

Michigan Technological University's Master Chemical Hygiene Plan

Administrative Review Copy ver 9/9/2024 REPLACES ALL PREVIOUS VERSIONS

This **Chemical Hygiene Plan (CHP)** can be downloaded and modified as needed for individual laboratory use.

Alternatively, it can be printed out and placed in a laboratory binder.

See the next page for the Table of contents.

Questions about this Chemical Hygiene Plan can be directed to ehs-help@mtu.edu.

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Introduction to the Chemical Hygiene Plan

Laboratory requirements for having a Chemical Hygiene Plan

Laboratories that meet the Michigan Occupational Safety and Health Administration (MIOSHA) definition for “laboratory use of hazardous chemicals,” must follow the requirements outlined in [PART 431. Hazardous Work in Laboratories](#) - also known as the “Lab Standard.” As part of the standard, laboratories must have a Chemical Hygiene Plan (CHP) for minimizing chemical exposures and protecting laboratory workers from the risks associated with the use of hazardous chemicals.

This written Chemical Hygiene Plan is intended to meet the requirements for having a CHP available for employees and other laboratory personnel to review and follow

The following definitions determine if the “Hazardous Work in the Laboratories” applies and if a Chemical Hygiene Plan is required:

- **Laboratory** means a facility where the "laboratory use of hazardous chemicals" occurs. It is a workplace where relatively small quantities of hazardous chemicals are used on a non-production basis.
- **Laboratory use of hazardous chemicals** means handling or use of such chemicals in which all of the following conditions are met:
 1. Chemical manipulations are carried out on a "laboratory scale;"
 2. Multiple chemical procedures or chemicals are used;
 3. The procedures involved are not part of a production process, nor in any way simulate a production process; and
 4. “Protective laboratory practices and equipment” are available and in common use to minimize the potential for employee exposure to hazardous chemicals.
- **Laboratory scale** means work with substances in which the containers used for reactions, transfers, and other handling of substances are designed to be easily and safely manipulated by one person. "Laboratory scale" excludes those workplaces whose function is to produce commercial quantities of materials.

Implementation of the Chemical Hygiene Plan

The departmental Chemical Hygiene Officer will assist with the implementation and customization of the University’s Chemical Hygiene Plan to meet the needs of individual, departmental laboratories. The resulting laboratory-specific Chemical Hygiene Plan(s) will contain procedures for procurement, storage, use, and disposal of laboratory chemicals as well as the use of emergency equipment, personal protective equipment, engineering controls, and administrative controls for student and employee protection against laboratory hazards. The laboratory-specific Chemical Hygiene Plan must also contain laboratory-specific standard operating procedures (SOPs) for each chemical procedure. The written laboratory-specific

SOPs must include a list of chemicals used, the required personal protective equipment to be used for each procedure, and the safe work practices for each procedure. Spill response and waste disposal procedures should also be addressed in the SOP.

Departmental requirements for having a Chemical Hygiene Officer

As outlined in the University's Safety Manual section [10.2.1](#), all university departments (or colleges) with laboratories meeting the MIOSHA definition for the use of hazardous chemicals must appoint a Chemical Hygiene Officer (CHO). The departmental Chemical Hygiene Officer shall be qualified by training or experience to provide technical guidance in the development and implementation of the provisions of the Chemical Hygiene Plan. This should include a knowledge of the regulatory requirements for laboratory work as well as chemical safety and related industrial hygiene practices; supervisory experience; knowledge of department-specific chemical operations (inventories, hazards, purchasing and disposal practices, and safety equipment); and good written and verbal communication skills.

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Chapter 1: Purpose and Individual Chemical Hygiene Responsibilities

1.1 Purpose

The Michigan Technological University Chemical Hygiene Plan (CHP) establishes a formal written program for protecting laboratory researchers against health and safety hazards associated with exposure to hazardous chemicals, as required by the Michigan Occupational Safety and Health Administration (MIOSHA) Laboratory Standard.

Safety is an integral part of laboratory research. The risks associated with laboratory research (e.g. injuries, chemical spills/exposures, environmental incidents, property loss/damage) are greatly reduced or eliminated when proper precautions and practices are observed in the laboratory. The CHP should be the cornerstone of the laboratory's chemical safety program to manage and mitigate the risks associated with the use of chemicals in the laboratory. It is intended that this CHP be adapted for use as a laboratory-specific CHP by the addition of laboratory-specific Standard Operating Procedures (SOPs) to Chapter 9 of this document.

1.2 Scope

This CHP applies to chemical laboratories that use, store, or handle hazardous chemicals as defined by the [MIOSHA laboratory standard](#):Part 431. Hazardous Work in Laboratories.

This document includes general guidelines on safe practices for common laboratory operations as well as some specific laboratory hazards. In its original form, it does not cover all the hazards that are likely to be encountered in a laboratory. It is the responsibility of the laboratory's principal investigator and/or laboratory supervisor to complete this Chemical Hygiene Plan by evaluating the specific hazards and risks that are present in their laboratory and then developing Standard Operating Procedures to mitigate those risks. A copy of the completed CHP must be readily available to all personnel working in the laboratory.

1.3 Implementation and responsibilities.

1.3.1 Employee rights and responsibilities

As part of the MIOSHA Laboratory Standard, employees and other personnel who work in laboratories have the right to be informed about the potential hazards of the chemicals in their workplace and to be properly trained to work safely with these substances.

While everyone at Michigan Tech has a role in creating and maintaining a culture of safety, implementation of the Chemical Hygiene Plan is the joint responsibility of the Deans, Shared Facility Directors, and Department Chairs. Under their direction, principal investigators, laboratory supervisors, laboratory professionals, student workers, and all others working in chemical laboratories have a responsibility to maintain a safe working environment. This includes but is not limited to:

- Staying informed about the chemicals used in the laboratory;
- following safe work practices;
- adhering to standard operating procedures;
- employing effective engineering and administrative controls; and
- wearing appropriate personal protective equipment (PPE) required for the safe performance of their work in the laboratory.

1.3.2 Responsibilities of Michigan Tech administration

Departmental Chairs, Deans, and the Vice President of Research will ensure that a progressive disciplinary process is enforced for Laboratory Supervisors that do not comply with or adequately enforce the provisions of the Chemical Hygiene Plan (CHP).

In addition, for university units that have laboratories that require a Chemical Hygiene Plan, the unit leader (i.e. Department Chair or Dean) will:

- Assign a departmental Chemical Hygiene Officer;
- review the recommendation to establish a safety committee made up of faculty, staff, and graduate students to assist with the implementation of the CHP in departmental laboratories;
- ensure that chemical laboratory occupancies are kept current in the university's space management system ([ASPIRE](#)); and

- ensure current up-to-date laboratory contact information is available.

1.3.3 Responsibilities of the Principal Investigator or laboratory supervisor

The Principal Investigator (PI) or laboratory supervisor is the individual that is ultimately responsible for the overall laboratory operation, including the lab safety program and ensuring that the requirements of the CHP are followed by all who work in the lab. For most research laboratories, the Principal Investigator (PI) is the laboratory supervisor. In some cases, the laboratory supervisor may delegate some safety duties to a qualified individual or may hire an individual such as a lab manager or postdoctoral graduate to manage the daily operations of the lab. The laboratory supervisor must:

- Ensure that individuals working in the lab receive CHP training before working with hazardous materials and subsequent CHP refresher training;
- ensure that work conducted in the laboratory is in compliance with occupational and environmental health and safety regulations;
- actively enforce all applicable safety procedures and ensure that the CHP is followed by all individuals working in the laboratory, including having a progressive disciplinary process for lab staff members that do not comply with safety rules;
- observe the behavior of staff while working in the laboratory;
- conduct hazard assessments to identify hazardous conditions or operations in the laboratory and establish SOPs to effectively control or reduce hazards;
- ensure that all laboratory personnel receive appropriate training and have access to Safety Data Sheets for the chemicals that are present in the laboratory;
- ensure documentation of lab-specific training (e.g., PPE training, safety training, training on specific experimental procedures);
- ensure that appropriate PPE (e.g., laboratory coats, gloves, eye protection) and engineering controls (e.g., chemical fume hood, equipment guards, shields, barriers) are made available, in good working order, and being used properly;
- conduct periodic lab inspections and immediately take steps to abate any hazards that may pose a risk to individuals working in the laboratory; and
- designate a responsible person to oversee safe operations when the PI/lab supervisor is not immediately available or traveling.

1.3.4 Laboratory employee responsibilities

All individuals (e.g., postdoctoral researchers, lab technicians, graduate students, undergraduate students, and visiting scientists) in laboratories that use, handle, or store, or dispose of hazardous chemicals must:

- Review and follow the requirements of the CHP;
- follow all verbal and written laboratory safety rules, regulations, and SOPs required for the tasks assigned;
- develop and practice good personal chemical hygiene habits such as keeping work areas clean and uncluttered;
- plan, review, evaluate and understand the hazards of materials and processes in the laboratory prior to conducting work;

- utilize appropriate measures to control hazards, including consistent and proper use of engineering controls, administrative controls, and PPE;
- understand the capabilities and limitations of PPE;
- immediately report all accidents, near misses, and unsafe conditions to the laboratory supervisor;
- complete all required safety training and provide written documentation to the laboratory supervisor; and
- inform the laboratory supervisor of any work modifications ordered by a physician as a result of medical conditions, occupational injury, or chemical exposure.

1.3.5 Laboratory safety officer responsibilities

It is highly recommended that each PI/laboratory supervisor designate a member of the laboratory to act as a laboratory safety officer, to assist with managing the daily operations of the lab's safety program. The laboratory safety officer may be empowered to make decisions on daily operations involving safety and compliance, including the authority to instruct other lab personnel in following all safety procedures (e.g., PPE use, hazardous waste procedures, etc.). This person should be familiar with how the lab operates and have demonstrated lab safety experience (e.g., senior graduate student, postdoc, lab manager).

Laboratory safety officer responsibilities should include:

- Providing training to new lab personnel; ensure appropriate training is given and that the training is properly documented;
- enforcing lab safety rules;
- working closely with the departmental Chemical Hygiene Officer and Safety Liaison to ensure the laboratory complies with university safety programs/policies; and
- reporting safety issues back to the PI when necessary.

1.3.6 Non-laboratory personnel / support staff responsibilities

Custodians and maintenance staff (support staff) often must enter laboratories to perform routine tasks such as cleaning and equipment maintenance. Support staff members are expected to follow the posted safety rules of each laboratory. Minimum PPE requirements for support staff working in a laboratory are safety glasses, long pants, and closed-toe shoes. If additional PPE is required or if other unique safety requirements must be followed, the laboratory must post a cautionary sign listing entry requirements at the entrance. When support staff will potentially be exposed to hazards for which they have not been previously trained, they must be provided with the necessary training before they begin the task. Custodial and maintenance staff must not be directed to assist with cleaning chemical or hazardous material spills, unless they've received training from, and have been directed to do so by, their immediate supervisor.

1.3.7 Departmental Chemical Hygiene Officer responsibilities

The departmental Chemical Hygiene Officer (CHO) is responsible for implementation of the CHP within the department. Working closely with PIs/laboratory supervisors and the university's chemical safety officer, the departmental CHO must:

- Be familiar with the hazards in each laboratory in the department and the safety controls used to minimize risk (engineering controls, administrative controls, and PPE);
- ensure regular laboratory inspections are conducted (annual inspections are recommended, but may be more or less frequent depending on hazards present in the laboratory);
- ensure that hazard assessments and SOPs are being prepared and filed within each lab's CHP;
- help develop and implement appropriate environmental health and safety policies and procedures;
- review and evaluate the effectiveness of the CHP within their department at least annually and update it as appropriate;
- ensure the contents of the CHP are followed; and
- report instances of non-compliance with laboratory, departmental and university safety procedures and policies to the department chair, Research Integrity or Environmental Health and Safety as appropriate.

1.3.8 Offices of Environmental Health and Safety (EHS) and Research Integrity (RI)

The offices of Environmental Health and Safety (General Counsel's office) and Research Integrity (Vice President for Researcher office) work to ensure the health and safety of the campus community through compliance with all federal and state regulations governing workplace safety and environmental health. Many of these regulations apply directly to laboratory safety, the MIOSHA Laboratory Standard in particular. To facilitate compliance with these regulations, EHS and RI manage a variety of services such as safety training, laboratory inspections, electronic access to safety data sheets, and chemical, biological, and radioactive waste disposal. More detailed information can be found on [EHS's website](#) and on [RI's website](#).

1.4 Additional resources

Additional information on safety in chemical laboratories can be found in the following publications.

- [Identifying-and-evaluating-hazards-in-research-laboratories.pdf](#). These are the 2015 guidelines developed by the hazards identification and evaluation task force of the American Chemical Society's (ACS's) committee on chemical safety.
- [Prudent Practices for Handling Hazardous Chemicals in the Laboratory](#) issued by National Research Council and published by National Academy Press.
- The [National Institute for Occupational Safety and Health \(NIOSH\) guide](#) to Chemical Hazards published by the CDC.

- ACS publications [Safety in Academic Chemistry Laboratories Vol 1](#) Accident prevention for college and university students and [Accident prevention for faculty and administrators](#).

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Chapter 2: Hazard assessment: determination and implementation of control measures in research laboratories

2.1 Hazard assessment in research laboratories

The need for appropriate control measures, when working in the laboratory, is determined by conducting a hazard assessment (also referred to as a “hazard analysis,” “risk assessment,” and “risk analysis”). A hazard assessment is the process of evaluating procedures in the laboratory, identifying the risks associated with the procedure, and employing controls to minimize the risks. Results of the hazard assessment are then used to develop Standard Operating Procedures that define the controls, safe work practices and personal protective equipment (PPE) that are needed to work safely in the laboratory. It is essential to conduct a hazard assessment and create at least a basic SOP prior to working with any hazardous chemical for the first time.

One simple approach to a hazard assessment is to answer these five questions: (a) What are the hazards? (b) What are the worst things that could happen? (c) What can be done to prevent these from happening? (d) What can be done to protect from these hazards? (e) What should be done if something goes wrong?

Research Integrity has created a [Hazard Assessment Tool](#)

2.2 American Chemical Society tools

The American Chemical Society (ACS) [Committee on Chemical Safety](#) is an excellent source for information on five different methods that may be used to “identify hazards, assess risk and select appropriate control measures to eliminate hazards and minimize risk” in your laboratory. All of the methods will help identify hazards in the laboratory and provide the first step to creating a written Standard Operating Procedure, as required in Chapter 8 and 9 of this CHP.

Each of these methods are summarized below. Clicking on the link for a method will take you to the ACS website where you can learn more about the method, see examples of how the method is used, and get templates that will facilitate hazard assessments in your laboratory.

2.2.1 [Standard Operating Procedures \(SOP\):](#)

Development of an effective SOP requires a comprehensive approach to hazard assessment. In addition to analyzing the hazards associated with each step of the experiment, an SOP must also consider other important aspects such as regulatory concerns, human factors (experience and training), the facility where the experiment will be performed, management of waste materials, emergency response, etc. Because of its comprehensive nature, development of an

SOP requires more time and effort but results in a greater appreciation and understanding of the process of identifying potential hazards and mitigating associated risks.

2.2.2 [Job Hazard Analysis](#)

Job Hazard Analysis (JHA) focuses on a specific job or task performed in the laboratory. The job is broken down into individual steps. The possible hazards/risks associated with each step are considered and appropriate controls are identified to reduce or eliminate the risk. The steps of a completed JHA can be easily converted into SOPs for routine laboratory operations with known hazards.

2.2.3 [What-if Analysis](#)

A what-if analysis is best suited to simple research applications. As the name implies, this analysis is structured around what if questions about the materials, the process or the equipment that will be used for the experiment. Controls to limit the identified risks are implemented based on the answers to these questions. This method of hazard analysis is easily understood and requires minimal training. However, it is essential that the person overseeing the analysis has sufficient knowledge and experience with the proposed research, to ensure that the right questions are asked.

2.2.4 [Checklists](#)

A checklist provides convenient access to a list of criteria that can be easily checked and implemented by someone who is not familiar with the process of hazard analysis. However, a checklist is limited to the items on the list and may not be adequate for evaluating every hazard associated with your work. The gaps in a checklist may be filled by using other hazard analysis tools to identify other criteria to include on a customized checklist. Once customized for the task, process or working environment, a checklist is a very effective tool for ensuring that complex operations are safe.

2.2.5 [Control Banding](#)

Control banding is best suited to laboratories performing routine procedures with known hazards. Using this approach, laboratory hazards are grouped into categories (i.e. bands) based on the nature of the hazard, the identified risks of working with or near the hazard, and the methods used to control the risks. For example chemicals in a laboratory can be grouped into four chemical safety levels (1-4) based on their chemical characteristics and the increasing risk associated with their use. Each successive safety level incorporates progressive implementation of controls and safe work practices to mitigate the increasing risks. After completing this process, a procedure or even an entire laboratory may be assigned to a specific safety level based on the chemicals being used. Everyone following this procedure or working in the lab understands the hazards and risks associated with the safety level and knows the controls and safe work practices that must be used.

2.3 Hazard assessment of chemical processes

Before beginning an experiment, consider all possible reactions, including side reactions, all reactants, intermediates, products, and wastes in terms of flammability, toxicity, and reactivity hazards. Consider the following:

- Does it decompose, and if so, how rapidly and to what products?
- What is its stability on exposure to heat, light, water, metals, or air?
- Is it impact sensitive?
- With what substances is the material incompatible?
- Is it toxic? Look at the safety data sheet. Review all potential exposure routes such as inhalation, absorption, ingestion, and injection. Consider that exposure may occur by more than one of these routes.
- What is the recommended first aid treatment in case of an accidental exposure?
- What is the quantity and rate of the evolution of heat and gasses that may be released during the reaction?
- How will the waste products be collected and managed? Are there any special disposal requirements?

2.3.1 Develop Contingency plans

Develop contingency plans that address the following:

- Electric power failure, including what will happen if power is restored when the device is unattended or being repaired;
- cooling system failure;
- exhaust system failure, including interruptions to laboratory exhaust, local exhaust, and filter/absorbent failures;
- over pressurization or loss of vacuum;
- interruptions of domestic water, air, natural gas, or steam supply;
- water leaks into the system;
- air leaks into the system;
- a fire occurs due to the reaction; and
- a reaction container breaks or contents spill.

2.3.2 During the process

Determine if any of the following are required:

- Cooling, ventilation, pressure relief, and gas purging;
- isolation of the reaction vessel;
- warning signs near any dangerous processes and equipment;
- informing others working in the area about the possible hazards associated with chemicals and processes being used; and
- evaluating safety of unattended operations -- processes that involve more serious or unusual hazards must be monitored continuously and should not be left unattended.

2.4 Additional resources for hazard evaluation

For information about a specific chemical, consult the manufacturer's Safety Data Sheet (SDS) sheet. The following sources listed below may also provide additional information about the hazards associated with your proposed experiment.

[PubChem database](#), hosted by the US National Library of Medicine, includes structural, physical and toxicological raw data, as well as chemical safety information from national and international agencies on over 90 million chemical compounds. Data provided by PubChem are intended to support, but not replace, laboratory risk assessments, Safety Data Sheets, and institutional guidance for safe laboratory practices and procedures.

[OSHA Occupational Chemical Database](#) 800 entries with information such as physical properties, exposure guidelines, and emergency response guidance.

[NIOSH Pocket Guide to Chemical Hazards](#) (information on several hundred chemicals commonly found in the workplace)

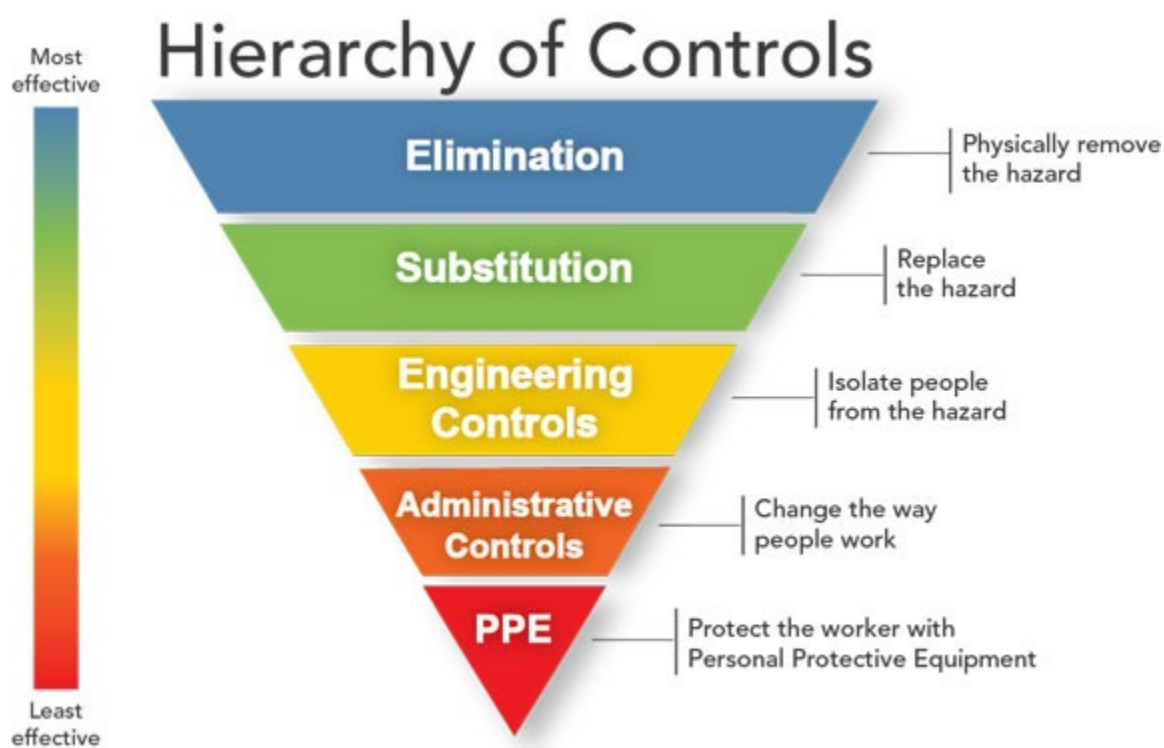
Environmental Protection Agency's (EPA's) [Toxic Substance Control Act \(TSCA\) Chemical Substances Inventory](#) information on more than 62,000 chemicals or chemical substances.

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Chapter 3: Controls for Mitigating Laboratory Hazards

3.1 Hierarchy of controls

The hierarchy of controls prioritizes hazard mitigation strategies on the premise that the best way to control a hazard is to systematically eliminate it from the workplace or substitute a less hazardous technique, process, or material. If elimination or substitution are not feasible options, engineering controls, administrative controls, and Personal Protective Equipment (PPE) must be used to provide the necessary protection.



[Hierarchy of Controls](#)

The hierarchy of controls from most effective to least effective (but still important) are defined below.

- **Elimination:** design the hazard out of the project plan; use alternative work procedures.
- **Substitution:** use a less hazardous material or find a less hazardous way to do the work.
- **Engineering Controls:** any device that is used to prevent contact with or exposure to the hazard (e.g. chemical fume hoods, splash guards, guards on moving parts, barriers, monitoring devices, and safety interlocks and other lock out devices).

- **Administrative Controls:** rules, regulations, warning signs, training, standard operating procedures, and emergency response procedures are all used to define hazards and describe methods for minimizing the risk of injuries and accidents.
- **Personal Protective Equipment (PPE):** gloves, safety glasses, splash goggles, face shield, lab coat, protective apron, respirators, and anything else you wear or put on your body to provide additional protection.

The emphasis should always be placed on the most effective methods for reducing risk. For example, a respirator (PPE) would not be used for primary protection from chemical fumes, if exposure can be reduced by using a chemical fume hood (engineering control).

3.2 Engineering controls and safety equipment

As noted in the hierarchy of controls, the implementation of engineering controls to reduce risk should be the first consideration if a hazard cannot be eliminated or reduced using substitution.

3.2.1 Chemical fume hood, general

Although laboratory spaces are designed with consideration for air circulation and ventilation, the general air handling system does not provide adequate worker protection when working with many hazardous chemicals. When used correctly, a chemical fume hood can prevent harmful exposures when working with hazardous chemicals in the laboratory. The need for a chemical fume hood can be determined by consulting the safety data sheet (SDS) for the chemicals you are working with. Some SDS terminology, as listed below, indicates a need for using a chemical fume hood or other specialized ventilation control:

- Use with adequate ventilation;
- avoid vapor inhalation;
- provide local exhaust ventilation; and
- use in a chemical fume hood.

Chemical fume hoods are inspected annually by the University. During the inspection, air flow measurements are taken with the sash set at its marked working height. Do not work in a chemical fume that has failed its inspection, has not been inspected within the past year or does not have the safe sash height marked. Contact Facilities Management or Environmental Health and Safety if the hood does not appear to be operating correctly.

Proper use of a chemical fume hood requires:

- Limiting the storage of chemicals and apparatus in the hood to those that are required for current work;
- working with the sash at the correct height as determined by the most recent inspection;
- keeping all apparatus at least 6 inches back from the face of the hood and keeping the slots in the hood baffle free of obstruction;
- elevating large equipment at least two inches off the base of the fume hood, to allow for the passage of air underneath the apparatus;

- minimizing movement and other forms of potential air disturbances past the face of the hood while you are working;
- eliminating sources of ignition inside the hood when flammable liquids or gasses are present; and
- keeping the hood sash closed at all times except when the hood is in use.

Also see additional operational guidelines in “10.2.3 Fume Hoods” in [Chapter 10 of University's Safety Manual](#).

Confirm the fume hood is operational at the time and day you are using it:

- For a fume hood that is locally controlled, i.e. there are controls for turning the hood on and off, confirm you understand how to operate the hood prior to using it; note that some locally controlled hoods have a switch to turn on the hood's interior light and a separate switch for the fan motor.
- For a fume hood that is on a schedule through the Central Heating Plant, review the schedule for both weekdays and weekends prior to using the hood.
- For a fume hood that is on a schedule through the Central Heating Plant, and it has local override control (often the hood controller has the term “hand” on it), make sure you understand how this works prior to using the hood.

Other types of chemical fume hoods

There are many other types of chemical fume hoods designed for specific functions and uses. Additional training may be required prior to using a:

- **Perchloric acid fume hood** - designed with a water wash-down system in the ductwork to prevent the build-up of corrosive and explosive perchlorates.
- **Radioisotope fume hood** - designed with HEPA and charcoal filters to prevent radioactive particles from entering the ductwork.
- **“Walk-in” fume hood** - extends to the floor to allow for large equipment to be easily moved into the hood. Despite their name they are not designed to allow you to “walk in” and do work inside the hood.
- **California or distillation hood** - a free standing hood with access to equipment from two sides and designed to operate correctly when all the sashes are in the closed position.

3.2.2 Glove box (used for chemical manipulations)

A glove box is a sealed container that is designed to allow one to handle material in a defined atmosphere (typically inert). Gloveboxes can be used to protect sensitive items inside the unit, protect the user, or both.

Note that a glove box intended for biological activities may not have the same protective capabilities as one designed specifically for chemical manipulations.

The following should be followed by all personnel using a glove box:

- Before any work in a glove box occurs, all personnel must receive training and must understand the design features and limitations of the glove box. Training must include detailed instruction on elements such as the ventilation and vacuum controls that maintain a pressure differential between the glove box and outside atmosphere and atmospheric controls (e.g., controlling oxygen concentrations and moisture). Training records should be kept in the laboratory or department.
- Prior to use, a visual glove inspection must be performed. Gloves must be in good condition and properly connected to the flange: they must be changed according to the glove box manufacturer's recommendations or whenever they start to degrade. Changing of a glovebox gloves should be documented (date, manufacturer, model of glove, and person performing change). Records of glove changes and other maintenance should be kept in the laboratory or the department.
- Plug ports that are never or infrequently used. A properly plugged port should have a stub glove and a glove port cap installed.
- Chemical resistant gloves (e.g., disposable nitrile gloves) should be worn inside the glove box gloves to protect from possible contamination.
- If the glove box is equipped for pressure measurement, the pressure must be checked every day, before use and immediately after gloves are changed. The pressure check must be documented and kept with other records supporting the glove box.
- Keep sharps in an approved container while in the glove box.
- Do not work in the glove box unless the lighting is working.
- Follow all safe work practices for using and handling compressed gas that may be associated with working in the glove box.
- All equipment and chemicals in the glove box must be organized and all chemicals must be labeled. Do not allow items, particularly chemicals, to accumulate in the glove box.
- Plan in advance emergency scenarios such as: gloves damaged during use, gloves disconnecting from the flange, failure of the vacuum or make up air system, unexpected chemical reactions, and spills in the chamber.

3.2.3 Biological Safety Cabinet (BSC)

A biological safety (or biosafety) cabinet is an enclosed, HEPA (or HEPA+) ventilated laboratory workspace for safely working with infectious and potentially infectious biological materials. All biological safety cabinets on campus must be certified by a trained technician on an annual basis. There are several different types of biological cabinets each designed for specific uses. All biological safety cabinets are designed to protect researchers from exposure to infectious materials. Some are also designed to prevent contamination of samples inside the cabinet.

Most are not designed for use with chemical applications. If you are unsure about the type of biological safety cabinet you are using and its proper use, or if you are unsure if the BSC is compatible with your chemical manipulations, contact Research Integrity. See the University's [Laboratory Biosafety Manual](#) for additional information on using a Biological Safety Cabinet

3.2.4 Laminar flow clean bench

A laminar flow clean bench **DOES NOT** provide worker protection and **MUST NOT** be used as a method for controlling exposure to chemical, biological or, other hazardous materials. These workspaces are specifically designed to prevent contamination of semiconductor wafers, samples, and other materials that are sensitive to contamination.

3.2.5 Other engineering controls

Other examples of engineering controls include splash guards and other barriers to prevent contact with the hazardous chemicals; tongs and other devices for manipulating hazards, self-closing containers; self-sheathing needles and scalpels; guards on moving parts and interlocks to automatically disconnect power when safety covers are removed.

3.3 Administrative controls

3.3.1 General rules for laboratory work with chemicals

Safe work practices are essential to laboratory safety. They must be understood and followed by all persons working with potentially hazardous chemicals and equipment in the laboratory. In addition to written SOPs, laboratories are required to develop or adopt general laboratory safety rules and policies and, like SOPs, must also be written and enforced. General rules for laboratory safety based on recommendations in the MIOSHA laboratory standard include:

- Regular work schedules should be followed unless a deviation is authorized by the laboratory supervisor;
- unauthorized experiments should not be performed;
- plan safety procedures before beginning any operation;
- follow Standard Operating Procedures at all times;
- always read the Safety Data Sheet and the container label before using a chemical;
- wear appropriate lab attire including long pants, closed-toe shoes, long hair should be tied back or contained; do not wear loose or baggy clothing, scarves, neckties, jewelry, etc. that may become entangled in equipment, catch on fire, or interfere with chemical manipulations;
- wear PPE when specified by the Standard Operating Procedure;
- use ventilation specified by the Standard Operating Procedure;
- pipetting should never be done by mouth;
- hands should be washed with soap and water immediately after working with any laboratory chemicals, even if gloves have been worn;
- eating, drinking, gum chewing, applying cosmetics, and taking medicine in laboratories where hazardous chemicals are used or stored is strictly prohibited;
- do not store food, beverages, cups, and other drinking and eating utensils in areas where hazardous chemicals and materials are handled or stored;
- laboratory refrigerators, ice chests, ice flakers, cold rooms, and ovens should not be used for food storage or preparation;

- contact the laboratory supervisor/PI, departmental CHO/safety officer/liaison, Research Integrity or, EHS with safety questions or concerns;
- know the location and proper use of safety equipment;
- maintain awareness of your surroundings (no listening to music using headphones, earbuds);
- inform others working in the laboratory of the hazards associated with your work;
- notify supervisors of chemical sensitivities or allergies;
- report all injuries, accidents, incidents, near misses and unsafe conditions to the Laboratory Supervisor, the departmental CHO/safety officer/liaison or EHS;
- unauthorized persons are not allowed in the laboratory; and
- properly dispose of chemical wastes.

Additional general safety rules and policies may be found in various sources including "[Prudent Practices in the Laboratory](#)" written by the National Research Council.

3.3.2 Gas cylinder management

Compressed gas cylinders, either empty or full, shall be used, handled, and stored in accordance with the following:

- Compressed gas cylinders must be stored in a vertical position and may not be stored in hallways, stairwells, receiving areas, or locations where they are subject to damage.
- A chain, bracket, clamp, or other restraining device shall be used at all times to prevent cylinders from falling.
- Acetylene or liquefied gas cylinders shall not be placed on their sides, but shall be stood valve-end up.
- A cylinder, whether empty or full, shall not be used as a roller or as a support.
- A cylinder, whether empty or full, in storage or during shipment, shall have the valve closed and cap connected in place, if a cap is provided in the design, or the valve shall be otherwise protected.
- Cylinders shall be marked with either the chemical or trade name. Marking shall be by stenciling, stamping, or labeling and shall not be tampered with or be readily removable. If the labeling is unclear or defaced, return the cylinder or obtain a new label from the supplier. Unlabeled cylinders shall not be used.
- Empty cylinders shall be marked "empty" or "MT" at time of depletion.
- Cylinders of oxidizers such as oxygen shall be stored at least 20 feet from fuel gas cylinders or a highly combustible material such as, but not limited to, oil, grease, flammable gas or a source of ignition, or be separated from the material by a noncombustible wall, not less than five feet high, having a fire resistance rating of one hour. All cylinders shall be stored away from heat in excess of 125 degrees Fahrenheit.
- Where different gasses are stored, they shall be grouped by types. Groupings shall separate the flammable gasses from the oxidizing gasses.
- Storage shall be set up to ensure "first-in, first-out" usage.
- A cylinder storage area shall be posted with the names of the individual gasses stocked, and a warning posted against tampering by an unauthorized employee. An assigned

storage area shall be located where a cylinder will not be knocked over or struck by a passing or falling object.

- A storage area for cylinders shall be well ventilated. A cylinder shall not be stored in basements or pits except where appropriate ventilation is furnished to keep the area purged of any accumulation of gasses.
- Cylinders shall be transported in an upright position and securely fastened by a restraining device to the truck or handcart. Approved hand carts are to be used when transporting cylinders within a building.
- When transported, the regulator must be removed and the protective cap replaced.
- A cylinder shall not be dropped, dragged, rolled on its side, or struck violently.
- A cylinder shall be lifted only by enclosed platforms when using a crane or hoisting device. Electromagnets, ropes, or slings shall not be used.
- When transporting cylinders in an elevator, other passengers should not be allowed to occupy the elevator.
- Use cylinders in an upright position and secure them firmly with chains or clamps.
- Do not use a cylinder of compressed gas without reducing the pressure through a regulator attached to the cylinder valve.
- Use regulators and pressure gauges only with gas for which they were designed and intended. Do not use adapters or modify connectors to circumvent this rule.
- Make sure the threads on a regulator or union correspond with those on the cylinder valve outlet. Do not force mismatched connections.
- Never use oil or grease on valves or attachments for oxygen cylinders. Avoid handling oxygen cylinders and apparatus with oily hands, gloves, or clothing.
- Open cylinder valves slowly with the valve outlet directed away from personnel. Close the main cylinder valve as soon as it is no longer necessary to have it open.
- Gasses shall not be mixed within a cylinder except by the supplier.
- A cylinder shall not be placed where it will become a part of the electrical circuit by accidental grounding or where it may be burned by electric welding arc. A cylinder shall not be placed so that hot slag or flame will reach it or it shall be protected by a fire-resistant shield. An electrode shall not be tapped against a cylinder to strike an arc.
- A frozen or ice-clogged valve shall be thawed either by warm air or use of warm water and dried before using. Boiling water or a flame shall not be used. Force shall not be applied to a valve or cap to loosen a cylinder frozen in place.
- A cylinder without fixed hand wheels shall have keys, handles, or non-adjustable wrenches on valve stems while in service. A multiple cylinder installation shall require only one key or handle for each manifold. A hammer shall not be used to open a cylinder valve or loosen a cap.
- A leaking cylinder or a cylinder with a valve stuck open or a valve in need of repair shall be taken outdoors—if it is safe to do so—away from sources of ignition, slowly emptied, tagged with a warning sign, and the manufacturer or distributor notified. Complete removal of the stem from the cylinder valve shall be avoided.
- Nothing shall be placed on top of a cylinder that would damage a safety device or interfere with the quick closing of the valve.
- Return empty cylinders to the vendor as soon as possible.

3.3.3 Laboratory security

All laboratory personnel have a responsibility to protect university property from misuse and theft of hazardous materials, particularly those that could threaten human health, contaminate the environment, or cause property damage. The following minimum-security measures pertain to all campus laboratories:

- The laboratory door should remain closed at all times and closed and locked when not occupied;
- only individuals authorized by University policy and by the laboratory supervisor are permitted in laboratories;
- do not leave chemicals or other hazardous materials unattended in spaces accessible to non-laboratory employees;
- particularly hazardous chemicals must be secured at all times, and
- if you see anything suspicious or someone displays suspicious behavior, immediately report it to the Michigan Tech Public Safety and Police Services.

3.4 Hazard Communication

3.4.1 Signs and information

Appropriate labels and warning signs should be placed in the laboratory to alert lab workers and emergency response personnel to potentially hazardous materials and allow those unfamiliar with the laboratory surroundings to identify hazardous chemical use and storage areas, safety facilities, emergency equipment, and exits. Specifically:

- All entrance doors, and entrances to rooms within the lab with new or different hazards, must post an [Emergency Response Poster](#);
- signage must be posted for Unattended Operations (see Chapter 6);
- areas where Particularly Hazardous Substances are being used must be delineated (see Chapter 6).

3.4.2 Safety Data Sheets (SDSs)

Chemical manufacturers and distributors are required to provide a Safety Data Sheet (SDS) that describes the hazards associated with the chemical and provides information for the safe handling, storage, and disposal of the chemical. An SDS has 16 standardized sections. Those concerned with chemical safety in the laboratory should give special consideration to the following sections of the SDS: Hazard identification (2); Composition (3); First aid measures (4); Accidental release measures (6); Handling and storage (7); Exposure controls/personal protection (8); and Stability and reactivity (10). Additional SDS information is provided through the University's Hazard Communication training.

Michigan Tech's electronic [eSDS](#) database provides access to digital copies of safety data sheets and is the University's official method for the management of SDSs. Therefore, a computer or other internet connected device for accessing digital documents must be readily available to laboratory workers for viewing SDSs. A link for accessing the eSDS database can

be found at the top of most Michigan Tech web pages, listed under the “Tech Links” dropdown menu, with the subheading “Safety Data Sheets.” The SDS database web address, a cell phone accessible QR code, and instructions for a fax back option, can also be found on the Emergency Response Poster posted at the entrance of each laboratory.

3.4.3 Labeling chemical containers in the laboratory

Every chemical container in the laboratory, whether hazardous or not, must be properly labeled.

3.4.3.1 Chemicals in original containers

The MIOSHA Part 430 Hazard Communication standard requires chemical manufacturers and distributors to label chemical containers with the following information:

- Product Identifier (name of the chemical);
- Signal Word (either “Danger” or “Warning” to indicate the relative severity of the hazards associated with the chemical);
- Hazard Statement(s) (a specific description of the nature and degree of the hazard);
- Precautionary Statement(s) (recommendations for minimizing/preventing exposure; responding to emergencies; proper storage and disposal of the chemical);
- Pictogram(s) (graphic symbols communicating information about the chemical’s hazards); and
- Name, Address and Telephone Number of the manufacturer/distributor/importer.

It is recommended that the laboratory add the following information to the label:

- The date the chemical is received in the laboratory;
- the name of the person receiving the chemical or other laboratory identifiers such as the PI’s name or room location; and
- the date the chemical is opened (this is extremely important for ethers, organic peroxide formers, and other potentially reactive chemicals).

Do not remove or deface the manufacturer’s original container label while the container is being used to hold its original contents. If any information on the label becomes illegible, a new label with the same information must be created and affixed to the container.

3.4.3.2 Chemicals in secondary containers

All secondary chemical containers (e.g., bottles, beakers, flasks, sample vials, wash bottles, or any other container holding a chemical that is not for immediate use or is left unattended for any length of time) must be labeled with:

- The full name of the chemical (abbreviations, chemical formulae, or structures are NOT acceptable unless there is a complete and up-to-date legend (e.g., MeOH = Methanol) prominently posted in the laboratory);
- the concentration of the chemical (e.g. 70% ethanol, 2M sodium chloride, 10% bleach in water, etc.); and
- a description of any hazards associated with the chemical (e.g. “flammable,” “corrosive,” “toxic,” etc.) using words or GHS pictograms.

It is recommended that the label also include:

- The date the chemical was placed into the container; and
- the name of the person responsible for the chemical.

Secondary container labels must be legible and durable so that the information cannot be easily washed off or stained. If any information on the label becomes illegible, a new label with the same information must be created and affixed to the container.

NOTE: Hazardous Waste collection containers have their own set of [labeling rules](#).

3.4.3.3 Research samples and chemicals developed in the lab

When labeling research samples, chemicals developed in the laboratory, and other similar containers:

- Research samples, reagents, and chemicals created or used in the lab must be labeled as described above for secondary containers (chemical name, concentration, and associated hazards, with a recommendation of also adding date created/collected/received, and responsible person).
- The labeling requirements for individual samples in a set or group of samples may be modified if the samples are stored together in a larger container that is labeled with all the information listed above. For example, samples in small tubes or vials, containing the same chemical hazards, may be consolidated and stored together in an appropriately labeled secondary container.
- Store samples in appropriate containers and according to compatibility and primary hazard class. At a minimum, determine the hazardous characteristics of the sample (flammable, corrosive, oxidizer, reactive, toxic, etc.) and store accordingly. An example of a system for segregating chemicals according to compatibility can be found in [Prudent Practices for Handling Hazardous Chemicals in the Laboratory](#).
- Properly dispose of samples as soon as they are no longer needed. The accumulation of unnecessary samples in the laboratory creates housekeeping issues, reduces laboratory efficiency and storage capacity, and may incur higher costs for disposal.
- If a chemical substance or sample is created or produced for another user outside of the lab, the laboratory supervisor must comply with the Hazard Communication Standard including the requirements for preparation of SDSs and container labeling.

3.4.4 Shipping Hazardous Materials

Shipments of hazardous materials—such as explosives, compressed gasses, flammable solids and liquids, oxidizers, toxic and infectious materials, radioactive materials, corrosive substances, and environmental pollutants—are regulated by the Department of Transportation (DOT). Employees who offer such materials for shipment, as well as those responsible for receiving shipments, must be trained in accordance with DOT regulations. Contact Environmental Health and Safety for information and assistance with training and shipments of materials that could potentially be regulated.

3.5 Personal Protective Equipment (PPE)

Appropriate Personal Protective Equipment (PPE) must be provided, at no cost (with limited exceptions) to all employees. Employees have the responsibility of properly using such equipment when it is required. Avoid using PPE as the primary protection in place of engineering and administrative controls when handling hazardous chemicals. Proper PPE selection can be determined by a combination of the following:

- Ask the laboratory supervisor about proper PPE selection.
- Review the SOP and associated hazard assessment for the task to be performed.
- Review Section 8 of the SDS, “Exposure Controls/Personal Protection” for each chemical(s) being used.
- Contact Environmental Health and Safety for additional information.

3.5.1 Eye and face protection

Eye protection is generally required for everyone entering a laboratory where hazardous chemicals are used and stored. The minimum acceptable requirements are for ANSI-compliant (stamped “Z87”) safety spectacles with side shielding. Standard prescription eyeglasses do not meet the eye protection requirements. See “[Current Intelligence Bulletin 59: Contact Lens Use in a Chemical Environment](#)” for guidance on wearing contacts in the laboratory. There are several types of eye protection for different hazards:

- **Safety glasses** with side shields offer protection against flying fragments, chips, particles (sand/dirt), and minor splashes. When a significant splash hazard exists, or if the chemical can cause significant eye damage, other protective eye equipment must be worn.
- **Safety goggles** (impact goggles) offer adequate protection against flying particles. These should be worn when working with glassware under reduced or elevated pressure or with drill presses or other similar situations.
- **Chemical splash goggles** have indirect venting for splash proof sides, which provide adequate protection against splashes.
- **Specialized eyewear** is available for laser, UV light, or infrared light hazards.
- **Face shields** protect the face and neck from flying particles and splashes. Always wear additional eye protection under face shields. Ultraviolet light face shields should be worn when working with UV light sources.

3.5.2 Hand protection

Appropriate hand protection must be worn when there is a potential for exposure of hands to hazardous chemicals, cuts, abrasions, punctures, or harmful temperature extremes.

When selecting appropriate chemically resistant gloves, it is important to evaluate the effectiveness of the glove in protecting against the specific hazardous chemical(s). Consult the SDS for the chemical and the glove manufacturer’s chart to select the most appropriate glove.

“All-purpose” disposable nitrile gloves used in many laboratories might provide adequate protection for incidental exposures to many hazardous chemicals but often are not suitable for prolonged chemical contact. For example, the typical 4 mils thick, nitrile glove (Solo Ultra 999) will provide protection for up to eight hours when working with concentrated sulfuric acid but will fail within one minute when working with acetone or toluene. Discard disposable gloves after they come into contact with a chemical and put on a new pair before continuing your work.

When handling materials or equipment with harmful temperature extremes such as liquid nitrogen or autoclaves, appropriate cryogenic gloves or heat-resistant gloves must be worn.

Note that the chemical compatibility rating systems used by glove manufacturers vary. Make sure you understand the rating system before making a decision on the gloves you will use.

Glove selection and use must be based on the hazards of the activity being performed and the practice of wearing disposable nitrile gloves for general protection all day in the laboratory should be discouraged. Remove gloves and wash your hands when leaving the workstation; disposable gloves should never be reused. Establish a laboratory workflow that prevents cross contaminating items (e.g computer keyboards, cell phones, laboratory equipment, pens and pencils) with gloved hands. Gloves must never be worn in the hallway, offices, or other areas outside the laboratory.

3.5.3 Body protection

Protective clothing must be worn to protect the body from recognized hazards. All unprotected skin surfaces that are at risk of injury should be covered. The upper torso must be fully covered, with no bare midribs. Full-length pants or a full-length skirt must be worn at all times by all individuals that are occupying the laboratory area; shorts are not permitted.

Lab coats, coveralls, aprons, or protective suits must be worn while working on, or adjacent to, all procedures using hazardous chemicals. Laboratory coats must be appropriately sized for the individual and be fastened to their full length. Laboratory coat sleeves must be of a sufficient length to prevent skin exposure while wearing gloves. Flame resistant laboratory coats, sometimes referred to as “FR lab coats,” must be worn when working with pyrophoric materials, open flames, or flammable liquids greater than 1 liter in volume. It is recommended that 100% cotton (or other non-synthetic material) clothing be worn under FR lab coats. Laboratory coats should not be worn outside of a laboratory unless the individual is traveling directly to an adjacent laboratory work area. Laboratory coats should not be worn in common areas such as break rooms, offices, or restrooms. Each department is responsible for providing laundry services as needed to maintain the hygiene of laboratory coats. In most cases a bucket and laundry detergent should suffice for a lab coat to be cleaned within a lab. They may not be cleaned by staff members at private residences or public laundry facilities. Alternatives to laundering lab coats include routinely purchasing new lab coats to replace contaminated lab coats, or using disposable lab coats.

3.5.4 Respiratory protection

Respirators may not be used unless they are approved through the Michigan Tech EHS [“Respiratory Protection Program.”](#) This program includes a review of the process to ensure that proper equipment is selected for the job; training of all users concerning the methods for proper use and care of equipment; fitting of respirator users and medical surveillance of respirator users. Cloth masks or disposable masks used to protect individuals from COVID-19 or similar infectious diseases do not fall under the respiratory protection program. Employees and students who wish to voluntarily use particle filtering masks, aka “dust masks,” must complete the requirements outlined in the [“Technical Guide: Voluntary Use of Dust Masks.”](#)

3.5.5 Other PPE

In addition to eye, hand and body protection some laboratories may require additional PPE. See the [University Safety Manual](#) for additional requirements for head (hard hat), foot (steel toed shoes), and hearing protection. In some special cases such as spill cleanup, working with potentially infectious materials, or clean rooms disposable over-the-shoe booties may be required.

3.5.6 Minimum PPE requirements for support staff and visitors

Support staff (e.g., custodians, maintenance workers, equipment service vendors) and visitors often enter laboratories to perform routine maintenance tasks or tour the lab. To enter the laboratory, the minimum PPE requirements include safety glasses, fully covered torsos, long pants, and closed-toe shoes. If additional PPE is required or if other unique safety requirements must be followed, it is the lab personnel’s responsibility to notify support staff and/or visitors of the additional requirements.

3.6 Safety equipment

3.6.1 Safety showers and eyewash stations

All laboratories using eye or skin corrosive chemicals must have access to safety showers and eyewash stations. All lab personnel must be aware of the location and know how to properly use the safety shower and eyewash stations. Eyewash and safety showers must meet the following requirements::

- A safety shower must be installed in an area where substances fitting the following Safety Data Sheet definitions are used: Skin Corrosion - Category 1A, 1B, 1C.
- An eyewash must be installed in an area where substances fitting the following Safety Data Sheet definitions are used: Serious Eye Damage/Eye Irritation - Category 1 and 2A.
- An eyewash must be installed in laboratories working at Biosafety Level 2 (BSL2).
- An eyewash or safety shower must be provided within a 10-second travel time (approximately 55 feet) of an operation where employees use an injurious or corrosive substance. The location of the eyewash and/or safety shower facility shall be on the

same level as the hazard, easily accessible (no obstacles, closed doors, or turns) clearly marked, and well lighted.

- Eyewash stations must be tested by the laboratory or department at least monthly (weekly is recommended by the ANSI standard). Facilities Management will do the annual inspection and flow verification.
- Portable eyewash stations require prior approval from Environmental Health and Safety.

If lab personnel are exposed to a hazardous chemical, they should call for assistance and proceed immediately to use the safety shower or eyewash unit (ideally, someone else in the lab that is not exposed should dial 911 and assist with the decontamination of the affected individual). The affected area should be flushed with water for at least 15 minutes or until emergency response personnel arrive and begin treatment. An exposed eye(s) should be held open to ensure an effective wash behind the lids. Contaminated clothing should be removed immediately after exposure or while under the shower. It is highly recommended that laboratories have blankets or lab coats available for modesty.

3.6.2 Fire extinguishers

Fire extinguishers in laboratories are supplied by the university and are inspected on a monthly basis. They must be mounted on a wall, or other sturdy surface, and kept free of clutter. All laboratory personnel should be familiar with the location, use, and classification of the extinguisher(s) in their laboratory. The fire extinguisher available in the laboratory must be appropriate for the anticipated type(s) of fire that may occur. If you have questions about the type, or location of the extinguisher in the lab or if an extinguisher appears to have been used, tampered with, or accidentally discharged, contact EHS. In addition to a fire extinguisher, the lab's hazard assessment may determine that laboratories using flammable metals, or other Class D fire hazards, may need sand or other free-powder extinguishing material such as Metal-X available.

In the event of a fire, DO NOT put yourself in danger to extinguish the fire. DO NOT attempt to extinguish a fire:

- If you have not been trained to use a fire extinguisher;
- it is not safe to do so;
- if it is larger than a small garbage bin in size.

If you cannot extinguish within 5 seconds using a fire extinguisher:

- pull the fire alarm (usually located near exits)
- exit the building; and
- call 911.

Note, the 911 phone call is answered by an emergency dispatch service located in Negaunee, MI. You will need to provide them with specific information about your location: Houghton, MI, Michigan Tech campus, building and room number.

If you are successful at extinguishing the fire, you must still call 911 to report the incident. It is possible, depending on the nature of the incident that flare-ups may occur.

3.7 Laboratory safety culture

The goal of any experimental design is to deliver useful data in an efficient and timely manner, without delays or incident. Some of the first considerations for an experiment design or modification are the use of potentially hazardous chemicals; the use of potentially dangerous equipment; and the potential injury they may cause. One rule-of-thumb is to assume that incidents, e.g., chemical spills, fires, etc., will happen and plan accordingly. This will drive decisions to:

- Eliminate a particularly hazardous chemical or process;
- substitute a hazardous material with one that is less hazardous;
- minimize quantities of hazardous chemicals;
- enclose processes in fume hoods or provide other local ventilation;
- place guards, screens, or barriers between the hazard and the researcher; and
- mandate personal protective equipment.

Be fully aware of the risks in the laboratory. A good working knowledge about the hazards of chemicals used in the research and the potential dangers of any equipment is critical. Read and understand the product safety warnings on research equipment and hazardous chemical labels.

Principal Investigators / Laboratory supervisors must:

- Thoroughly review Safety Data Sheets for chemicals that staff, students, and postdocs are using, so that they can discuss specific hazards and safeguards;
- consider how to train the staff, students, and postdocs to assure they retain the knowledge;
- think about the response and performance expected from the staff, students, and postdocs if an incident occurs; and
- correct those who do not follow standard safety precautions, or disregard good laboratory practices.

The following tips reproduced verbatim from the National Academy of Sciences “Prudent Practices in the Laboratory” will help to create a culture of safety within an academic laboratory:

- Make [the] topic of laboratory safety an item on every group meeting agenda.
- Periodically review the results of laboratory inspections with the entire group.
- Encourage students and laboratory employees to contact EHS if they have a question about the safe methods of handling hazardous chemicals.
- Require that all accidents and incidents, even those that seem minor, are [reported](#) so that the cause can be identified.
- Review new experimental procedures with students and discuss all safety concerns. Where particularly hazardous chemicals or procedures are called for, consider whether a substitution with a less hazardous material or technique can be made.
- Make sure the safety rules within the laboratory (e.g., putting on eye protection at the door) are followed by everyone in the laboratory, from advisor to undergraduate researcher, including custodial and facility staff.
- Recognize and reward students and staff for attention to safety in the laboratory.

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Chapter 4: Required Employee Training

This chapter details the minimum training and training documentation requirements for all Michigan Tech employees and researchers working with hazardous chemicals in a laboratory.

Training is the cornerstone that ensures laboratory workers are aware of health responsibilities, safety guidelines, and accident prevention procedures. Many activities that take place in the course of University operations, research, and academia require specialized instruction on how these activities can be conducted safely and with minimal exposure to workplace hazards. Michigan Tech's [Online Training Center](#) is one valuable tool to help you work safely and create a safe working environment for all. Note that for most chemical activities, task specific training will be required in addition to any completed online training.

Effective training is crucial to a successful laboratory safety program. Laboratory supervisors (in most cases the laboratory Principal Investigator or Faculty in charge of the laboratory) are responsible for ensuring that their lab workers and researchers receive the training they need. Michigan Tech employees are required to participate in the University's safety training program.

MIOSHA's [General Industry and Construction Safety and Health Standard Part 431 Hazardous](#) (aka the "Lab Standard") specifies the following minimum training requirements:

- [The] Methods and observations that may be used to detect the presence or release of a hazardous chemical (such as monitoring conducted by the employer, continuous monitoring devices, visual appearance or odor of hazardous chemicals when being released, etc.);
- the physical and health hazards of chemicals in the work area; and
- the measures employees can take to protect themselves from these hazards, including specific procedures the employer has implemented to protect employees from exposure to hazardous chemicals, such as appropriate work practices, emergency procedures, and personal protective equipment to be used.

In addition the employee shall be trained on the applicable details of the employer's written Chemical Hygiene Plan.

According to state and federal laws and Michigan Tech policy, Principal Investigators (PIs) and laboratory supervisors are responsible for ensuring that all employees receive adequate training in order to understand the hazards present in their work area. Training must occur prior to assignments involving new hazards. Refresher training or retraining may be required by law and for personnel who demonstrate they did not understand the initial training or are not following required procedures.

In addition to general training assigned and managed at the departmental or university level, each laboratory must also provide laboratory specific training to new employees prior to working with hazardous chemicals or other hazards in the laboratory. Training records for each individual working in the lab must include a training checklist or other documentation demonstrating the scope of the training, an evaluation or assessment to determine the effectiveness of the training, and a signature acknowledgement by the employee that they have received and understand the training. Records should be included as part of the lab-specific CHP and be readily available during safety audits and inspections.

The CHP focuses on work with hazardous chemicals in the laboratory. However, other common types of hazards are present in many research laboratories (e.g., biological hazards, lasers, etc.). Research Integrity and Environmental Health and Safety have developed various [Safety Documents](#) as tools to assist researchers with compliance and training requirements for a broad range of common hazards and regulatory requirements found in the laboratory.

4.1 Hazardous Communication Training

Training on the Michigan Tech chemical [Hazard Communication Plan](#) is required for all employees and researchers that handle or use chemicals as part of their work or research responsibilities. This training must be documented.

As part of this communication plan, all employees and researchers must have access to the Safety Data Sheets that they are using. The university maintains an official electronic [Safety Data Sheet database](#) which can be accessed by anyone with Michigan Tech login credentials. Laboratory workers may keep paper copies of SDSs, downloaded from either the original vendor or the university's electronic SDS database, for quick reference.

4.2 Chemical Hygiene Plan (CHP) training

All laboratory employees or researchers working in laboratories using hazardous chemicals (i.e. graduate students, lab technicians/managers, postdocs, visiting scientists, etc.) must 1) receive training on the elements of the Chemical Hygiene Plan and 2) review the laboratory specific Chemical Hygiene Plan before working in the laboratory. This training must be documented.

The employee or researcher must also review the Standard Operating Procedures and receive any task specific training related to their activities using hazardous chemicals in the laboratory.

4.3 Requirements for additional training

After their initial CHP training, all employees and laboratory researchers shall review the Chemical Hygiene Plan:

- When a new version containing significant changes in content (i.e. changes beyond minor editorial updates) is released; or

- when personnel demonstrate they did not understand the initial training or are not following required procedures.

Prior to starting a new activity using hazardous chemicals employees or researchers shall review the Standard Operating Procedures and receive any task specific training related to these activities.

4.4 PPE training

Laboratory supervisors must ensure that all employees receive Personal Protective Equipment (PPE) training before any work with hazardous materials occurs. This training must be documented in the relevant SOPs. Each lab employee must be trained to know at least the following:

- When PPE is necessary and how to select it;
- how to properly put on and remove, adjust, and wear PPE;
- the limitations of the PPE; and
- the proper care, maintenance, storage, and effective life of PPE.

Everyone working in the laboratory must demonstrate an understanding of the training provided, and the ability to use the PPE properly, before performing any work that requires the use of PPE. Retraining is required if laboratory workers show a lack of understanding of the purpose or appropriate use of PPE (e.g., the worker is seen handling hazardous materials without wearing proper PPE).

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Chapter 5: Medical Consultations and Examinations

Employees must notify their laboratory supervisor of all work-related injuries and illnesses regardless of the magnitude; their immediate supervisor must then complete the [Michigan Tech Incident and Injury Report Form](#). Supervisors should report serious injuries and injuries or illness requiring hospitalization immediately to Environmental Health and Safety.

5.1 Consultations and examinations

All employees who work with hazardous chemicals must have an opportunity to receive medical attention, including any follow-up examinations which the examining physician determines to be necessary, under the following circumstances:

- Whenever an employee develops signs or symptoms associated with a hazardous chemical to which the employee may have been exposed in the laboratory, the employee shall be provided an opportunity to receive an appropriate medical examination.
- Where exposure monitoring reveals an exposure level routinely above the chemical's action level (or in the absence of an action level, the chemical's Permissible Exposure Limit) for an MIOSHA regulated substance for which there are exposure monitoring and medical surveillance requirements, medical surveillance shall be established for the affected employee as prescribed by the particular standard.
- Whenever an event takes place in the work area such as a spill, leak, explosion or other occurrence resulting in the likelihood of a hazardous exposure, the affected employee shall be provided an opportunity for a medical consultation. Such consultation shall be for the purpose of determining the need for a medical examination.

All medical consultations and examinations must be performed by or under the supervision of a licensed health care provider and must be provided without cost to the employee, without loss of pay, and at a reasonable time and place. The University, in conjunction with the lab supervisor, shall provide the following information to the health care provider:

- The identity of the hazardous chemical(s) to which the employee may have been exposed;
- a description of the conditions surrounding the exposure, including available quantitative exposure data; and
- a description of any signs and symptoms of exposure that the employee is experiencing.

The University shall obtain a written opinion from the examining health care provider which shall include the following:

- Any recommendation for further medical follow-up;
- the results of the medical examination and any associated tests;
- any medical condition which may be revealed in the course of the examination which may place the employee at increased risk as a result of exposure to a hazardous chemical found in the workplace;

- a statement that the employee has been informed of the results of the consultation or medical examination and any medical condition that may require further examination or treatment; and
- any work restrictions.

NOTE - The written opinion of the health care provider shall not reveal specific findings of diagnoses unrelated to occupational exposure.

Reference [General Industry and Construction Safety and Health Standard Part 431 Hazardous Work in Laboratories](#)

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Chapter 6: Laboratory work requiring prior approval

Prior to conducting any work in the laboratory, the Principle Investigator or laboratory supervisor must review the appropriate Standard Operating Procedure with the lab worker. Some specific research areas also require additional review or approval by the laboratory supervisor, a university review board, and/or Environmental Health and Safety.

6.1 Special provisions for Particularly Hazardous Substances (PHS)

MIOSHA mandates special provisions for handling particularly hazardous substances. A lab worker using one of these substances listed below for the first time is required to get prior approval from the lab supervisor.

- Any chemical designated as highly toxic by oral, dermal or inhalation routes of exposure as defined in the [MIOSHA Hazard Communication Standard](#).
- Any chemical designated as a carcinogen based on the following:
 - [MIOSHA regulated carcinogen](#);
 - [National Toxicology Program](#) (NTP) as "Known To Be Carcinogenic"
 - NTP "Reasonably Anticipated To Be Carcinogenic;"
 - A Group 1, 2A, or 2B carcinogen by the [International Agency for Research on Cancer](#) (IARC).

As detailed in chapter 7, the lab PI shall identify designated areas for using PHS materials, confirm users use the appropriate engineering controls, and that they are trained in the appropriate techniques to open, transfer, handle, clean up, and dispose of these materials.

Also [see Chapter 7 of this CHP "Employee protection from particularly hazardous substances."](#)

6.2 Hazardous procedures

Procedures involving pyrophoric, water reactive, or potentially explosive materials, and procedures involving extreme temperatures, extreme high/low pressures, high voltages or non-ionizing radiation (e.g. open beam class 3 and 4 lasers) may require prior review before starting; check with your departmental Chemical Hygiene officer, departmental safety committee, or Environmental Health and Safety. Radioactive materials require review and approval by the university's Radiation Safety Officer. Research using biohazardous materials or recombinant DNA, human subjects, or vertebrate animals, require prior approval from the appropriate university Review Board.

6.3 Hazardous Waste

The laboratory supervisor must plan for the appropriate collection, container labeling, and disposal of any listed or characteristic [hazardous waste](#), as well as [other laboratory wastes](#), prior to starting any experiment.

PIs should discuss their experimental plans with the Environmental Health and Safety if experiments are likely to generate (1) large quantities of waste exceeding 5 gallons (20L) or 45 pounds (20kg); (2) waste with mixed chemical, biological and/or chemical hazards; (3) leftover or unused acutely hazardous P listed waste In the EPA [table 205A](#).

6.4 Working alone

Working alone in a laboratory can be dangerous and should generally be avoided. If working alone on nonhazardous tasks workers must set up a check in/check out notification system with workers in other labs or another responsible adult that knows how to activate emergency contacts if the worker fails to check out.

Before working alone with hazardous chemicals or performing other hazardous activities that require an SOP, a hazard analysis for working alone must be conducted and incorporated into the SOP. The updated SOP may indicate that the procedure cannot be conducted safely by a lone worker, limit or specify the time of day when the work may be conducted, define additional check in/check out procedures or implement new emergency signaling requirements.

6.5 Unattended operations

Unattended laboratory operations involving hazardous substances should be avoided if possible. When experiments must run continuously or overnight with no one present, prior planning must be made to ensure the continuous safe operation of equipment and prevent the unintended release of hazardous materials. Planning must include contingencies for interruption, and possibly the subsequent restoration of, electricity, cooling water, and/or the flow of gasses. A hazard analysis must be conducted to determine if additional alarms, liquid or gas detection equipment, automatic notification systems, or automatic shutdown equipment need to be installed. All doors to the lab must have up-to-date postings that include hazards associated with the operating equipment and emergency contact information. Additionally, a notification of continuous operation including emergency shutdown procedures and contact information for the person responsible for the experiment must be posted near the equipment in operation. When appropriate, arrangements should be made for regularly scheduled inspections of the operation.

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Chapter 7: Employee protection from Particularly Hazardous Substances

The MIOSHA Laboratory Standard requires that certain chemicals be identified as particularly hazardous substances (PHS) and handled using special additional procedures. As defined in [Chapter 6](#) of this CHP, PHSs include chemicals that are select carcinogens (those strongly implicated as a potential cause of cancer in humans), reproductive toxins, and compounds with a high degree of acute toxicity. A thorough hazard analysis must be conducted before working with any of these substances. The individual(s) conducting the hazard analysis and developing the resulting SOP should consult with the PI, department CHO, safety officer, Research Integrity, Environmental Health and Safety, or other qualified individuals as needed. The final SOP must be reviewed with the individual who will be working with the PHS to ensure they understand the potential risks and are properly trained to perform the work safely.

7.1 The establishment of a designated area or areas that indicate the physical limits of exposure to particularly hazardous substances.

A designated area indicating the physical limits of exposure to particularly hazardous substances can be indicated by placing yellow caution tape on the floor, setting up physical barriers, or other clear demarcations. Lab workers can only enter this area if they are appropriately trained and suitably protected against the hazard. The area should:

- Be marked with a "danger (specific agent), authorized personnel only," or comparable warning sign;
- have an emergency response plan posted near the area; and
- be evaluated to determine if chemical detection equipment is required.

7.2 The use of containment devices, such as laboratory-type hoods or glove boxes.

Work with PHS must minimize the exposure as much as possible and personnel exposure may not exceed the MIOSHA Permissible Exposure Limits or similar consensus standards for that chemical. All work with carcinogens, reproductive toxins, and acutely toxic chemicals should be done within a functioning chemical fume hood, glove box, sealed system, or other containment device designed to minimize exposure to these substances. The exhaust air from the ventilation systems may require scrubbing before being released into the atmosphere. The ventilation efficiency and operational effectiveness of the containment equipment, must be evaluated at intervals recommended by the manufacturer and applicable regulatory agencies.

Compressed gas cylinders that contain acutely toxic chemicals must be kept in continuously mechanically ventilated gas cabinets. A hazard analysis of acutely toxic gasses must be

performed to determine if additional sensors, alarms, fire suppression, or other safety equipment needs to be installed.

7.3 Procedures for the safe removal of Particularly Hazardous Waste.

Prior to starting work with PHS, the PI is responsible for developing a plan, in consultation with Research Integrity, for the appropriate collection, container labeling, and disposal of any listed or characteristic [hazardous waste](#).

7.4 Housekeeping, decontamination, and chemical spills.

The following housekeeping, decontamination, spill response procedures must be established when using hazardous chemicals, including using PHS:

- Chemical laboratories must be maintained in a clean and orderly manner to minimize the chances of accidental exposure to hazardous chemicals;
- all work surfaces and equipment must be immediately cleaned and decontaminated after completion of procedures involving the use of PHS, and other hazardous chemicals and materials.
- all equipment used with PHS and other hazardous chemicals and materials must be cleaned and decontaminated prior to repair, service, decommissioning, or disposal; and
- the procedure for cleanup and decontamination following [chemical spills](#) must be documented in operational SOPs for each chemical used in the laboratory. See Section 2.4

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Chapter 8: Writing Standard Operating Procedures

The MIOSHA Laboratory Standard requires that written Standard Operating Procedures (SOPs) are developed for all laboratory work that involves hazardous chemicals or physical hazards. SOPs are written documents that provide step by step instructions for completing laboratory procedures. A well-written SOP will also include information about potential hazards associated with the procedure and how the risks associated with these hazards will be mitigated. For this reason, a hazard analysis is the first step in developing an effective SOP (see section 2.1).

Laboratory-specific SOPs must be prepared by laboratory personnel who are knowledgeable and involved with the experimental process/or procedure. The laboratory supervisor/PI is ultimately responsible for approving SOPs regardless of who prepares them. Laboratory-specific SOPs for laboratory work involving hazardous chemicals and physical hazards will comprise Chapter 9 of the laboratory's CHP. These SOPs must be followed by faculty, staff, and students working in the laboratory.

A template for developing laboratory-specific SOPs is provided below. Note: Some laboratory equipment may present special hazards that will require a written SOP to assure safety. A similar approach for developing equipment SOPs may be followed though outside the requirements of the CHP. If adapting a SOP produced at another institution or sourced from a generic SOP database, the SOP must be edited to reflect Michigan Tech specific resources and requirements as well as the specific hazards occurring in the Michigan Tech laboratory.

In addition to promoting safety and helping ensure consistent experimental results, SOPs can also be used as a tool for instruction and training in the laboratory. As a standardized document, a written SOP can be used to effectively communicate the risks associated with research in the laboratory, helping to ensure that one person is not over-trained while another is under-trained. A written SOP also provides for continuity in laboratory training, making sure that instructions are not distorted or weakened over time and by staff turn-over. SOPs should be updated as necessary and as part of the CHP should be included in annual lab-specific CHP training/retraining.

8.1 Standard Operating Procedure template:

An example standard Operating Procedure template is shown below. This template is also available as a stand alone [Google document](#). Research Integrity has developed a [Google Form](#) template version.

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Standard Operating Procedure Template

Name of Procedure: *[Identify the intended scope of the SOP here]*

Lab Location: *[Building, room number, and/or laboratory name]*

Type of SOP:

- Procedural
- Hazardous Material
- Equipment Specific
- Other

Prepared by:

Date Established:

Revision date:

Hazards

The following hazards exist with this procedure;

Chemical Hazards

- Strong Acids
- Strong bases
- Hydrofluoric acid
- Flammable solids, liquids, or gasses
- Toxic or highly toxic substances
- Possible organic peroxides
- Pyrophoric chemicals
- Highly reactive chemicals, chemicals that undergo rapid polymerization
- Chemicals classified as explosives (GHS or DOT categories)
- Other chemical hazards (specify)

Physical Hazards

- Distillations
- High/low pressure
- Lasers (class 3 or 4, open beam)
- Extreme temperatures
- High voltage
- Mechanical hazards
- Other physical hazards (specify)

Biological Hazards

- BSL II manipulations
- Biological activities that might create aerosols

Methods of controlling identified hazards

Engineering Controls (ventilation and/or containment) - The following engineering controls are required for this activity:

Control of chemical exposure and/or control of physical conditions

- Chemical fume hood
- Additional local ventilation (i.e. snorkel)
- Glove box (inert atmosphere)
- Glove box (humidity/temperature control)
- Blast shields
- Spray guards
- Pressure relief

Control of biological exposure

- Glove box (biological protection)
- Biological Safety Cabinet

Other engineering controls

- Other engineering controls (specify)

Personal Protective Equipment (PPE) - The following personal protective equipment must be worn:

Eye protection

- Impact resistant eye protection
- Splash resistant goggles
- UV, IR, or laser eye protection
- Face shield
- Other (specify)

Hand protection

- Chemical resistant gloves (specify material type and thickness)
- Extreme temperature gloves
- Cut resistant gloves
- Disposable lab coat
- Standard cloth lab coat
- Fire resistant lab coat
- Other specialize lab coat, coveralls, or other protective clothing (specify)

Other personal protective equipment

- Hearing protection
- Head protection (specify)
- Foot protection (specify)
- Other PPE (specify)

Special provisions for working alone

[Indicate if this activity may not be allowed if working alone; if allowed, list any special provisions]

Unattended Operations - If portions of this activity are being run unattended list the emergency shutdown procedures for the process to be posted.

Storage and Handling Requirements – describe any specific storage or handling requirements of any hazardous chemicals:

[State the precise methods of storage and handling issues that are pertinent to this procedure.]

Waste disposal - List the waste products that will be generated, how they will be collected, and how the container will be labeled:

Accidental Spill - In the event that a hazardous material used in this procedure are spilled, be prepared to execute the following emergency procedure:

Procedure

[Provide an exact description of the procedure (usually in a step-by-step format) that you will be conducting; include appropriate safety measures in associated steps.]

Name (author) _____ Signature _____

Laboratory supervisor _____ Signature _____

Date Approved _____

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Chapter 9: Laboratory Specific Standard Operating Procedures

9.1 Every Laboratory under the MIOSHA laboratory standard must:

- Conduct hazard assessments for the activities conducted in the laboratory and use these assessments to develop written Standard Operating Procedures.
- Make these procedures available to employees and train them to follow these procedures.
- Document this training.

The laboratory specific Chemical Hygiene Plan, written Standard Operating Procedures, and training documentation, may be available in either printed or electronic formats. However, they need to be readily available to anyone that enters the laboratory including all employees, Research Integrity, Environmental Health and Safety, and MIOSHA inspectors.

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Glossary of Terms

- **Action level** means a concentration which is designated in established MIOSHA health standards for a specific substance, calculated as an 8-hour, time-weighted average, and which initiates certain required activities, such as exposure monitoring and medical surveillance.
- **Chemical Hygiene Officer (CHO)** means an employee who is designated by the employer, and who is qualified by training or experience, to provide technical guidance in the development and implementation of the provisions of the Chemical Hygiene Plan. This definition is not intended to place limitations on the position description or job classification that the designated individual shall hold within the employer's organizational structure.
- **Chemical Hygiene Plan (CHP)** means a written program which is developed and implemented by the employer, which sets forth procedures, equipment, personal protective equipment, and work practices that are capable of protecting employees from the health hazards presented by the hazardous chemicals used in a particular workplace, and which is in compliance with Part 431.
- **Emergency** means any occurrence, such as equipment failure, the rupture of containers, or the failure of control equipment, that results in an uncontrolled release of a hazardous chemical into the workplace.
- **Employee** means a person who is assigned to work in a laboratory workplace and who may be exposed to hazardous chemicals in the course of his or her assignments.
- **Hazardous chemical** means any chemical which is classified as a health hazard or simple asphyxiant (see below) in accordance with the Occupational Health Standard Part 430 "Hazard Communication," as referenced in R 325.70102a.
- **Health hazard** means a chemical that is classified as posing 1 of the following hazardous effects:
 - Acute toxicity, any route of exposure.
 - Skin corrosion or irritation.
 - Serious eye damage or eye irritation.
 - Respiratory or skin sensitization.
 - Germ cells mutagenicity.
 - Carcinogenicity.
 - Reproductive toxicity.
 - Specific target organ toxicity, single or repeated exposure.
 - Aspiration hazard.
 - The criteria for determining whether a chemical is classified as a health hazard are detailed in Appendix A of Occupational Health Standard Part 430 "Hazard Communication," as referenced in R 325.70102a, rule §1910.1200(c) which includes the definitions of "simple asphyxiant".
- **Laboratory** means a facility where the "laboratory use of hazardous chemicals" occurs. It is a workplace where relatively small quantities of hazardous chemicals are used on a non-production basis.

- **Laboratory scale** means work with substances in which the containers used for reactions, transfers, and other handling of substances are designed to be easily and safely manipulated by one person. "Laboratory scale" excludes those workplaces whose function is to produce commercial quantities of materials.
- **Laboratory-type hood** means a work chamber which is used in a laboratory, which is enclosed on 5 sides and has a moveable sash or fixed partial closure on the remaining side, which is constructed and maintained to draw air from the laboratory and prevent or minimize the escape of air contaminants into the laboratory, and which allows chemical manipulations to be conducted in the enclosure without inserting any portion of the employee's body other than hands and arms. The term includes walk-in hoods with adjustable sashes if the sashes are adjusted during use so that the airflow and the exhaust of air contaminants are not compromised and so that employees do not work inside the enclosure during the release of airborne hazardous chemicals.
- **Laboratory use of hazardous chemicals** means the handling or use of such chemicals in which all of the following conditions are met:
 - Chemical manipulations are carried out on a laboratory scale.
 - Multiple chemical procedures or chemicals are used.
 - The procedures that are involved are not part of the production process, nor in any way simulate a production process.
 - Protective laboratory practices and equipment are available and in common use to minimize the potential for employee exposure to hazardous chemicals.
- **Medical consultation** means a consultation that takes place between an employee and a licensed physician to determine what medical examinations or procedures, if any, are appropriate.
- **Mutagen** means chemicals that cause permanent changes in the amount or structure of the genetic material in a cell. Chemicals classified as mutagens in accordance with Occupational Health Standard Part 430 "Hazard Communication," as referenced in R 325.70102a, shall be considered mutagens for purposes of these rules.
- **Physical hazard** means a chemical that is classified as posing 1 of the following hazardous effects:
 - Explosive.
 - Flammable, gasses, aerosols, liquids, or solids.
 - Oxidizer as a liquid, solid, or gas.
 - Self-reactive.
 - Pyrophoric as a gas, liquid, or solid.
 - Self-heating.
 - Organic peroxide.
 - Corrosive to metal.
 - Gas under pressure.
 - In contact with water emits flammable gas.
 - Combustible dust.
 - The criteria for determining whether a chemical is classified as a physical hazard are in Appendix B of Occupational Health Standard Part 430 "Hazard

Communication,” as referenced in R 325.70102a, rule §1910.1200(c) which includes the definitions of "combustible dust" and "pyrophoric gas."

- **Protective laboratory practices and equipment** means those laboratory procedures, practices, and equipment that are accepted by laboratory health and safety experts as effective, or that the employer can show to be effective, in minimizing the potential for employee exposure to hazardous chemicals.
- **Reproductive toxins** mean chemicals that affect the reproductive capabilities, including adverse effects on sexual function and fertility in adult males and females, as well as adverse effects on the development of the offspring. Chemicals classified as reproductive toxins in accordance with the Occupational Health Standard Part 430 “Hazard Communication,” as referenced in R 325.70102a, shall be considered reproductive toxins for purposes of these rules.
- **Select carcinogen** means any substance which meets one of the following criteria:
 - It is regulated by OSHA/MIOSHA as a carcinogen; or
 - It is listed under the category, “known to be carcinogens,” in the Annual Report on Carcinogens published by the National Toxicology Program (NTP) (latest edition); or
 - It is listed under Group 1 (“carcinogenic to humans”) by the International Agency for Research on Cancer Monographs (IARC) (latest editions); or
 - It is listed in either Group 2A or 2B by IARC or under the category, “reasonably anticipated to be carcinogens” by NTP, and causes statistically significant tumor incidence in experimental animals in accordance with any of the following criteria:
 - After inhalation exposure of 6-7 hours per day, 5 days per week, for a significant portion of a lifetime to dosages of less than 10 mg/m³;
 - After repeated skin application of less than 300 (mg/kg of body weight) per week; or
 - After oral dosages of less than 50 mg/kg of body weight per day.

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