHA as “a chemical that produces destruction of skin tissue, namely, visible necrosis through the epidermis and into the dermis or a chemical which by chemical action will materially damage, or even destroy, metals. Corrosives can be further divided into acids and bases. In general, acids with a pH of 2 or below and bases with a pH of 12.5 or above are considered corrosives. Acids can be further divided into organic acids and inorganic acids; bases can be similarly divided into organic bases and inorganic bases. If a chemical label or SDS has a pictogram of a test tube and hand, then it is corrosive. Corrosives will typically have NFPA health hazard ratings of 3 or 4, but those NFPA ratings could indicate a different health hazard. The DOT class 8 label is another way to identify corrosive chemicals.

Examples of inorganic acids include hydrochloric acid, sulfuric acid and nitric acid (nitric acid is also an oxidizer). Examples of organic acids include acetic acid and formic acid. Common inorganic bases include sodium hydroxide and ammonia. Common organic bases include ethanolamine and phenol (phenol is technically an acid, but it is reactive with other acids so it is stored with bases).

There are some acids (hydrofluoric acid, perchloric acid, picric acid, etc.) that have additional requirements. These will be covered in chapter 9 (highly hazardous chemicals).

8.3.1 Safe Use

Here are the guidelines for using corrosive chemicals safely:

- Corrosive chemicals should be handled in a fume hood.
- Gloves, safety glasses and a lab coat are the minimum required PPE when handling corrosive chemicals. Additional PPE may be required; see the chemical label and SDS for guidance.
- Safety showers and eyewashes are required where corrosive chemicals are used. Note the location of the closes safety shower and eyewash before using corrosive chemicals.
- If corrosive chemicals contact the eyes or skin, immediately seek and use a safety shower or eyewash. Flush the affected area for a minimum of 15 minutes. If symptoms persist, seek medical attention.
- If corrosive chemicals contact clothing, remove the contaminated clothing.
- When mixing acids and water, always slowly add acid to the water not the other way around. Adding water to acid can cause the acid to splatter and react violently.

8.3.2 Storage

Corrosives must be stored in the right types of containers and cabinets. Here are the guidelines for safe storage of corrosives:

- Corrosive chemicals must not be stored in metal containers.
- Corrosive solids may be stored in normal cabinets, but should be kept separate from other chemical categories.
- Corrosive liquids should be stored, if possible, in a corrosive liquid cabinet.

Figure 55: Corrosive Storage Cabinet. These cabinets are suitable for storage of corrosive materials like acids and bases. If acids and bases will be stored in the same cabinet, each has to be in its own secondary container to prevent the possibility of the two mixing in the event of a leak or spill.

- Acids and bases should be stored in separate cabinets. If stored together, they should be within separate secondary containers.
- Organic acids and inorganic acids should be stored separately. If they are stored in the same cabinet, each should be within separate secondary containers such as plastic trays or pans. The same is true of bases; organic and inorganic bases should be stored separately.
- Corrosive liquids should not be stored above eye level.
- When transporting a corrosive liquid bottle more than just a few feet (to the next lab, for example), use a protective bottle carrier or a cart.

8.3.3 Incompatible Materials

No chemicals should be stored near chemicals with which they are incompatible. If incompatible materials are stored in the same cabinet, each material must be stored in a separate secondary container such as a pan or tray. Incompatible storage conditions to **avoid** are:

- Corrosives with any flammable or organic solvents
- Acids with amines
- Acids and bases together
- Organics and inorganics together
- Oxidizing acids and organic acids

8.4 Toxic Chemicals

The toxic chemical category is a group of chemicals that require some additional explanation. The chemical exposure limits mentioned in chapter 7 mean very little if the toxicity of a chemical is not understood. Chemical toxicity is simply the ability of a chemical to cause harm to the body. The toxicity is dependent on many factors including:

- The amount and concentration of the chemical
- The length of exposure (time)
- The frequency of exposure
- The route of exposure
- Other chemicals present
- Physical factors of the person being exposed (gender, age, medical condition, etc.)

A chemical may cause acute effects, chronic effects or both. Acute effects are observed upon a short-term single exposure to a chemical. Many times, acute effects are reversible. An example of this would be an acid burn. Chronic effects are observed when exposure is frequent; these effects are generally delayed and are often not reversible. An example of this is mesothelioma after repeated exposure to asbestos.

Toxicity is normally measured by the dose that is given to test animals that is lethal to 50% of the test subjects. This dose is defined as Lethal Dose 50 or LD50. LD50 is recorded in units of mg/kg of body weight of a certain test animal (ex. mg/kg rat). If the dose is given via aerosol or gas, the dose will be defined as a Lethal Concentration 50 or LC50. LC50 is recorded as a concentration in air such as parts per million (ppm) or mg/m^3. The lower the LD50 or LC50, the more toxic a chemical is. When possible, it is advisable to substitute chemicals that are less toxic for those that are more toxic. Substitution should be explored when the LD50 for a substance is 50 mg/kg or less. More information on acutely toxic chemicals and chemicals that have chronic effects is given in the section on highly hazardous substances (Chapter 9).

Exposure to toxic chemicals must be controlled. Controlling chemical exposure is covered in chapter 7; refer to the appropriate section for more details.

There are several ways to quickly identify a toxic chemical. If a chemical label or SDS has a pictogram of a skull and crossbones or star on chest, then it is toxic. Toxics will typically have NFPA health hazard ratings of 3 or 4, but those NFPA ratings could indicate corrosivity. The DOT class 6 label is another way to identify toxic chemicals.

8.4.1 Safe Use

Here are the guidelines for using toxic chemicals safely:

- Toxic chemicals must always be used in a chemical fume hood. If you are unsure if a chemical is toxic, check the toxicology data on the Safety Data Sheet. If the Threshold Limit Value or Permissible Exposure limit is 50 ppm or below, chemical fume hood use is required.
- Gloves, safety glasses and a lab coat are the minimum required PPE when handling toxic chemicals. Additional PPE may be required; see the chemical label and SDS for guidance.

- Always wash hands when work with toxic chemicals is completed.
- Never work with toxic chemicals alone in the lab; make sure others are present in the lab or an adjacent office.

8.4.2 Storage

Toxic chemicals should be segregated first based on whether they fall into one of the previous categories (flammable and/or corrosive). Toxic chemicals that fall into neither of these categories may be stored with other non-hazardous chemicals; however, they should be stored together in a separate section of the cabinet. This makes toxic chemicals easy to identify and indicates to the user that there are special requirements for these types of chemicals.

8.4.3 Incompatible Materials

There are no categories of chemicals with which all toxic chemicals are incompatible. Check the Safety Data Sheet for a specific toxic chemical to see if there are specific conditions that should be avoided when storing it.

8.5 Compressed Gases

Compressed gases are simply gases under pressure. There are multiple classes of compressed gases; oxidizing gases, toxic gases, flammable gases and non-flammable gases. Compressed gases come in special containers called cylinders, so they are easy to identify. They are represented with the cylinder pictogram on a SDS and are labeled with class 2 DOT labels in transit. DOT further subdivides compressed gases into divisions as follows:

- Division 2.1: Flammable gases- examples include methane and acetylene
- Division 2.2: Non-flammable gases- examples include nitrogen and oxygen
- Division 2.3: Poisonous by Inhalation gases- examples include ammonia and chlorine

The primary hazard of compressed gases is the physical hazard, and this is covered in chapter 11. However, there are some properties of some compressed gases that cause them to be chemical hazards as well. The following precautions should be taken with compressed gases that are also chemical hazards:

- Any compressed gas with a health or reactivity hazard rating of 3 or greater according to NFPA 704 shall be stored and used in a ventilated enclosure. This includes lecture bottles.
- Oxygen cylinders must be stored at least 20 feet from any combustible compressed gas or separated from such gases by a non-combustible barrier of at least 5 feet with a fire-resistance rating of at least 30 minutes.
- No more than 1 cylinder of each chemical hazard type should be present in any lab at any one time. An exception may be made for large labs where greater than 50 feet separation is possible.

8.6 Oxidizers and Organic Peroxides

OSHA defines an oxidizer as "a chemical other than a blasting agent or explosive that initiates or promotes combustion in other materials, thereby causing fire either of itself or through the release of oxygen or other gases. In other words, oxidizers are chemicals that can supply oxygen to a fire to help sustain combustion for a longer period than in the presence of air alone. An oxidizer can be easily identified by the flaming circle pictogram on the label and SDS. The DOT class 5.1 label is also indicative of an oxidizer. Examples of oxidizers include potassium permanganate, nitric acid, hydrogen peroxide and sodium nitrate.

Organic peroxides are a special class of oxidizers. These are organic chemicals with a bivalent oxygen (-O-O-) structure. These relatively unstable chemicals readily release oxygen in the presence of fire and may also themselves be flammable. These can be identified by a flaming circle pictogram on the label and the SDS and are labeled with the DOT class 5.2 label when in transit.

The following guidelines should be followed when using oxidizing chemicals:

- Do not store oxidizing chemicals with organic chemicals; especially flammables.
- Use plastic or ceramic implements to remove oxidizing chemicals from containers; avoid using metal objects.
- Store oxidizers in plastic containers rather than glass.
- Oxidizing chemicals should be handled with extreme caution around organic chemicals.

8.7 Peroxide-Forming Chemicals

While it is easy to identify chemicals that are classified as peroxides, there are some chemicals that may form peroxides under certain conditions. Unfortunately, there is no special label or any other indication if a chemical is a peroxide former. Many commonly used organic solvents can form peroxides upon exposure to oxygen or light. Peroxides are shock, heat and friction sensitive. An activity as simple as opening a bottle of a solvent that has formed peroxides can result in an explosion or fire. Peroxides can form the source of ignition for a solvent that is already flammable. Explosions are more common when solvents that already have peroxides forming are concentrated by evaporation or distillation.

Common examples of peroxide-forming solvents include diethyl ether, tetrahydrofuran (THF) and 1,4-dioxane. Since there is not a reliable way to identify chemicals that are peroxide forming, a list is provided on the EHS website. Please note that this list is not comprehensive. Consult product labels and the EHS department if you need help determining whether a chemical forms peroxides.

8.7.1 Safe Use

Peroxide-forming chemicals should be used according to the guidelines given in the section on the class of chemicals to which they belong (ex. diethyl ether should be handled according to the flammable chemicals section) with a few extra rules:

- Circle or highlight the expiration date of all peroxide-forming solvents.
- Test peroxide-forming chemicals using peroxide test strips (available from VWR or Fisher) at the recommended intervals. Record the test results on the label provided on the container for the chemical. If the container does not have such a label, contact EHS to receive one.
- Do not use peroxide-forming chemicals that have expired without written approval from EHS.

8.7.2 Storage

Peroxide-forming chemicals should be stored according to the guidelines given in the section on the class of chemicals to which they belong (ex. diethyl ether should be stored as described in the flammable chemicals section) with a few extra rules:

- Do not retain peroxide-forming chemicals beyond their expiration date without written permission from EHS.
- Keep peroxide-forming chemicals in cabinets where they are not exposed to light or shock.

Chapter 9: Highly Hazardous Chemicals

Highly hazardous chemicals are chemicals that do fall into one of the categories in the previous section but are more hazardous than standard lab chemicals. Thus, additional precautions are required for these types of chemicals. Additional rules that apply to all these types of chemicals include:

- Standard Operating Procedures (SOPs) must be written for each one of these chemicals. The SOP should be reviewed annually and signed by every person that works in the lab that stores or uses these chemicals.
- Designated areas should be established where these chemicals are used and the use of these chemicals outside of these areas must be prohibited.
- These chemicals must be stored:
  - According to manufacturer's suggestions,
  - With chemicals of like hazard but further segregated in special containers marked with the hazard
- Researchers must ensure the security of these chemicals.

Highly hazardous chemicals include Particularly Hazardous Substances, explosive chemicals, pyrophoric chemicals, water-reactive chemicals and otherwise violently reactive chemicals.

9.1 Particularly Hazardous Substances

Particularly hazardous substances are chemicals that, according to OSHA, are "select carcinogens", reproductive toxins and substances which have a high degree of toxicity. EHS has decided to include chemicals defined as acutely toxic by the Environmental Protection Agency (EPA) in this section as well. The EHS website includes a list of chemicals that are considered particularly hazardous. The list is by no means comprehensive; so if you are unsure whether your chemical is a particularly hazardous substance and it is absent from the list, contact EHS. OSHA mandates that when working with these substances, special consideration should be given to these provisions:

- Establishment of a designated area
- Use of containment devices
- Procedures for safe removal of waste
- Decontamination procedures

EHS further requires a SOP for any chemical that falls into this category. EHS can assist in the development of SOPs for these substances. Review of these SOPs is required for all workers that may use these substances.

9.1.1 Designated Area

There is no specification for the size of a designated area. It can be a portion of a room, a room within a suite of rooms or one containment device within a room. The purpose of the designated area is to make all users of the laboratory aware of where particularly hazardous substances (PHSs) are used. Containment devices are strongly recommended for the use of these substances. A temporary designated area may be used assuming that decontamination procedures are strictly followed at the end of work with PHSs in the area. Designated areas should be well labeled and required PPE for entering and working in the designated should be indicated and available outside of the designated area.

Figure 56: Designated Area sign. This sign or something similar should be posted when a particularly hazardous substance is being used. A list of these substances is available on the EHS website in the chemical and lab safety section.

9.1.2 Waste Removal

Waste removal practices (as well as the establishment of a designated area) should be outlined in the chemical SOP. EHS should be consulted to discuss disposal options for these chemicals. Waste requests for pickup of these chemicals by people not trained on the SOP for the chemical will be rejected (except with special permission from EHS).

9.1.3 Decontamination Procedures

Some PHSs may require specific decontamination procedures. Review Safety Data Sheets for these chemicals and consult with EHS to determine the best procedure (if required by the SDS or other authority). Then, these procedures should be included in the SOP for the chemical and training should be conducted on decontamination.

9.2 Explosives

EHS considers explosives highly hazardous chemicals. According to OSHA, an explosive is “a solid or liquid chemical which is in itself capable by chemical reaction of producing gas at such a temperature and pressure and at such a speed as to cause damage to the surroundings”. An explosive can be identified by the “exploding bomb” pictogram on the product label and the safety data sheet. Explosives are listed in DOT hazard class 1. The EHS website includes a list of chemicals that are considered explosive. The list is by no means comprehensive; so if you are unsure whether your chemical is an explosive and it is absent from the list, contact EHS.

Since SOPs are required for use of any highly hazardous chemicals only general rules will be given for storage and use of explosives in the lab. The following rules must be adhered to regarding explosives:

- Explosives may not be used or ordered in the laboratory without the expressed written consent of EHS.
- A SOP must be developed and reviewed by all lab workers prior to ordering the chemical.
- All workers must be trained on the use of the chemical prior to it arriving in the lab.
- Explosive chemicals must be doubly secured (i.e. inside a locked lab further locked inside a cabinet) in storage.
- Segregate explosive chemicals from all other chemical types.
- Always use the smallest amount possible of the chemical.
- When working with explosives, keep all other chemicals and as many objects as possible away.
- Always use explosives in a fume hood with a safety shield of appropriate rating.
- Other lab workers and workers in adjacent labs (when working in a lab suite) should be notified prior to work with explosives starting.
- Use non-sparking tools (such as plastic) when using explosives. Do not use wooden tools.
- Ensure all safety precautions are in place prior to work starting.
- Always wear appropriate PPE.
- Work only within the designated area.

- Make arrangement for disposal of wastes prior to work starting.
- Pay careful attention to any of the following signs of deterioration:
    - Degradation of the container
    - Crystal growth inside or outside of the container
    - Discoloration of the chemical

    NOTE: If any of these signs are noticed; contact EHS immediately!

9.3 Pyrophoric Chemicals

Pyrophoric chemicals are also considered to be highly hazardous by EHS. OSHA defines a pyrophoric chemical as a solid, liquid or gas "that will ignite spontaneously in air at a temperature of 130˚F (54.4˚C) or below". Pyrophoric chemicals will have the flame pictogram on the product label and SDS and are hazard class 4.2 (spontaneously combustible) according to the DOT. They have an NFPA flammability rating of 4. Some examples of pyrophoric chemicals are organolithiums, silanes and alkali metals. These materials are often stored in other materials (ex. t-butyllithium in ethyl ether or potassium metal in mineral oil) to keep them from being easily exposed to the air. The EHS website includes a list of chemicals that are considered pyrophoric. The list is by no means comprehensive; so if you are unsure whether your chemical is a pyrophoric and it is absent from the list, contact EHS.

Since SOPs are required for use of any highly hazardous chemicals only general rules will be given for storage and use of pyrophoric chemicals in the lab. The following rules must be adhered to regarding pyrophorics:

- A SOP must be developed and reviewed by all lab workers prior to ordering the chemical.
- All workers must be trained on the use of the chemical prior to it arriving in the lab.
- Segregate pyrophoric chemicals from all other chemical types.
- Pyrophoric gases must be stored in a ventilated gas cabinet with the appropriate controls.
- Always use the smallest amount possible of the chemical.
- Always use pyrophorics in a containment device with an inert atmosphere (such as a glove box or glove bag under nitrogen).
- Have inert solid compounds readily available (such as solid lime) and an appropriate fire extinguisher readily available.
- Ensure all safety precautions are in place prior to work starting.
- Always wear appropriate PPE.
- Work only within the designated area.

9.4 Water Reactive Chemicals

Water-reactive chemicals are also considered to be highly hazardous by EHS. OSHA defines a water-reactive chemical as "a chemical that reacts with water to release a gas that is either flammable or presents a health hazard". Water-reactive chemicals will have the flame pictogram on the product label and SDS and are hazard class 4.3 (dangerous when wet) according to the DOT. The NFPA denotes a water-reactive chemical by placing the letter "W" with a line through it (as indicated in chapter 7) in the white section of the NFPA diamond. The EHS website includes a list of chemicals that are considered water reactive. The list is by no means comprehensive; so, if you are unsure whether your chemical is a water-reactive and it is absent from the list, contact EHS.

Since SOPs are required for use of any highly hazardous chemicals only general rules will be given for storage and the use of water-reactive chemicals in the lab. The following rules must be adhered to regarding water-reactive chemicals:

- A SOP must be developed and reviewed by all lab workers prior to ordering the chemical.
- All workers must be trained on the use of the chemical prior to it arriving in the lab.
- Segregate water-reactive chemicals from all other chemical types.
- Always use the smallest amount possible of the chemical.
- Use water-reactive chemicals in a containment device with an inert atmosphere or no moisture (such as a glove box or glove bag under nitrogen).
- Have a class D fire-extinguisher readily available.
- Ensure all safety precautions are in place prior to work starting.
- Always wear appropriate PPE.
- Work only within the designated area.

9.5 Otherwise Violently Reactive Chemicals

Some are violently reactive without exposure to water or air. These chemicals may undergo vigorous polymerization, vigorous condensation or decomposition or may self-react when shocked are exposed to increases temperature or pressure. These types of chemicals will generate a lot of heat and/or pressure very quickly and thus have the potential to cause fire or over-pressurize the containers in which they are stored.

There is no way to readily identify these types of chemicals, although most of them are hazardous for another reason. The NFPA diamond, if supplied, will have a 3 or 4 in the yellow section and the SDS will indicate that they are reactive. These types of chemicals should be well-labeled, indicating their reactivity. A SOP is required for these chemicals as well as a designated area. If you are not sure if a chemical falls into this category, contact EHS.

9.6 Hydrofluoric Acid and Perchloric Acid

There are a couple of chemicals that EHS considers highly hazardous that do not necessarily fit well into one of the above categories. Those two chemicals are hydrofluoric acid and perchloric acid. Both acids are commonly found in labs, but they are infrequently found being used and stored properly. There are additional precautions required for both chemicals outside of the normal precautions for acids.

9.6.1 Hydrofluoric Acid

Hydrofluoric acid (HF) is commonly found in the acid cabinet in a laboratory. The only indication that it may be different than the other acids is that it is in a plastic bottle instead of a glass bottle. HF is commonly used to etch glass and can eat through glass; thus, HF cannot be stored in glass. If HF is present in the lab, then all lab workers must be educated on its use and storage.

HF is not only corrosive, but also a fairly potent contact poison. Some of the more dilute solutions can be particularly insidious in that a spill on the skin can go unnoticed because it does not burn at first and is absorbed through the skin. HF wreaks havoc in the body by reacting with calcium and magnesium. The fall in blood and tissue calcium can cause serious problems; a large enough exposure can cause cardiac arrest due to reduced blood calcium levels.

Additional precautions for HF include:

- A SOP is required for HF.
- Training on its proper use and storage is required.
- Calcium gluconate gel must be readily available and regularly checked to see if it is expired.
- Work must be performed with very specific PPE and in a designated area.
- Anyone exposed to HF, even in a very small amount should rinse the affected area, use calcium gluconate gel according to the instructions given in the SOP or on the package and seek medical attention. HF exposure may not cause a burning sensation for several hours, so a feeling of well-being should not preclude seeking medical attention.

9.6.2 Perchloric Acid

Perchloric acid is also commonly found in the laboratory. Perchloric acid is highly hazardous because of its potential to form explosive perchlorate salts wherever it vaporizes and then condenses to concentrated forms. Thus, several additional precautions must be taken with perchloric acid. Those include:

- As with all highly hazardous chemicals, a SOP is required.
- Training on its proper use and storage is required.
- Heating of perchloric acid may only take place in a perchloric acid fume hood (a hood with a washdown system specifically designed for perchloric acid use).
- Concentrations of 70% or above must be used or diluted within a perchloric acid fume hood.
- Perchloric acid should be stored separately from organic solvents, organic acids and other oxidizers.
- If perchloric acid begins becoming discolored, then it may be reaching the point of becoming very unsafe; it must be disposed by EHS.
- Perchloric acid should be stored away from combustible materials such as wood, cardboard or paper.
- Do not use paper towels to clean up spills of perchloric acid as it can ignite combustible materials under certain conditions. Contact EHS in the event of a spill.

Chapter 10: Hazardous Chemical Disposal and Shipping

All chemicals that are present in the lab will eventually leave the lab by one of two methods. Most often, the chemicals are used up and disposed of as chemical waste. Occasionally, chemicals are shipped by lab workers. There are several rules that must be followed whether chemicals are being shipped or disposed of.

10.1 Chemical Waste Disposal

Disposal of chemical waste is regulated by the Environmental Protection Agency at the federal level and the Tennessee Department of Environment and Conservation at the state level. The requirements for University of Memphis employees that generate chemical waste are given in the Hazardous Waste Management Plan available on the EHS website. Please note that no chemical may be thrown into trash or dumped down the drain without written approval from EHS. Without written permission, all chemicals must be collected for disposal and given to EHS. This is the process to follow when a chemical waste is going to be generated:

1) Make sure you have completed hazardous waste training for laboratory workers (on EHS website).
2) Determine the amount of waste that is going to be generated as the result of your process. If the process is going to generate less than 1 gallon per month, obtain an empty gallon-size bottle. If you are going to generate more than 1 gallon per month because of your process, contact EHS to obtain a larger container.

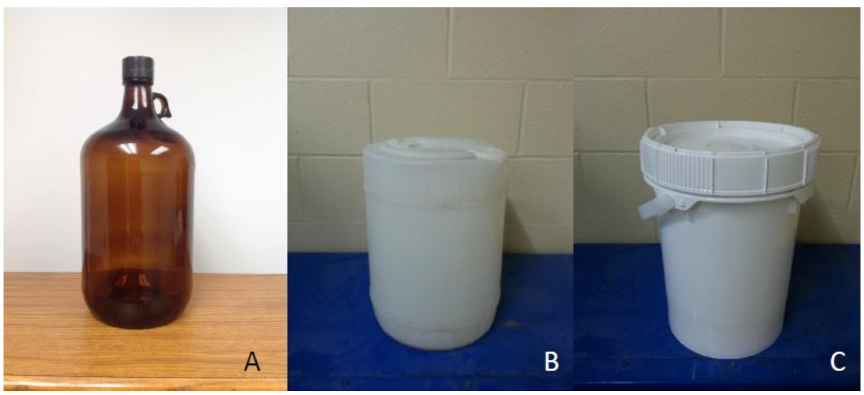


Figure 57: Hazardous waste containers. A-*4L bottle.* This type of waste container is obtained by finding an empty container in the lab, rinsing it and removing the label. The label may be left on the bottle as long as it is defaced. **B**-*5 gallon jug*. This used for liquid waste when the generation rate will exceed 1 gallon per month. These must be requested from EHS. **C**-*5 gallon solid waste bucket.* This waste container is supplied by EHS upon request when solid waste will be generated at rate sufficient to fill or nearly fill the bucket within 6 months.

3) Do not mix incompatible chemicals in the same waste container. If there is a question about chemical compatibility, contact EHS.
4) Before putting waste in the container, determine if the waste is a regulated hazardous waste or not. Then, place the appropriate label on the container. Add a description of the chemicals in the waste on the label.

5) Place a request to have the container removed from the lab when:
    a. The container is full,
    b. The process is complete, and no more waste will be generated or

The complete requirements for chemical waste generation are contained in the Hazardous Waste Management Plan, but here is a summary of the rules:

- Again, be sure that you have completed hazardous waste training prior to generating hazardous waste. This can be completed online or by attending a scheduled live training.
- All containers of waste must have a label on them that indicates the contents. If the waste is a hazardous waste, then the hazard associated with the waste (flammable, toxic, corrosive, etc.) must be included on the label. The label provided by EHS should be used.
- Containers of waste should be tightly closed unless waste is being added to them.
- No chemical may be poured down the drain or thrown into the trash without written permission from EHS.
- The waste container must remain in the lab in which it was first placed. Waste containers may not be moved from lab to lab.
- Be sure that the container into which waste is being placed is compatible with the waste going into it. For example, acid waste should not be generated in a metal container.

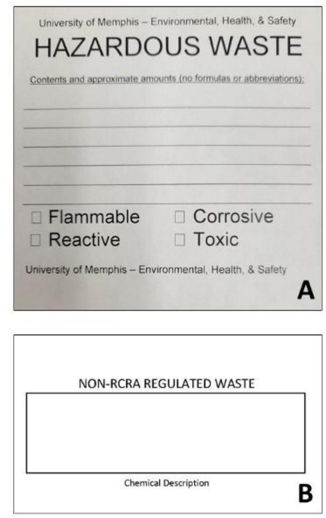


Figure 58: Waste Label Templates. A- *Hazardous Waste Label.* **B-** *Non-Hazardous Waste Label*

10.2 Hazardous Chemical Shipping

The shipping of hazardous chemicals is highly regulated. Only individuals that have been trained may ship hazardous materials. The type of training that is required depends on the material being shipped and the method of shipping (ground, air, vessel, etc.). Training is required for anyone that has any responsibility in the shipping including filling the container that will be shipped, packing the container, preparing the paperwork, making or labeling the package or signing the shipping paperwork.

Hazardous chemical shipping requirements are given in the university Hazardous Materials Shipping Plan available on the EHS website. A list of approved training programs is given in the plan. Most of them have a cost associated with them; one is free if you are exclusively shipping by ground. Whatever training program is chosen, the shipper must provide EHS with a certificate demonstrating completion of the required training that meets the conditions of the plan. EHS will then provide certification to the shipper that gives approval to ship hazardous chemicals. Employees may not ship any chemical until this certification is received.

While the full requirements for shipping hazardous materials are given in the Hazardous Materials Shipping plan, some of the rules are summarized below. A flowchart for determining (if training has been completed) if the material being shipped (by ground) is fully regulated is given below as well.

- Do not ship chemicals without first completing training. Training expires in 2-3 years, depending on the shipping method. Training must be kept up to date.
- A list of commonly overlooked hazardous materials that are shipped includes:
    - Dry ice
    - Samples on ethanol or in formaldehyde
    - Some batteries of battery-powered equipment
    - Magnetized materials (if shipping by air)
- EHS does not ship hazardous materials for employees but will assist if there are questions. It is ultimately the responsibility of the principal investigator/faculty member to ensure that all who work in the lab that may ship hazardous materials are trained.

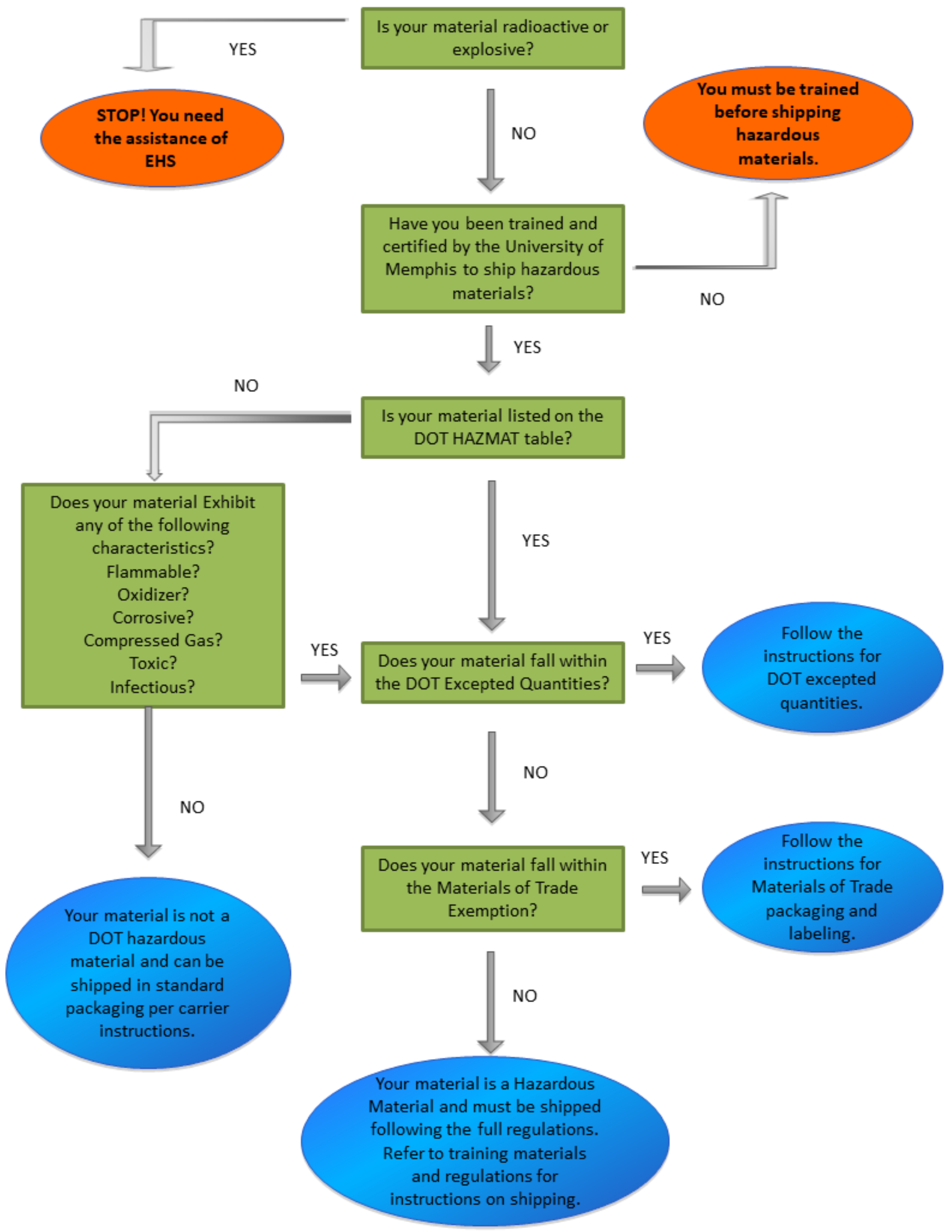


Figure 59: Hazardous materials shipping flowchart. This flowchart is available on the EHS website and shows the process for determining if the material that is going to be shipped is hazardous when shipped by ground only.

Chapter 11: Physical Hazards

Hazardous chemicals are not the only thing that presents risk in the laboratory. There are several different kinds of physical hazards present. Other types of hazards include high-pressure hazards, electrical hazards, high-temperature and low-temperature hazards and many others. Some of the items below have chemical and physical hazards. The chemical hazards of those items are discussed in chapter 8. As much as practical, the focus in this chapter will be physical hazards.

11.1 Compressed Gases

One of the most common physical hazards in the laboratory is compressed gas cylinders. Compressed gas cylinders contain gases at high pressures and present many hazards. Gas cylinders are heavy and easy to tip thus they can fall causing injury to anyone in the path of their fall. The pressure of the gas in the cylinder itself can cause a hazardous release of gas causing objects in the path of the gas being released, including the cylinder itself, to move at very high velocities causing bodily injury and/or property damage. Because of these and other hazards, compressed gas cylinders must be handled with extreme care. An informative video on compressed gas cylinder safety can be found here: https://www.youtube.com/watch?v=1jzyucwIqs4

There are four ways a compressed gas cylinder may be encountered by a lab worker: when it is being delivered or transported, when it is being stored, when it is in use and when it is returned or disposed. Each of these areas presents unique hazards and safety precautions and is covered in the subsequent sections.

11.1.1 Delivery and Transport

In general, compressed gases are delivered to a centralized location within a building. Upon delivery, the following safety precautions should be followed:

- Cylinders should be visually inspected for wear (rusting, pitting, etc.)
- Cylinders should be stored in areas designated for their storage.
- Cylinders should be secured in the storage area before signing for their delivery.
- Cylinders must be transported on carts specifically designed for the transport of compressed gas cylinders (which include wheels to allow the cylinder to rest when the cart is tipped back). Secure the cylinder to the cart with the provided chain or strap. Do not roll or drag cylinders.
- Do not transport a compressed gas cylinder on an elevator with passengers. If a cylinder needs to be moved to a higher or lower floor, two people should do it together; one person should deliver it to the elevator and send it up fully secured on an approved cart and a second person should be waiting to receive the cylinder on the destination floor.

Figure 60: Compressed gas cylinder cart. This is a typical cylinder cart that is appropriate for transport.

- Cylinders must have the valve cap fully attached before being transported. Do not transport cylinders with regulators still attached to them.
- Do not drop or violently jar compressed gas cylinders.

11.1.2 Storage

Storage of compressed gas cylinders can mean storage in a centralized location or storage within a lab when the cylinder is not in use. A cylinder in storage has the potential to fall over causing bodily injury because of its weight. An improperly capped cylinder can cause catastrophic damage because of the high pressure (and thus high potential energy) of the gas within. The following safety precautions should be taken when a compressed gas cylinder is being stored:

- Gas cylinders must be properly secured when in storage. They should be secured in such a way as to prevent their falling if they are bumped.

Figure 61: Compressed gas cylinder storage. A-*Unsecured cylinder*. An unsecured compressed gas cylinder can be very dangerous, particularly if it does not have the cap on it as pictured. The valve can be knocked off if the cylinder were to fall over making the cylinder a very heavy projectile because of the pressure within being suddenly released. **B-***Secured cylinder.* These cylinders are appropriately secured to the wall by a chain and the cylinder that is not in use has the protective cap in place.

- Keep gas cylinders away from heat.
- Adhere to the guidelines given in section 8.5 regarding the storage and separation of certain compressed gases.
- When a cylinder is not in use, the valve cap should be on the cylinder.
- Do not store cylinders in unventilated areas. If a cylinder were to leak, even a non-flammable, non-reactive gas can displace enough oxygen to cause rapid asphyxiation in an unventilated area.
- Cylinders in centralized storage areas should be tagged as full or empty. Cylinders in the lab should be tagged as in-use unless they are full or completely empty. Empty cylinders should be returned to the central storage area for the building.

11.1.3 Safe Use

Any compressed gas cylinder that does not have the protective cap secured to the cylinder shall be considered in use. There are varying operating instructions and safety features associated with compressed gas cylinders depending on the gas that is contained within them. The following are general precautions that should be used with all compressed as cylinders:

- Keep the cylinder secured.
- Use only the appropriate regulator for the gas being used. Do not use homemade adapters or connectors.
- Wear safety glasses and turn your face away from the regulator before slowly opening the valve on top of the cylinder. If the valve does not open by hand, do not use the cylinder and return it to the vendor.
- Do not attempt to refill or otherwise add gas to a compressed gas cylinder.

11.1.4 Return or Disposal

When a cylinder is empty or no longer needed, something must be done with it. Most compressed gas cylinders are provided by a vendor. The user is charged rent for the cylinder until it is returned. Some compressed gas cylinders are owned by the user; particularly the small cylinders called *lecture bottles*. When these are no longer needed, they are normally disposed of as hazardous waste. The following are considerations and precautions to be used when a compressed gas cylinder is no longer needed:

- Before removing a regulator, make sure the main cylinder valve is fully closed and the pressure from the system to which the cylinder was connected has been bled down to atmospheric pressure.
- Return the empty (or no longer needed) cylinder, still using the appropriate cart, to the central storage area of the building. Let the person responsible for managing cylinders know that it is no longer needed so that rent will not continue to be paid on an unnecessary cylinder.
- Lecture bottles are very expensive to dispose of if they contain any gas. Avoid ordering them unless it is certain that all the gas contained within them will be used or the manufacturer will accept the unused portion of the cylinder.

Figure 62: Lecture Bottles. Lecture bottles are small compressed gas cylinders; many of them contain highly hazardous chemicals like those pictured above. Use storage and disposal of these types of gases is both complicated and expensive. EHS should be consulted before ordering lecture bottles of hazardous gases.

- Do not attempt to vent cylinders of hazardous gases for disposal purposes.

11.2 Electrical Safety

Most laboratories contain a wide variety of equipment that is powered by electricity. Hot plates, electrophoresis equipment, heater, pumps, shakers, computers and pumps are just a few of the examples of electrically powered equipment. The presence of electricity presents the risk of electrical shock. Shocks occur when the human body becomes a part of an electrical circuit either by touching two wires and completing an electrical circuit or by becoming the path of electricity in an energized circuit to the electrical ground. The extent of effects from electricity on the body depends on the amount of current (measured in amps), the path of the current through the body and the length of time the body has the current running through it.

Current (milliamps)	Reaction
< 1	Generally not perceptible
1	Faint tingle
5	Slight shock felt; not painful bu disturbing. Average individual can let go. Strong involuntary reactions can lead to other injuries.
6-30	Muscular control may be lost; let-go threshold. Individual can be thrown away from the circuit if extensor muscles are stimulated.
50-150	Extreme pain, respiratory arrest, severe muscular contractions. Death is possible.
1,000-4,300	Rhythmic pumping of the heart ceases. Muscular contraction and nerve damage occur; death likely.
10,000	Cardiac arrest, severe burns; death probable.

Source: https://www.osha.gov/Publications/3075.html

Figure 63: The effects of electricity on the body.

As the table above shows, a current as low as 50 milliamps can have fatal results. Circuit breakers are designed to protect equipment and the building electrical system; they will not trip unless the current backflow reaches much greater than the milliamp range. This means that a circuit breaker will not trip until long after enough current has been released through the human body to be fatal. Other safety measures must be taken to protect workers from electrical hazards.

The following rules and precautions should be followed regarding electricity:

- Do not perform electrical repairs in the lab. Electrical repairs to equipment and infrastructure should be done by a qualified electrician.
- Do not work on energized circuits. Equipment that can be unplugged must be unplugged prior to maintenance. The end of the cord should be locked to prevent inadvertent re-energizing of the equipment. Equipment that is hard-wired must be locked or tagged-out per the university lock-out/tag-out procedures.
- Extension cords and power strips must not be used *in lieu* of hard wiring. Extension cords are meant to be temporary.
- Daisy chaining of power strips (plugging on power strip into another) is prohibited.

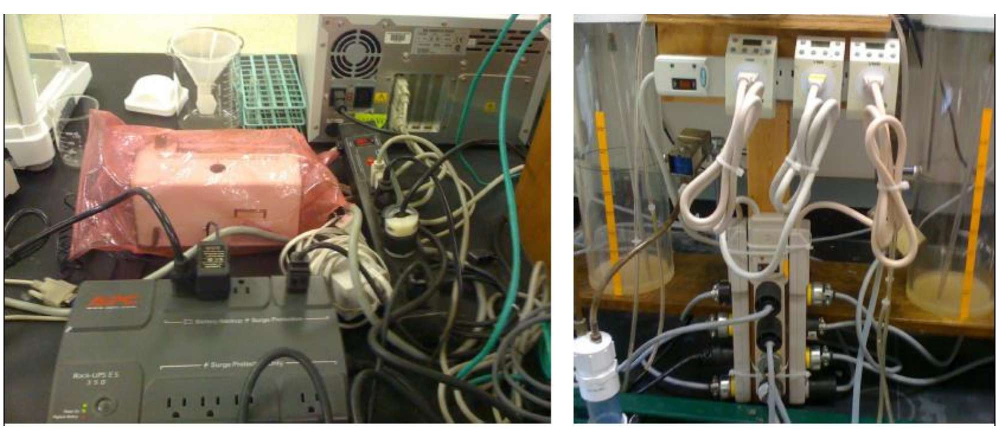


Figure 64: Examples of daisy chaining. Daisy chaining is plugging power strips into one another primarily to create more places to plug in equipment. This can lead to overloading of circuits that can result in fires.

- Keep areas around electricity clean and dry. Any outlet within 6 feet of a water source should be GFCI.
- Do not store flammables near electrical equipment, not even temporarily.
- Do not block access to electrical panels.

Additional information on electrical safety can be found in OSHA pamphlet 3075 found here: https://www.osha.gov/Publications/osha3075.pdf.

11.3 Machine Guarding

Machines with moving parts pose many hazards. In the worst-case scenario, the machine can do to body parts what it is designed to do to the materials that it cuts, shapes and forms. The best way to reduce the risk of injury due to moving machine parts is to use properly installed machine guards. Common hazards posed by machines with moving parts include:

- Pinch point (nip point): point where moving parts (ex. gears or wheels) come together and can either pinch or pull a body part into machinery.
- Cutting hazard: point where sharp objects are exposed (ex. saw blade) and can cut body parts when unguarded.
- Crushing hazard: point where two objects come together (ex. press) and have the potential to crush body parts if in the path.
- Entanglement point: point where machinery can grab clothing or a body part and wrap it around a shaft or other object.
- Thrown object hazard: point on machinery where an object being placed in the path of motion can be thrown out at a worker (ex. grinding wheel).

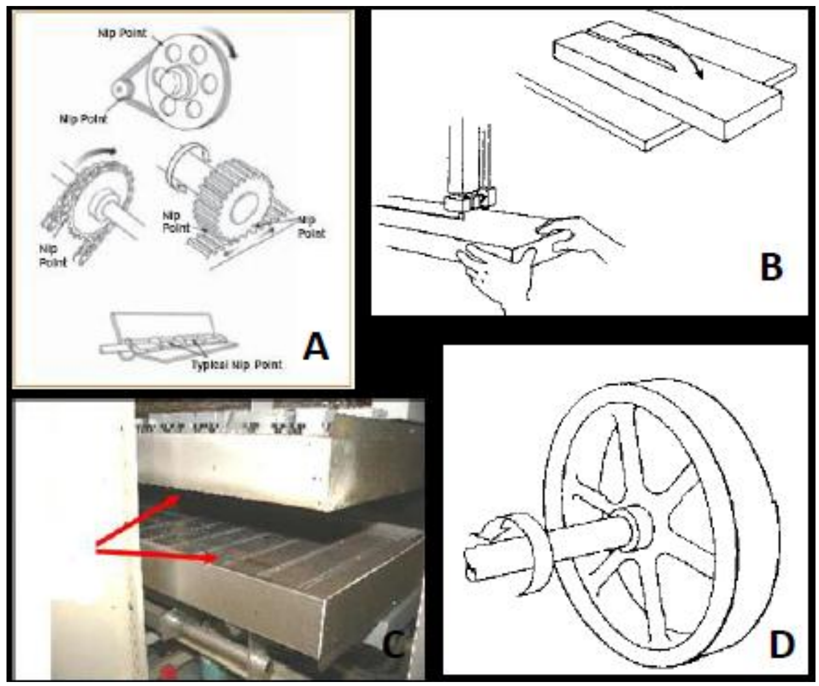


Figure 65: Common areas that need machine guarding. **A**-*Pinch point (aka nip point).* **B**-*Cutting hazard.* **C**-*Crushing hazard.* **D**-*Entanglement hazard.*

Precautions that should be taken in the laboratory regarding machine guarding include:

- Do not remove factory-installed machine guards.

- In the event that a factory-installed guard is not available, contact EHS for guidance on fabrication and installation of an appropriate guard.
- Do not remove or disable safety devices from laboratory equipment.
- Follow lock-out/tag-out procedures in the university's hazardous energy control plan when maintenance must be performed on laboratory machinery.
- Do not attempt to unblock machinery while the machine is running. Power down the machine and disable power before unblocking.
- Use PPE where required.

11.4 Cryogenic and Cold-Item Safety

Cryogenic liquids are liquids that have a boiling point below -130˚F (90˚C). After being cooled to a liquid state, these are gases held under pressure to keep them to a liquid state at ambient temperature. Cryogenic liquids and other cold items (such as dry ice) present several safety hazards. Hazards include fire, explosion, hazardous buildup of pressure, frostbite, asphyxiation and embrittlement, depending on the cryogenic material. Most of these hazards are the same as those posed by other compressed gases; however, there are two hazards that are unique to cryogenic liquids: extremely low temperatures and vaporization.

Extremely low temperatures cause metals to become stronger; however, other materials such as plastic and rubber become brittle. Thus proper selection of materials is important. Extremely low temperatures are also a hazard to human tissue as cryogenic liquids will readily freeze skin, blood and muscle tissue as the heat from the body is transferred to the cryogenic liquid to boil it. This can result in cold burns and frostbite.

Rapid vaporization of cryogenic liquids (and the rapid sublimation of dry ice) also presents a unique safety hazard. These materials placed in a sealed container that is not designed to withstand a buildup of pressure can cause the vessel to rupture violently. In the case of liquid oxygen, the vaporization of the liquid can cause an oxygen-rich atmosphere that supports and accelerates the combustion of other materials. In the case of all other cryogenic liquids (and dry ice), if the vaporization happens in an enclosed area, asphyxiation can result.

When handling cryogenic liquids:

- Always use the appropriate PPE. This includes:
  - A full face shield over safety glasses
  - Cryogenic gloves (like those shown in chapter 6)
  - Lab coat or long-sleeved shirt and long pants
- Use cryogenic materials (and dry ice) in well-ventilated areas. Cryogenic liquids and dry ice expand to many times their volume when they turn to gas.
- Always use appropriate containers for the storage and transport of cryogenic materials such as:
  - Dewars

    - Cryogenic liquid cylinders
    - Cryogenic storage tanks
- Transfer cryogenic liquids slowly to minimize boiling and splashing.
- Never touch uninsulated pipes or containers that have cryogenic liquids.
- Do not immerse gloved hands in cryogenic liquids; use wooden or rubber tongs instead.
- Do not pour cryogenic liquids or place dry ice in the sink.

11.5 Autoclave and Hot-Item Safety

Items at elevated temperatures present many hazards. Not only can burns be an issue, but buildup of pressure and weakening or breaking of materials can occur. There are several types of devices that can cause elevated temperatures including autoclaves, Bunsen burners, ovens and hot plates. Safety precautions for each are discussed below.

One very important point to remember regarding hot items is that glassware that is hot looks exactly same as cool glassware. Whether it has been on a hotplate or just come from the autoclave, remember to label hot glassware (or any objects that cannot be identified as hot by looking at them) so that no one accidentally touches it with bare hands or skin.

11.5.1 Autoclaves

Autoclaves heat items and include steam under pressure to enhance the ability of the heat to kill microorganisms. Hazards presented by the autoclave include:

- Burns from hot items or steam
- Cuts from broken glass because of over-pressurized containers

The following precautions should be taken when using the autoclave:

- Do not use the autoclave unless you have been trained.
- Follow manufacturer's instructions regarding loading of the autoclave.
- Do not fill bottles of liquid completely; fill them a maximum of 2/3 full.
- Do not tightly cap bottles of liquid; leave the caps loose enough for vapor to escape.
- Do not open the autoclave as soon as the cycle is complete. Wait a minimum of five minutes.
- Stand away from the door and open it slowly. Do not put your head or face in the path of steam that is leaving the opening.
- Use heat-resistant gloves and/or tongs to remove items from the autoclave.
- Place items removed from the autoclave onto a cart. Do not carry recently autoclave materials by hand.
- Use additional PPE as appropriate.

Additional information on autoclave safety is available in the university Biosafety Manual, which is available on the EHS website.

11.5.2 Bunsen Burners

Bunsen burners are devices that provide an open flame using natural gas provided by building service or a nearby cylinder. They are used for heating, sterilizing objects and combustion. The following rules and precautions should be followed when using a Bunsen burner:

- Make sure the burner is placed in an area where there is nothing overhead that is combustible (shelving, equipment, etc.).
- Move anything that is combustible away from the area.
- Inspect hoses for cracks or other damage and replace as necessary.
- Make sure loose hair is tied back before lighting.
- Use a sparker to light a Bunsen burner, not a match or a lighter.
- Do not leave the lit burner unattended.
- Shut-off the gas when work is complete.
- Do not use a Bunsen burner inside of a biological safety cabinet. Several fires in university labs have resulted from this.

11.5.3 Ovens

Ovens are frequently used in the lab for drying and heating. Fires can easily occur because of this equipment even though they are probably the most familiar in terms of how they work. The following rules and precautions should be followed when using an oven:

- Do not use plasticware in ovens! This is a common cause of fires.
- Do not use mercury thermometers in ovens as the mercury can easily vaporize if the thermometer breaks.
- Do not use flammable materials in ovens.
- Use heat-resistant gloves, hot-hands or tongs to remove hot vessels from an oven.

11.5.4 Hot Plates

Hot plates are devices that heat by an electric element. The temperature is controlled by a knob. Hot plates are often combined with magnetic stirrers. The following rules and precautions should be followed when using a hot plate:

- Use only heat-resistant glassware.
- Examine vessels for cracks before heating.
- Make sure the hotplate surface is larger than the vessel being heated.
- Do not use the maximum heat setting unless necessary.
- Use heat-resistant gloves, hot-hands or tongs to remove hot vessels from a hot plate.
- Do not touch the hot plate surface with bare hands or skin as there may be no visible evidence that the hot plate surface is hot.
- Do not use the hot plate near combustible or flammable materials.

- Make sure the hot plate surface and the surface of the vessel touching the hot plate are dry before heating.

11.6 Sharps and Glassware

Sharps and glassware are the cause of many injuries in the laboratory, so care should be used when using either of these. There are also methods for handling and disposing of these items. While there are more hazards associated with these than are listed below, these are the most commonly found in labs.

11.6.1 Sharps

Sharps are objects that can easily cut or puncture the skin. This includes items like razor blades, scalpels and syringe needles. The rules regarding sharps and sharps containers in the lab are:

Figure 66: Sharps container.

- Each lab must order and have available a sharps container if sharps are used in the lab.
- When a sharps container is full, contact EHS for removal and disposal.
- Only sharps may be placed in sharps containers. No vials or syringes filled with liquid may be placed in them.
- Do not reach into sharps containers.
- Sharps must be placed in sharps containers; they may not be thrown in the trash.
- Do not attempt to resheath a needle.
- Do not bend needles.
- Do not autoclave sharps containers.
- Broken glass contaminated with biohazardous materials should be placed in a sharps container.

See the Biological Waste Management training and the Biosafety Manual on the EHS website for more information on the management of sharps.

11.6.2 Broken Glass

Figure 67: Broken glass container.

Broken glass can be a hazard to lab personnel and those that clean the lab. When glass is broken, it is placed in a broken glass box like the one pictured. Broken glass boxes must be ordered by the laboratory and must be present in any lab that uses glassware. While the premanufactured broken glass boxes are convenient, any box with a thick plastic liner or with the seams well-taped can serve as a broken glass box so long as it is well-labeled. Other safety precautions to take with broken glass are:

- Only broken glass should be in a broken glass box. No chemicals, including water, may be placed in a broken glass box.

- The broken glass box must have a liner or have all of the seams taped to prevent bits of glass from escaping.
- Broken glass must not be placed in the trash; it must go in designated containers.
- A broom and dustpan should be available in the lab in the event that glass is broken.
- Pasteur pipettes and serological pipettes should be disposed of in the broken glass container unless they are contaminated with a biohazard.

11.6.3 Glass under Vacuum

When glassware is used under vacuum, there is the possibility of it collapsing a breaking. This can cause injury to workers in the lab. The following precautions should be taken when using glassware under vacuum:

- Inspect glassware for cracks or other signs of damage prior to use.
- Only use glassware that is approved for low-pressure use.
- Do not use glassware with a flat bottom; use rounded flasks whenever possible.
- Protect lab workers from the process by using a shield or placing it inside a hood.
- When possible, use tape around glassware under vacuum to lessen the impact of an implosion.

11.6.4 Extractions and Distillations

Performing extractions and distillations has the potential to burst glassware. All extraction and distillation should have specific written SOPs; the lab safety manual only provides a summary of typical guidance. When performing extractions:

- Wait until the solution is below its boiling point before extracting to prevent over pressurization of the vessel.
- If the solvent being used is volatile, the solution should be regularly swirled and vented to reduce pressure.
- When the stopcock is opened, keep the plug firmly in place with your hand.
- Keep the stopcock lubricated between uses.
- The smallest volume possible should be used to help prevent over pressurization.
- Do not vent funnels into the open lab. Vent into a fume hood or dedicated exhaust (not a device that vents into the lab).

When performing distillations:

- Heat evenly and stir to prevent sudden boiling (bumping) that may break apart distillation apparatuses. A nitrogen bleed tube may be necessary when distilling at low pressures as bumping occurs more often under these conditions.
- Do not overheat.
- Do not add anything to liquid that is near its boiling point as this can cause the liquid to boil over suddenly.

- Do not distill organic compounds to dryness unless they are known to be free of peroxides.
- When completing a low pressure distillation, allow to cool first then slowly bleed air. When possible use pure nitrogen instead of air for cooling.

Chapter 12: Biological and Radiological Hazards

Biological hazards and radiological hazards are both areas that are covered in detail in different manuals available on the EHS website. Links are provided below

12.1 Biological Hazards

Requirements for work with biological hazards are found in the university of Memphis Biosafety Manual: https://www.memphis.edu/ehs/pdfs/biosafetymanual.pdf.

12.2 Radiation

Requirements for work with radioactive materials are found in the University of Memphis Radiation Safety Manual: https://www.memphis.edu/ehs/pdfs/radman2024.pdf.

12.3 Lasers

Requirements for work with lasers are found in the University of Memphis Laser Safety Manual: https://www.memphis.edu/ehs/pdfs/laser_safety_program.pdf.

Chapter 13: Laboratory Emergency Preparedness

Most emergency situations that may be encountered in the laboratory are the same as those that will be encountered in other facilities. These emergencies are addressed in the Emergency Procedures (https://www.memphis.edu/campusrec/about/emergency-procedures.php). However, there are some emergency situations that may occur in a laboratory that need to be addressed in more detail. Two specific emergencies are fire and hazardous material spills. Both situations are addressed below.

13.1 Fire

For the purposes of laboratory safety, fires fall into two different categories; there are fires that involve chemicals and those that do not involve chemicals. Fires that do not contain chemicals may be handled in the manner described in the Emergency Procedures Handbook linked above. Fires that involve chemicals require additional caution and the procedure is described below:

1) If there is a fire that involves chemicals and you do not know the chemicals present AND the chemical by-products of the combustion of those chemicals, do not attempt to fight the fire. Instead, activate the fire alarm and call 911 from a cell phone (or 9-911 from a land line). Leave the building to the emergency assembly area.

2) If a fire involving chemicals is small and you know all the chemicals involved and none of the products of combustion are toxic, then you may attempt to extinguish the fire with a fire extinguisher using the method described in the Emergency Procedures handbook.

13.2 Hazardous Material Spills

Hazardous materials spills could include chemical spills, biological material spills and radioactive material spills. Biological materials spills are covered in the Biosafety Manual (see section 12.1 for the website) and radioactive materials are covered in the Radiation Safety Manual (see section 12.2 for the website). This section will focus on chemical spills.

In the event of a chemical spill, the priority shall be personnel decontamination. Any personnel that have been exposed to hazardous chemicals on the skin or in the eyes should use the emergency eyewash or safety shower as soon as possible. If no one has been exposed or all exposed personnel have been adequately treated, the next priority shall be containment of the spill to keep it from leaving the immediate area. Once the spill is contained, the last step is clean up.

Whether or not lab workers can clean up a hazardous chemical spill will depend on the type of chemical that has been spilled and the quantity. No lab worker should attempt to clean up a spill that they do not feel comfortable cleaning. Below are some basic criteria for determining whether you can clean up a chemical spill.

13.2.1 Spills That May Be Cleaned up by Lab Personnel

OSHA defines these types of spills as incidental spills. Lab personnel may clean up a hazardous chemical spill if:

- The quantity of spilled chemical is small (less than one liter).
- The chemical is known.
- The chemical is not a highly hazardous chemical or a chemical that may require respiratory protection.
- The personal protective equipment required to clean up the spill safely is available.
- The materials to clean up the spill are available.
- The hazards presented by the chemical are well understood.

If all these criteria are met, then lab personnel may first contain the spill and then clean up the spill. Spill cleanup materials shall be placed in a container and labeled as chemical waste. Fill out the waste request form available on the EHS website to have the materials removed from the lab.

13.2.2 Spills That Require EHS Assistance

Some spills may not require a HAZMAT team response but may be outside the scope of cleanup by lab personnel. A hazardous chemical spill that may require EHS assistance includes:

- A spill that is greater than 1 liter but less than 5 gallons (20 L).

- A small spill of a highly hazardous material inside a chemical fume hood.

In these cases, lab personnel must make sure the spill is contained and keep others out of the area until the spill is cleaned up by EHS personnel.

13.2.3 Spills That Require HAZMAT Team Response

Some spills are too large or too dangerous for lab personnel or EHS to handle. Outside assistance is required in these cases. A hazardous chemical spill that may require a HAZMAT team response includes:

- A spill larger than 5 gallons (20 L.)
- A spill that cannot be contained to the site (may leave the university).
- A spill of a highly hazardous chemical outside of a chemical fume hood or other containment device.

The procedure for responding to this type of spill is given below.

1) Evacuate the immediate area.
2) If a anyone became contaminated during the spill, take them to the nearest safety shower that is outside the immediate area where the spill occurred. The person or people should remove contaminated clothing and remain under the shower for 15 minutes if the area is safe to do so. While one person should remain with each person that is placed under the shower, all others should evacuate the building.
3) Pull the fire alarm to indicate evacuation of the building.
4) Do not shut down the HVAC system. The areas most likely to have a spill are those where the HVAC system will be pulling contaminant away from the office areas. A shutdown of the HVAC system will upset that balance.
5) Notify the local authorities (including the fire department) that this is a chemical spill, not a fire so that the local hazmat team can be dispatched.
6) Notify the EHS director after the local authorities have been contacted.
7) If the constituents of the spill are known, provide the SDS for each constituent to the hazmat team.
8) Once the local authorities give the all clear to return to the building, EHS shall do a quick building check to make sure critical operations are again online before allowing all others to re-enter.

13.2.4 Spills of Unknown Material

All the above scenarios assume that the material spilled is known. The procedure for spills of unknown materials is given below.

1) Evacuate the immediate area and close the door to the area.
2) Post a sign that indicates the area must not be entered until the spill is cleaned.

3) Attempt to determine the materials in the spill by asking others that work in the area.
4) If that exact nature of the spill cannot be determined, consult EHS.
5) Try to determine if the spill could be a material that is unsafe to clean up. In other words, if there is no possible way it is a highly hazardous material then EHS should be able to safely clean up the spill.
6) If there is the possibility that the spill is a highly hazardous material and the nature of the spill cannot be determined, it will be necessary to contact the local authorities. If this happens to be the case, follow steps 3-8 of the procedure for a large chemical spill (Section 13.2.3).

13.2.5 Spill Kits

It is the responsibility of the lab to ensure that proper materials are available for the cleanup of chemical spills. Here are the requirements for a chemical spill kit:

- A 5-gallon bucket with a closeable lid
- Absorbent (vermiculite, cat litter or other multi-purpose absorbent)
- Scoop
- Small broom
- Required PPE (if not already available in the lab)

A few additional items that may be useful in a spill kit but are not required are:

- pH paper
- Sponge
- Small plastic zipper bags
- Sodium bicarbonate (for acid spills)
- Citric acid or boric acid (for base spills)

Chapter 14: Laboratory Safety Culture

While this is the last chapter of the laboratory safety manual, it may be the most important. A positive safety culture in a laboratory can do more to keep lab workers safe than any engineering control and personal protective equipment. Furthermore, a poor safety culture can overcome the protection provided by PPE, engineering controls and administrative controls to cause injury and exposure. The following paragraph from the American Chemical Society sums it up well:

> *"A strong safety culture is required to protect employees but is especially important in protecting students and in developing students' skills and awareness of safety. It also protects academic institutional reputations. This culture emanates from ethical, moral, and practical considerations, rather than regulatory requirements. Academic administrators, faculties, and staff members have ethical responsibilities to care for their students' safety and to instill awareness about safety. They need to teach students the safety skills required to work in*

laboratories on campus and in the workplace. In a strong safety culture, students will acquire the skills to recognize hazards, to assess the risk of exposures to those hazards, to minimize the risk of exposures to hazards, and to be prepared to respond to laboratory emergencies."

Safety culture is simply the overall attitudes and beliefs shared by employees in the workplace regarding safety. The safety culture in a laboratory emanates from the leadership in the lab. As the principal investigator or responsible faculty goes, so goes the rest of the organization below them. Thus, it is important for faculty and administration to stress the importance of working safely.

More guidance will be provided in this area in the coming years, but for a great summary, read the American Chemical Society report *Creating Safety Cultures in Academic Institutions.* It can be found here:
https://www.acs.org/content/dam/acsorg/about/governance/committees/chemicalsafety/academic-safety-culture-report.pdf.