Michigan Tech

Michigan Technological University

Chemical Hygiene Plan

Adopted: September 1, 2015
Revised: _September 5, 2015

Lab-Specific Plan

MICHIGAN TECHNOLOGICAL UNIVERSITY

Chemical Hygiene Plan

Lab-Specific Plan

This is the Chemical Hygiene Plan (CHP) specific to the following areas:

Building(s): ______________________________

Room Number(s): ______________________________

Principal Investigator (Lab Supervisor): ______________________________

Department: ______________________________

Revised *(Must be reviewed at least annually.)*: ______________________________

Laboratories engaged in the laboratory use of hazardous chemicals must maintain a lab-specific Chemical Hygiene Plan (CHP) which conforms to the requirements of 29 CFR 1910.1450, the Occupational Safety and Health Administration (OSHA) Occupational Exposure to Hazardous Chemicals in Laboratories Standard (Lab Standard). Michigan Technological University laboratories may use this document as a starting point for creating their lab-specific CHP. At a minimum, this cover page must be edited for location specificity. In addition, all lab employees must complete a Lab-Specific Training Certification form, Section 11.3.1. This instruction and information box should remain. This model Chemical Hygiene Plan is the 2015 version; the most current version can also be found on the Michigan Tech OSHS website page at www.mtu.edu/oshs/.

Important Telephone Numbers

Campus Emergency: 911 for fire-explosion-medical emergencies (i.e., all emergencies).
Michigan Tech Public Safety: 906-487-2216 for basic services

OSHS

Biosafety Officer David Dixon at 906-487-2131
Executive Director, Compliance, Integrity, and Safety Joanne Polzien 906-487-2902
Lab Safety Scientist Aparupa Sengupta 906-487-3153
OSHS Director and Radiation Safety Officer Al Niemi at 906-487-2118
Staff Assistant, Compliance, Integrity, and Safety Office Kimberly Puuri 906-487-2902

Michigan Tech Chemical Hygiene Officers			**updated 7/15/15**	
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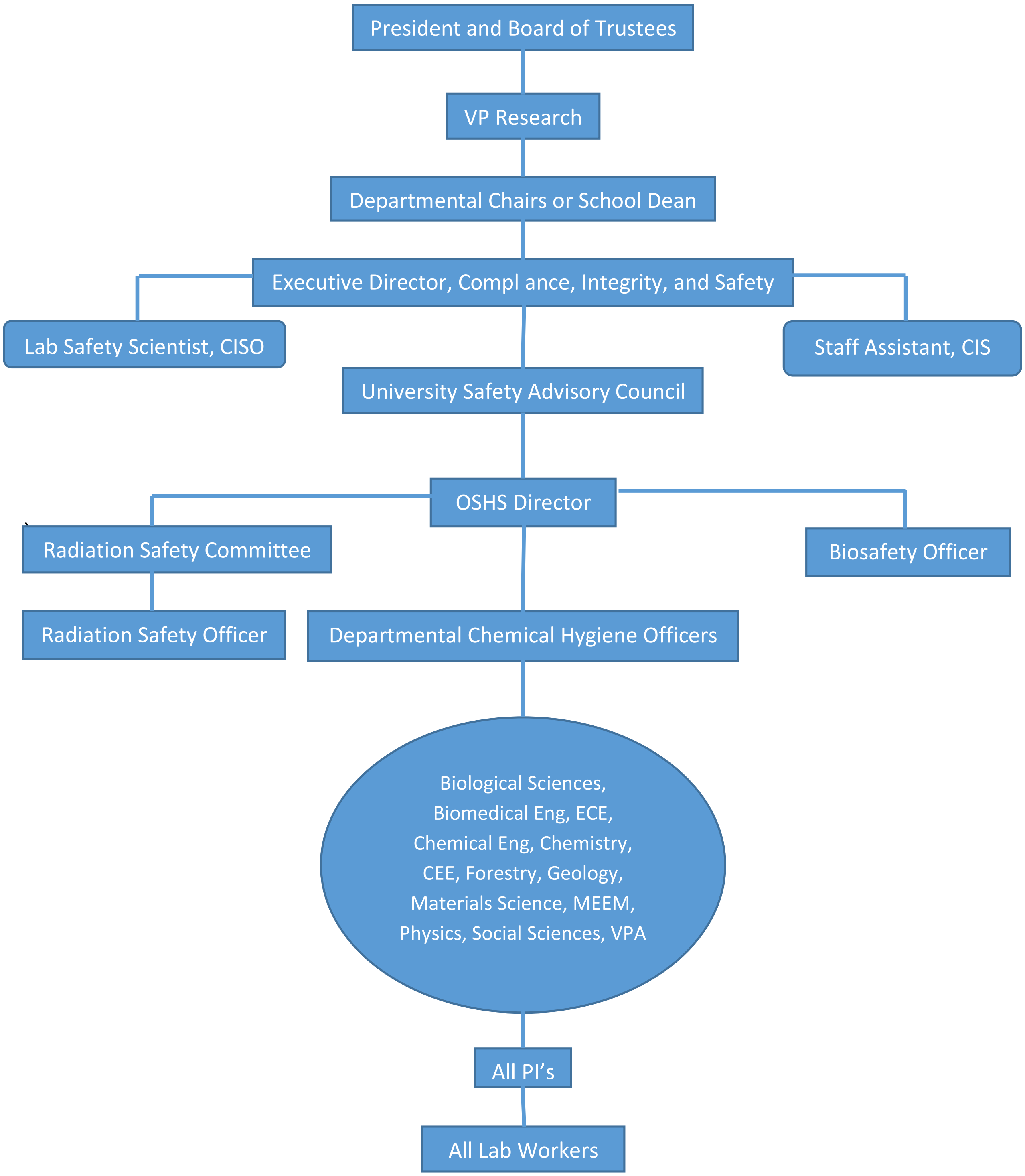
Social Sciences	Tim Scarlett, Assoc Prof (7-2359)	scarlett@mtu.edu	Hugh Gorman	hsgorman@mtu.edu
VPA	George Hommowun, Production Manager (7-1883)	gdhommow@mtu.edu	Jared Anderson	jaredand@mtu.edu

Central Heating Plant 906-487-2707 for ventilation issues

Safety Structure at Michigan Technological University



Acknowledgements

This document is based on material from Michigan Tech's "Chemistry Department Safety Information" and also includes materials present in the 2015 versions of the Chemical Hygiene Plans of Purdue University and the University of Michigan. Selected sections of these documents have been used with permission from the respective officials as stated below.

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Senior Director
Environmental Health and Public Safety
Purdue University
610 Purdue Mall, West Lafayette, IN 47907

2. Terry Alexander, PE, CIH, BCEE
Executive Director
Occupational Safety & Environmental Health and Office of Campus Sustainability
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Additionally, this CHP was prepared in accordance with the requirements of the Occupational Safety and Health Administration (OSHA) Occupational Exposure to Hazardous Chemicals in Laboratories Standard (Lab Standard) found in 29 CFR 1910.1450, and is based on best practices identified in, among other sources, the "Global Harmonized System of Classification and Labeling of Chemicals"; "Prudent Practices for Handling Hazardous Chemicals in Laboratories", published by the National Research Council, the American Chemistry Society Task Force on Laboratory Chemical and Waste Management's "Laboratory Waste Management, A Guidebook"; the Princeton University "Laboratory Safety Manual"; and the University of California – Los Angeles "Chemical Hygiene Plan".

David Perram and Jeff Lewin, CHOs of the Civil and Environmental Engineering and Biological Sciences departments respectively contributed to this document.

Table of Contents

CHP Document Abbreviations List

ACS	American Chemical Society
ALARA	As Low As is Reasonably Achievable
ANSI	American National Standards Institute
ASTM	American Society of Testing and Materials
BO	Biosafety Officer
CHO	Chemical Hygiene Officer
CHP	Chemical Hygiene Plan
DOT	Department of Transportation
DRU	Documented Responsible User
EHS	Environmental Health and Safety
EPA	Environmental Protection Agency
GFCI	Ground Fault Circuit Interrupter
GHS	Globally Harmonized System of Classification and Labeling of Chemicals
HEPA	High-Efficiency Particulate Air
LC_{50}	Lethal Concentration 50%
LD_{50}	Lethal Dose 50%
MDELEG	Michigan Department of Energy Labor and Economic Growth
MiOSHA	Michigan Occupational Safety and Health Administration
MSDS	Material Safety Data Sheet
NFPA	National Fire Protection Association
NOV	Notice of Violation
OSHS	(Michigan Tech's) Occupational Safety and Health Services
PCB	Polychlorinated Biphenyl
PHS	Particularly Hazardous Substance
PI	Principal Investigator
PPE	Personal Protective Equipment
PSPS	Public Safety and Police Services
rDNA	Recombinant Deoxyribonucleic Acid
RSC	Radiation Safety Committee
SAA	Satellite Accumulation Area
SAC	(Michigan Tech's) Safety Advisory Council
SDS	Safety Data Sheet
SOP	Standard Operating Procedure

Chapter 1: Introduction and Individual Chemical Hygiene Responsibilities

Laboratory safety is an integral part of laboratory research and is essential to ensure that Michigan Technological University's compliance with all applicable environmental, health and safety laws, regulations and requirements are met. The risks associated with laboratory research (workplace injuries, environmental incidents, and property losses or damage) are greatly reduced or eliminated when proper precautions and practices are observed in the laboratory. To better manage and mitigate these risks, Michigan Technological University has developed the Chemical Hygiene Plan (CHP), which is intended to be the cornerstone of your laboratory safety program and is designed to aid faculty, staff, and students in maintaining a safe environment in which to teach and conduct research. Each laboratory using hazardous materials (i.e., any chemical that is a health hazard or a physical hazard) is required to have a copy of the CHP readily available to all laboratory personnel. Each laboratory worker must be familiar with the contents of the CHP and the procedures for obtaining additional safety information needed to perform their duties safely.

Safety is a very important component of your career. All workers in a laboratory must work in a manner that is in the interest of their safety and that of their coworkers. This document includes general guidelines on safe practices for common laboratory operations as well as some more specific hazards in the lab. The manual does not cover all the hazards you are likely to encounter in the lab. Your research advisor will be knowledgeable about specific hazards associated with your work. The appendix contains 6 sections which list information regarding Biological Safety, Radiation Safety, Security Issues, Classes of Hazardous Chemicals, Safety Aspects associated with common lab procedures and Case Studies in the form of Appendices A-F respectively. **Some of you do not conduct research involving biological hazards and radiation and therefore it is not required that you examine this information which is located in the appendix of this CHP. However, those involved with biological hazards and radiation are required to examine these sections. The remaining sections may be consulted for additional safety information as needed.**

In addition you can consult the following books for more information:

(1) "Identifying and *Evaluating* Hazards in Research Laboratories." These are 2015 guidelines developed by the hazards identification and evaluation task force of the American Chemical society's (ACS's) committee on chemical safety.

(2) "*Prudent Practices for Handling Hazardous Chemicals in the Laboratory*" issued by National Research Council and published by National Academy Press.

(3) "*Safety in the use of chemicals at work*" by the international Labour Office in Geneva.

(4) The National Institute for Occupational Safety and Health (NIOSH) guide to Chemical Hazards published by the CDC.

(5) ACS publications “Safety in Academic Chemistry Laboratories Vol 1“Accident prevention for college and university students” and “Accident prevention for faculty and administrators.”

(6) The OSHA Laboratory Safety Guidance manual

(7) The "*Merck Index*" provides useful information on the physiological properties of many compounds.

Access to the laboratories, stock room and other research facilities is a privilege. Willful or neglectful violations of the safety guidelines will result in loss of your access to these services and facilities.

1.1 Purpose

Michigan Technological University is committed to providing a healthy and safe work environment for the campus community. The Michigan Technological University CHP establishes a formal written program for protecting laboratory personnel against health and safety hazards associated with exposure to hazardous chemicals and must be made available to all employees working with hazardous chemicals in a laboratory setting. The CHP describes the proper use (but not for all situations) and handling procedures to be followed by faculty, staff, and all other personnel working with hazardous chemicals in laboratory settings.

1.2 Scope

The CHP applies to all laboratories that use, store, or handle hazardous chemicals and all personnel who work in these facilities. The information presented in the CHP represents best practices and provides a broad overview of the information necessary for the safe operation of laboratories that utilize hazardous chemicals. Laboratory use of hazardous chemicals is defined as 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 made available and in common use to minimize the potential for employee exposure to hazardous chemicals.

1.3 CHP Use Instructions

The information presented in the CHP represents best practices and provides a broad overview of the information necessary for the safe operation of laboratories that utilize hazardous chemicals. It is not intended to be all inclusive. Departments engaged in work with hazardous chemicals or hazardous operations that are not sufficiently covered by the CHP must customize this document by adding appropriate sections, in the form of standard operating procedures (SOPs), hazard assessments, and any other written (or referenced) lab-specific operating procedures or protocols that address the hazards and how to mitigate risks. The following instructions detail how this CHP template should be used and customized by each laboratory:

1.3.1 Planning Safe Research

1.3.1.1 Safety and Environmental Expectations for Research at Michigan Tech

Safety and environmental stewardship are the responsibility of every student, faculty, staff, and visitor to Michigan Tech. As is evident from the “Safety Structure” chart at the beginning of this document, at the university, safety is the joint responsibility of Deans, Directors, and Department Heads. However Principal Investigators (PI) and their researchers (i.e., students and postdocs) are primarily in charge of the planning and conduct of research involving physical, chemical or other hazards at the University. In short as detailed on the “Safety Structure” chart, everyone working at the university shares in producing and maintaining a culture of safety.

1.3.1.2 Expectations

Principal Investigators are expected to be fully aware of the risks posed by their research materials/methods and effectively communicate this awareness to their students. The expected method for instilling this awareness is through written standard operating procedures (SOP), used to instruct the students and identify necessary precautions to avoid injury, equipment damage, or release. Written records of this instruction must be maintained by the lab involved and copies of these sent to OSHS. Equally important to communication is direct involvement of the PI in observing the behavior of their students, and enforcing safety procedures. Research equipment safety features such as exhausted enclosures, sensor/alarm systems, power-interlocked guards and shields, system pressure gauges, and other measures must be installed to reduce exposure risks and monitor system performance. The management aspects of meeting these expectations is sometimes difficult for Principal Investigator, so the task may be assigned to a laboratory manager or other designated responsible person. The absence of such a lab manager leaves the Principal Investigator responsible for the safety of day-to-day activities and resulting incidents.

1.3.1.3 Resources

Michigan Tech provides health, safety, and environmental resources to the research community through the Department of Occupational Safety and Health Services (OSHS). Technical assistance regarding research material risks, method refinement, equipment specifications and training, hazard containment, protective equipment, and hazardous waste disposal is available from OSHS. The OSHS web page (http:/www.mtu.edu/oshs/) is a readily available resource for initial query into these areas. Templates for SOPs, safety plans, and recommended methods are all easily accessible from this on-line system. OSHS representatives for the research campuses are a phone call away and will provide personalized service for specific research challenges.

1.3.1.4 Case studies

Appendix B contains six case studies that may provide you with some indication as to the critical need for planning safe research.

1.4 Expectations – The Basics

1.4.1 Plan for Safety

It is the goal of the PI to have an experimental design deliver useful data in an efficient and timely manner, without delays or incident. Some of the first considerations for an experiment design or method change are the potentially hazardous chemicals to be used, potentially dangerous equipment to be purchased, 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: minimize experimental quantities; mandate protective equipment; enclose processes in fume hoods or provide other ventilation; place guards, screens, or barriers between the hazard and the researcher; and other prudent practices. OSHS is a resource for this planning process and can help identify points of consideration. Be fully aware of the risks – a good working knowledge about the hazards of any 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. Thoroughly review Safety Data Sheets for chemicals that staff, students and postdocs are reading and using, so that you 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. 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 and we should implement these strategies.

- *Make a 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 the OSHS office if they have a question about 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.*

1.4.2 Communicate Awareness

Staff and students must be knowledgeable about the hazards of their work and what action to take in the event something goes wrong. Make absolutely sure that students and staff who are working with hazardous materials and equipment have been fully briefed on the risks they are exposed to and what to do when things go wrong (assume they will). Provide them with written emergency procedures and training to handle laboratory emergencies and personal injuries.

1.4.3 Write Standard Operating Procedures (SOPs)

Experimental protocol must be followed closely and without deviation. When writing methods, include precautions and warnings that address protective equipment, chemical storage, fume hood use, and chemical waste disposal. Write these precautionary instructions into the protocol at points where the risks appear. **USE SOPs FOR INSTRUCTION**. Staff and students must be familiar with and follow prepared and approved SOPs. Use the SOP to provide employees instruction in the lab about expectations for performance and safety. A written SOP lends an element of consistency to instruction, so one person is not over-trained while another is under-trained. Continuity is also important, so the instructions are not distorted or weakened over time and by staff turn-over.

1.4.4 Observe the Behavior of the Staff

The PI's instructions must be followed in practice, on a daily basis. The PI is responsible for personally verifying that approved methods and precautions are being followed. Regular presence of the PI in the research lab, observing the experimental methods, indicates a serious approach to safety.

1.4.5 Enforce Safety Procedures

The PI must know about and correct those who do not follow instructions. In the event employees are not following standard safety precautions, or flagrantly ignoring good lab practices, firm action must be taken to clarify safety expectations to the employee and others in the lab.

1.4.6 Designate a Responsible Person

A management structure must be in place to maintain the quality of operations when the PI is away. Long-term management of a research project is best accomplished with the aid of experienced and empowered laboratory managers. Such lab managers can efficiently instruct new staff, maintain the quality of practices, and offer ideas for improvements.

1.4.7 Assure Equipment Safety Features

Hazardous equipment must have features that prevent injury, even if the user intentionally tries to defeat the guards and shields. Many modern scientific instruments contain features that reduce or eliminate the potential for accidental exposure and injury to the user. These features are present to reduce product liability, based on past injury experience. For thousands of older instruments that contain few or no safety features, the PI is responsible for identifying critical hazard points and guarding them with shields or power interlocks.

1.4.8 Planned Obsolescence

Scientific equipment (or a sophisticated facility) needs to function safely for a long period of time. Nothing man-made lasts forever, and most equipment requires expensive maintenance to operate past 5-10 years. At 20 years, most equipment is obsolete and parts are hard to find. At this point the equipment may become unsafe. Planning for maintenance costs and eventual replacement costs for critical equipment and specialty facility infrastructure should be undertaken as a lab management function. Too often, the day comes for replacement and no funding is available. Michigan Tech's-OSHS provides consultation and technical support for all of the above responsibility areas and can be reached by calling 906-487-2118.

1.5 Fill Out the CHP Provided by OSHS.

- Place your lab-specific standard operating procedures (SOPs) at the end of your departmental customized CHP using the blank document in Section 2.2 of this CHP document. These should be listed under the different rooms in your department. More details regarding SOPs can be found in Chapter 2 of this CHP.
- Insert your lab-specific hazard assessments in Box 2 of the SOP form. More details regarding hazard assessments can be found in the appendix of the CHP.
- Insert all other documented lab-specific rules, requirements, and procedures (e.g., engineering controls, PPE equipment protocols (Chapter 3), how to contain spills (Chapter 8) and waste disposal (Chapter 9)).
- Review, update (if necessary), and retrain all employees on the lab-specific CHP at least annually.

1.5.1 Employee Rights and Responsibilities

As part of the OSHA 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 work areas and to be properly trained to work safely with these substances. This includes custodial and maintenance personnel (support staff) who work to maintain laboratories. All personnel, including principal investigators, laboratory supervisors, laboratory professionals, student workers, and support staff have a responsibility to maintain a safe work environment. All personnel working with chemicals are responsible for staying informed on the chemicals in their work areas, safe work practices and SOPs, and proper personal protective equipment (PPE) required for the safe performance of their laboratory work.

1.5.2 Laboratory Supervisor Responsibilities

The 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 cases where the PI has hired an individual such as a lab manager or postdoctoral scholar to manage the daily operations of the lab, the PI is still ultimately responsible for the overall operation of the lab and is considered to be the Laboratory Supervisor. The Laboratory Supervisor may delegate some safety duties to a qualified individual, but ultimately remains responsible for the safety of all personnel working in the laboratory. Specifically, the Laboratory Supervisor must:

- Understand applicable environmental health and safety rules regarding the specific work in the lab, including the contents of the CHP;
- Identify hazardous conditions or operations in the laboratory and establish SOPs and hazard assessments to effectively control or reduce hazards;
- Ensure that all laboratory personnel that work with hazardous chemicals receive appropriate training (refer to Chapter 11 for detailed training requirements);
- Maintain written records of lab-specific training (e.g., PPE training), general storage/audit;
- Ensure that appropriate PPE (e.g., laboratory coats, gloves, eye protection, etc.,) and engineering control equipment (e.g., chemical fume hood) are made available, in good working order, and being used properly;
- Conduct periodic lab inspections and immediately take steps to abate hazards that may pose a risk to life or safety upon discovery of such hazards; and
- Actively enforce all applicable safety procedures and ensure that the CHP is followed by lab staff and all visitors, including having a progressive disciplinary process for lab staff members that do not comply with safety rules.
- Departmental Chairs, Deans and the VP of Research will ensure that a progressive disciplinary process for Laboratory Supervisors that do not comply with or adequately enforce safety rules.

Laboratory Supervisors must ensure that employees receive CHP training and information before any work with hazardous materials occurs. Laboratory Supervisors must also ensure that all employees receive annual CHP refresher training. The Laboratory Supervisor can provide the training or delegate this task to a qualified individual (e.g., Laboratory Safety Officer, senior lab employee). The CHP training must be documented. See Section 11.3.1 for the CHP Lab-Specific Training Certification form, which can be used to document reading the CHP. Failure to follow the requirements of the CHP could possibly result in injuries, fines from regulatory agencies such as MiOSHA, and/or disciplinary action.

It is the responsibility of the lab supervisor to ensure the following items are either displayed or made available:

1.5.2.1 Signs and information

Labels and warning signs should alert employees to potentially hazardous materials and allow those unfamiliar with the laboratory surroundings to identify hazardous chemical use and storage areas, safety facilities, emergency equipment, exits, and aid emergency response personnel. Signs and labels are generally available from the Michigan Tech's-OSHS Office at 7-2118 or the chemistry department's main office.

1.5.2.2 Safety Data Sheets (SDSs).

A Safety Data Sheet (SDS) is a document containing chemical hazard identification and safe handling information and is prepared in accordance with the OSHA Hazard Communication Standard and the Michigan Right-to-Know law. Chemical manufacturers and distributors must provide the purchasers of hazardous chemicals an appropriate SDS for each hazardous chemical/product purchased.

The Michigan Right-to-Know law requires that units keep SDSs in a systematic and consistent manner. The system a unit uses to store SDSs can vary from keeping them organized rationally (i.e., perhaps grouped by chemical type but arranged alphabetically) in a notebook or file cabinet to using the OSHS online request system at www.mtu.edu/sds/. Some kind of computational facility should be nearby for access to the online system. More important, during lab inspections, workers will have to demonstrate that they have examined the SDSs for the chemicals they are currently using. The system adopted must provide easy access to SDSs for hazardous chemicals used in the lab. Each unit must post a Michigan Right-to-Know Law poster, which indicates the location of all SDSs for hazardous chemicals used in the lab.

1.5.3 Laboratory Employee Responsibilities

All employees (e.g., lab technicians, graduate students, undergraduate students, post-doctoral researchers, and visiting scientists) in laboratories that use, handle, or store hazardous chemicals must:

1. Review and follow the requirements of the CHP;

2. Follow all verbal and written laboratory safety rules, regulations, and SOPs required for the tasks assigned;
3. Develop and practice good personal chemical hygiene habits such keeping work areas clean and uncluttered;
4. Plan, review, and understand the hazards of materials (i.e., read the SDSs in advance of doing experiments) and processes in the laboratory prior to conducting work;
5. Utilize appropriate measures to control hazards, including consistent and proper use of engineering controls, administrative controls, and PPE;
6. Understand the capabilities and limitations of PPE;
7. Immediately report all accidents, near misses, and unsafe conditions to the Laboratory Supervisor;
8. Complete (and submit to OSHS) all required OSHS and/or other mandatory safety training and provide written documentation to the Laboratory Supervisor;
9. Participate in the OSHS managed medical surveillance program when required; and
10. Inform the Laboratory Supervisor of any work modifications ordered by a physician as a result of medical surveillance, occupational injury, or chemical exposure.

1.5.4 Laboratory Safety Officer Responsibilities

Very often it is not practical for the Laboratory Supervisor to be present in the lab on daily basis to ensure that safe and compliant practices are being carried out by all lab staff. For this reason, it is highly recommended that each Laboratory Supervisor establish a Laboratory Safety Officer to manage the daily operations of the lab’s safety program. The Laboratory Supervisor should empower the Laboratory Safety Officer to make decisions on daily operations involving safety and compliance, including the authority to instruct other lab personnel to follow 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, post-doc, lab manager). Having a Laboratory Safety Officer in each lab provides many benefits such as:

- Other lab personnel know who to contact with questions about daily operations involving safety and compliance;
- Empowers someone other than the Laboratory Supervisor to enforce lab safety rules;
- Provides consistency within the respective academic department; idea is that each Laboratory Safety Officer attends departmental safety committee meetings and reports issues back to the lab; and
- Provides good, marketable experience for the Laboratory Safety Officer to be involved in a safety leadership role.

- Ensure that workers are safely attired. Care must be exercised with religious garments (specifically, Chadors, Turbans, Shawls, etc.) to ensure that loose fitting materials do not come into contact with moving objects.

The role of the Laboratory Safety Officer should include:

- Provide training to new lab personnel; ensure appropriate training is given and that the training is properly documented;
- Enforce lab safety rules;
- Attend departmental/college level safety committee meetings and report significant information back to the lab; and
- Report safety issues back to the Laboratory Supervisor when necessary.

1.5.5 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, it is the lab personnel's responsibility to notify support staff.

1.5.6 Departmental Chemical Hygiene Officer Responsibilities

The Departmental Chemical Hygiene Officer has the primary responsibility for ensuring the implementation of all components of the CHP. The Chemical Hygiene Officer must:

- Inform Laboratory Supervisors of all health and safety requirements and assist with the selection of appropriate safety controls (engineering controls, administrative controls, and PPE);
- Ensure that Laboratory Supervisors have the necessary resources to maintain compliance with the CHP and that all lab staff receive appropriate training;
- Act as the liaison between the Laboratory Supervisors and the Chemical Laboratory Safety Committee;
- Conduct periodic (per semester but at least annually) lab inspections and immediately take steps to abate hazards that may pose a risk to life or safety upon discovery of such hazards;
- Ensure that SOPs and hazard assessments are being prepared and submitted to OSHS;
- Maintain employee exposure-monitoring records, when applicable;

- Help to develop and implement appropriate environmental health and safety policies and procedures;
- Review and evaluate the effectiveness of the CHP program within their domain at least annually and update it as appropriate; and
- Actively enforce all applicable safety procedures and ensure the contents of the CHP are followed; notify OSHS when safety procedures are not followed.

1.6 Office of Occupational Safety and Health Services

The Office of Occupational Safety and Health Services (OSHS) serves as the environmental health and safety department for Michigan Technological University. OSHS's primary role is to manage regulatory compliance with all federal, state, and Michigan Tech regulations involving environmental health and safety issues. OSHS facilitates a number of programs that apply to laboratory safety, a few of which include biological safety, laser safety, personal protective equipment program, radiation safety, development of SOPs, as well as the CHP. OSHS also performs numerous safety inspections of facilities throughout the year to monitor compliance with regulatory requirements. OSHS provides a variety of services such as training, chemical, biological, and radioactive waste pickups, and safety consultation. More detailed information regarding all of OSHS's resources and services can be found on the OSHS website. http:/www.mtu.edu/oshs/

1.7 Integrated Safety Plan

It is the policy of Michigan Technological University to integrate environmental health and safety into all operations. The University's Safety Advisory Council (SAC) is the committee established and facilitated by OSHS, and was developed to provide a framework for laboratories to comply with environmental health and safety (EHS) regulations. The SAC assists in communication of EHS issues across the organization and calls for departmental level safety committees and individual self-audits. The SAC provides indemnification from regulatory fines for units with a certified safety program. An SAC certified safety program must have the following elements:

- Regular safety committee meetings;
- Means of communicating safety issues to the department in a timely manner;
- Upper administrative support for safety;
- Self-audits checklists, which is a self-inspection program, must be completed for all areas;
- Abatement of deficiencies found during the self-audits;

- An annual safety program audit and walk-through by OSHS;

Current membership of the SAC can be found on the following website www.admin.mtu.edu/admin/committe/members1.htm#safety%20advisory.

1.8 Michigan Tech Safety Guidelines

Michigan Tech has provided, and will continue to provide, safe and healthful working conditions for all faculty, staff, and students. OSHS will work with the Principal Investigators to prevent incidents and achieve compliance with safety regulations. The goal of laboratory safety follows the established line of supervision from the VP of Research to all Principal Investigators, to staff and students who work in these laboratories. Each individual has the responsibility to participate actively in the achievement of an effective safety program. Each Principal Investigator (PI) has a responsibility to protect their personnel from occupational hazards. This responsibility is of great importance and, while the PI may appoint a senior graduate student or a postdoc to function in the capacity as a Laboratory Supervisor, the PI is still responsible for their personnel. Each individual should understand the hazards associated with his or her work before starting, and should feel comfortable with the safeguards employed to ensure their safety. No work is so important that it can be undertaken in an unsafe manner. Any work that may be potentially unsafe or harmful should be questioned. Everyone has to be involved in a responsible manner to help assure safety. Laboratory safety requirements include, at a minimum:

- Becoming acquainted with the Chemical Hygiene Plan. This general plan may be used to develop more specific plans for different research groups.
- Designating a Chemical Hygiene Officer (CHO) and committee (possibly comprising of students and staff) within each department group. The CHO and committee should be responsible for developing, implementing, and documenting specific portions of the Chemical Hygiene Plan, performing random unannounced safety inspections, arranging appropriate training, maintaining safety equipment, and maintaining records. Principal Investigators are also CHO by default unless another qualified individual within each research group is designated and supervised effectively.
- Developing general and lab-specific written Standard Operating Procedures (SOPs). These become essential parts of the CHP and serve as the basis for training employees in safe work practices.
- Training employees on the contents of the CHP, the MiOSHA Laboratory Safety Standard, its appendices, and other important safety matters. This includes mandatory

basic training offered by the Michigan Tech's OSHS. It also includes training and guidance in laboratory-specific safety issues and procedures.

- Enforcing safe work practices and adherence to Standard Operating Procedures.
- Maintaining and submitting appropriate records to OSHS.

1.9 Laboratory Rooms

All Departmental Offices should contain a current listing of all laboratory personnel, their laboratory room numbers and related phone numbers. These rooms include laboratories and other types of rooms such as temperature-controlled rooms, storage rooms (containing hazardous chemicals), storage closets (containing hazardous chemicals), and animal research facilities that are subject to the laboratory standard. The Departmental Office should also know which groups share "common" rooms and the Departmental Chair has to indicate a plan for assignment of primary responsibility for safety and compliance in the "common" rooms. This information is to be submitted to OSHS and updated annually at the start of the Fall Semester. This list is mandated by 29 CFR 1910.1450 and also serves as a readily available reference in emergency situations.

1.10 Laboratory Decommissioning

It is the policy of the Michigan Tech and the OSHS that formal decommissioning is conducted prior to the transfer of "ownership" of laboratory space. Upon notification of the departure or relocation within the University of a researcher, OSHS personnel will visit the laboratory space(s). The researcher/department is provided with a summary of decommissioning activities (chemical removal, cleaning, etc.) that must be performed prior to vacating the premises including a close out evaluation by OSHS. The following materials and services are available:

- Biohazardous (Medical) Waste Disposal Guideline
- Biological Safety Cabinets Guideline
- Relocating Laboratory Hazardous Materials Guideline

If the lab uses radioactive materials, OSHS's Radiation Safety Services must also be contacted for a radiation decommission survey. Building Services will not service or clean rooms that have not been decommissioned by OSHS.

1.11 Office Safety

Office personnel at the University are not covered by or required to maintain Chemical Hygiene Plans. However, the safety of personnel in non-laboratory situations is equally important as that for lab situations. All personnel are encouraged to communicate any safety concerns to administration and/or to the department's Chemical Hygiene Officer.

Chapter 2: Standard Operating Procedures

SOPs are written instructions that detail the steps that will be performed during a given procedure and include information about potential hazards and how these hazards will be mitigated. SOPs must be prepared by laboratory personnel who are the most knowledgeable and involved with the experimental process. However, the Laboratory Supervisor/PI is ultimately responsible for approving SOPs regardless of who prepares them. The OSHA Lab Standard required SOPs to be developed for all high-hazard tasks that are performed in the lab. High hazard tasks include any work with the following types of chemicals:

- Explosives
- Water-reactive, pyrophoric, self-heating, or self-reactive chemicals
- Particularly hazardous substances, which includes carcinogens, reproductive toxins, and acutely toxic substances
- Compressed gases
- Work involving more than 1 liter of flammable liquids, flammable solids, corrosives, oxidizers, or organic peroxides at one time
- High-hazard tasks can also include work with equipment that creates particularly hazardous conditions. Examples include solvent distillation, work with high-pressure systems, hydrogenation, work with cryogenic chemicals such as liquid nitrogen, etc.
- Consult "Identifying and *Evaluating* Hazards in Research Laboratories" published by the ACS in 2015. www.acs.org/content/dam/acsorg/about/governance/committees/chemicalsafety/publications/identifying-and-evaluating-hazards-in-research-laboratories.pdf. This is an excellent source for chemical hazard analysis and SOP development.

OSHS has developed an SOP template given in Section 2.2 that can be used by laboratories. This SOP is not complete as is; it is a template that must be customized by each laboratory before it can be considered complete. Instructions for completion are included in the SOP template. Laboratories are encouraged to use this template format to develop their own SOPs. Contact OSHS at 906-487-2118 if assistance is needed with developing lab-specific SOPs. For the up to date list of SOP templates, visit the OSHS website. http:/www.mtu.edu/oshs/.

SOPs are to be completed for all procedures (one can have general procedures such as handling flammable solvents, drying solvents, etc. in one SOP) and are to be filed with OSHS by sending a pdf copy of each to staff assistant Kimberly Puuri at kjpuuri@mtu.edu. Michigan Tech intends to compile a database of all SOPs and have these available on a secure website.

2.1 Requirements for an SOP

In order to be in compliance with this chapter of your CHP the following items must be completed

- Develop written basic safety rules.
- Develop written general SOP.
- Develop written lab-specific SOP.

Safe work practices are essential to laboratory safety. They must be known, understood and followed by all persons working with potentially hazardous chemicals and equipment. To be most effective, they must be developed and documented as “Standard Operating Procedures” (SOPs). SOPs are an integration of the technical requirements to complete laboratory procedures and actions necessary to assure safety. SOPs may be described in three (3) categories: Basic Safety Rules, General SOPs and Lab-Specific SOPs.

2.1.1 Basic Safety Rules

Some actions may be described as basic or fundamental to safety in any laboratory or other situation where potential hazards exist, e.g., wearing appropriate eye protection, closing hood sashes when leaving a hood, not smoking or eating in the vicinity of hazardous chemicals, etc. These simple, somewhat “common sense” rules are important. If basic rules are followed, it is more likely that other, more complex and perhaps less intuitive, safety procedures will also be followed. Other examples of basic safety rules for chemical laboratories include: restraining long hair, jewelry, or loose clothing, prohibiting sandals and open-toed shoes, requiring laboratory coats at all times when working with hazardous chemicals, prohibiting loose woven, frilly, or flammable synthetic clothing materials when working with open flames, pyrophorics, or flammable liquids. The weight and weave of the fabric will affect how easily the material will ignite and burn. Recommended fabrics are materials with a tight, heavy, weave that will burn more slowly than loose, light, fabrics of the same material. The surface texture of the fabric also affects flammability. Fabrics with long, loose, fluffy pile or "brushed" nap will ignite more readily than fabrics with a hard, tight surface. Most synthetic fabrics, such as nylon, acrylic or polyester resist ignition but should be avoided. Once ignited, the fabrics melt resulting in severe burns from the melted burning substance. Again care must be exercised with religious garments (specifically, Chadors, Turbans, Shawls, etc.) to ensure that loose fitting materials do not come into contact with moving objects. Laboratory groups should develop their own “Basic Safety Rules” and post them in the laboratory. Examples of additional basic safety rules may be found in various sources like “Prudent Practices in the Laboratory” written by the National Research Council.

2.1.2 General SOP

General SOP are those that apply for more than one laboratory or laboratory group. They may include procedures recommended or required on a university-wide basis. They may also include “generic” procedures for using some types of chemicals or laboratory equipment. Sources of information on general SOP include reference books, chemical suppliers, equipment manufacturers, and training materials. OSHS recommends the following General SOP which apply for the storage, use and disposal of chemicals that may present a physical or health hazard. Anyone conducting research in a laboratory is required to abide by the following general standard operating procedures:

1. Chemical Labels Carefully read the labels of all hazardous chemicals before they are used. Upon receipt of purchased chemicals the date and owner should be written on the label. Any in-house dilution made from stock chemical bottles are required to be labeled with the chemical identity, concentration, and primary hazard with the date and owner also indicated on the label.

2. Safety Data Sheets (SDS) Anyone using chemicals should be aware of the hazardous properties associated with the use of those chemicals. This can be accomplished by reviewing the MSDS or SDS. The SDS for hazardous chemicals should be located internally for the lab in a notebook. SDS may be obtained from the website www.mtu.edu/sds/ or whichever source you like to use. SDS location posters should be conspicuously posted on departmental bulletin boards and in each laboratory in compliance with the Federal Hazard Communication Standard. These posters should be available in your department’s main office.

3. Personal Protective Equipment (PPE) Personal protective equipment recommended on a chemical's hazard warning label or SDS (e.g., neoprene gloves, vinyl splash aprons, chemical splash goggles, etc.) may be required to be used during handling of the chemicals. Lab requirements for PPE must be specified by the Principal Investigator, based on evaluation of potential hazards. This section should list the types of PPE available, what it is used for and where it is stored. Proper cleaning, care and repair instructions should also be included. PPE includes eye, hand, foot, face and head protection. If adequate information cannot be obtained from the SDS or other sources, contact OSHS at 906-487-2118 for technical assistance.

4. Containment Devices Any containment devices recommended on chemical container labels or SDS, e.g., chemical fume hood, glove box, explosion proof refrigerator, etc., will be required for the storage and active handling of the chemicals.

5. Chemical Waste Chemical waste is required to be disposed of in compliance with Federal, State and Local environmental regulations. Chemicals should be in a labeled waste container specific for the class of chemicals. Evaporation in a chemical fume hood is not an option. Waste chemicals, no matter how seemingly innocuous, may not be poured down the drain to the sanitary sewer unless specific permission is given by the OSHS at 906-487-2118.

2.1.3 Lab-Specific SOP

Every laboratory and laboratory group will have some chemicals and/or procedures and equipment that can potentially present specific hazards not addressable by general or "generic SOP." Principal Investigators should determine these situations and develop lab-specific SOP accordingly. Copies of these SOP should be kept in the CHP Notebook and also deposited with OSHS by sending a pdf copy electronically to kjpuuri@mtu.edu.

*See Examples of SOPs: www.mtu.edu/chemistry/labs/safety/ and at the Department of Civil and Environmental Engineering.

*Specific Standard Operating Templates for additional assistance: Section 2.2 of this document.

The following discussion may be helpful in the development of Laboratory-Specific SOP for handling hazardous chemicals.

Consider the chemical process

- Consider all possible reactions, including side reactions, before beginning.
- Think through all reactants, intermediates, and products 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, etc.?
- Is it impact sensitive?
- With what substances is this material incompatible? Are any incompatible materials in the vicinity of the reaction?
- Is it toxic? If so, what type of hazard (inhalation, ingestion, skin contact)? What protective measures are required?
- What is the recommended first aid treatment in case of an accidental exposure?

- Follow recognized, safe practices concerning protective equipment, housekeeping, handling hazardous chemicals, and proper use of lab equipment.
- Determine the quantity and the rate of the evolution of heat and gases that may be released during the reaction. Use the thermodynamic and kinetic data from the reaction chemistry.

Question the process dynamics

- How violent will it be?
- What is the effect of catalysts or inhibitors?
- How will air affect the reaction?
- How are the waste products to be handled and disposed of properly?

Develop contingency plans

- Electric power failure
- Cooling system failure
- Exhaust system failure
- Over pressurization
- Water leaks into system
- Air leaks into system
- A fire occurs due to the reaction (Is the appropriate extinguishing agent nearby?)
- Reaction container breaks or contents spill

During the process

- Provide adequate cooling, ventilation, pressure relief, and gas purging.
- Isolate the reaction vessel, if possible, and make frequent inspections of equipment during reaction.
- Post appropriate warning signs near any dangerous equipment.
- Inform others working in the area of the chemicals being used and the possible hazards involved.
- Always stay in the area and monitor systems that may present unusual hazards.
- Report all incidents and unusual occurrences at once.
- Some laboratory equipment present special hazards, which will require SOP to assure safety. Follow a similar, thorough approach for developing equipment SOP.

2.1.4 Materials and Procedures Requiring Special Provisions

Each Principal Investigator should identify and prepare a list of those materials and procedures in their lab for which special provisions will be applied. The MiOSHA Laboratory Standard (www.michigan.gov/lara/0,4601,7-154-11407_40217-147508--,00.html) suggests that these include reproductive toxins, highly (acutely) toxic materials, and "Select Carcinogens." A list of these lab-specific substances and situations should be placed in the CHP Notebook. The MiOSHA Laboratory Standard indicates that specific consideration should be given to:

- Establishment of a designated storage and work/use area
- Containment devices such as fume hoods or glove boxes
- Procedures for safe removal of contaminated waste
- Decontamination procedures

Consideration should be given to the conditions of handling, skin exposure potential, inhalation hazard, use of personal protective equipment, continuous air monitors, alarms, the need for contamination control devices such as glove boxes, decontamination procedure, and the handling of waste materials. All special provisions should be reviewed and discussed by several individuals prior to implementation. The MiOSHA Laboratory Standard has mandated that a special review be conducted in any laboratory in which a "particularly hazardous substance" is being used in order to determine if the hazard potential warrants implementation of special controls or procedures to control employee exposure. There is some flexibility in determining whether a particular chemical falls into the category of a special hazard chemical. The following types of chemicals should be considered for special controls or procedures:

- 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 one of the following:
- MiOSHA regulated carcinogen
- Listed by National Toxicology Program (NTP) as "Known To Be Carcinogenic"
- Listed by NTP "Reasonably Anticipated To Be Carcinogenic"
- Listed as Group 1 carcinogen by International Agency for Research on Cancer (IARC)
- Listed as a 2A or 2B carcinogen by IARC
- Any chemical designated as "Known To Cause Reproductive Toxicity" according to the Safe Drinking Water and Toxic Enforcement Act of 1986.
- Other chemicals which have been shown through laboratory experience to present significant or special hazards during laboratory processing activities.
- For mixtures, the special evaluation requirement may be waived in those instances where the mixture contains less than one (1) percent by weight of highly toxic chemicals

and less than 0.1 percent by weight of suspect Carcinogens and Reproductive hazards, where there is no information indicating that the mixture would pose the risk of the individual substance.

The Principal Investigator is responsible for identifying chemicals which meet the criteria of a special hazard material. When special hazard chemicals have been identified, the Principal Investigator is responsible for developing and implementing laboratory procedures, practices and equipment which are known to be effective or can be shown to be effective to eliminate the special hazard. These procedures and practices could include, but are not limited to, the following: designated areas, containment devices such as fume hoods and glove boxes, procedures for safe removal of materials, decontamination procedures, or pre-approval requiring specialized operating procedures.

2.2 Blank Standard Operating Procedure

Name of Procedure:____

Prepared by:____________________________ **Revision date: _______________**

Location-This procedure may be performed at the following location(s):

Hazards- The following materials and equipment associated with this procedure present exposure or physical health hazards. Safety precautions are prudent and mandatory:

Engineering Controls- Prior to performing this procedure, the following safety equipment must be accessible and ready for use: (ex. Chemical fume hoods, laminar flow hood, chemical spill kits)

Protective Equipment-Prior to performing this procedure, the following personal protective equipment must be obtained and ready for use: (ex. Acid resistant gloves, safety eyewear, lab coat, chemical splash apron)

Waste disposal-This procedure will result in the following regulated waste which must be disposed of in compliance with environmental regulations:

Accidental Spill- In the event that a hazardous material spills during this procedure, be prepared to execute the following emergency procedure:

Prior Approval- This procedure is considered hazardous enough to warrant prior approval from the laboratory supervisor. **Yes/No**

Certification- I have read and understand the above SOP. I agree to contact my Supervisor if I plan to modify this procedure.

Signature__________________________Name (print)________________________

Date_______________________________Room____________________________

Chapter 3: Personal Protective Equipment

3.1 Purpose

All Michigan Tech lab employees must be aware of the PPE requirements and procedures to adequately protect themselves against chemical, radiological, biological, or mechanical hazards. This policy has been prepared in accordance with the requirements of the OSHA PPE regulations (29 CFR 1910.132 - 29 CFR 1910.140, 29 CFR 1910.95). As briefly discussed in Chapter 5 of the CHP, PPE should never be used in place of engineering and administrative controls when handling hazardous chemicals. Proper PPE selection can be determined in the following ways:

- Ask the Laboratory Supervisor about proper PPE selection.
- Review the SOP and associated hazard assessment for the task to be performed.
- Review Section 8, “Exposure Controls/Personal Protection” of the SDS for the chemical(s) being used. This will provide basic information on the PPE recommended for use with the particular chemical. The SDS addresses "worst case" conditions; therefore, all the equipment described may not always be necessary for a specific job. In addition, the SDS may not provide sufficient information concerning a specific respirator or type of glove appropriate for the chemical.

Maintaining a safe laboratory environment is the responsibility of the professor in charge of the lab, but all employees play a role in observing safety guidelines. Personal protective devices and safety equipment must be provided to all employees under the appropriate circumstances and employees have the responsibility of properly using such equipment.

The SDS will provide some information on the personal protective equipment and safety procedures recommended for a given chemical, though the SDS may not provide sufficient information concerning the specific type of safety equipment required (for example, it may say "use gloves" but not list the best glove to use).

MiOSHA has adopted the American National Standards Institute (ANSI) consensus standards for eye protection and emergency shower and eyewash facilities

3.2 Scope

This Laboratory PPE Policy applies to all personnel that work with or around hazardous chemicals or other safety and health hazards. This policy is a part of the larger, allencompassing Michigan Tech PPE Policy that applies to all areas (not just laboratories) of the Campus. This Laboratory PPE Policy does not cover all potential hazards (e.g., confined space entry, welding operations, and high voltage) in all operations or settings. If a laboratory worker encounters hazards not covered in this Laboratory PPE Policy, then refer to the Michigan Technological University Personal Protective Equipment (PPE) Policy for more information (to be developed shortly).

3.3 Hazard Assessment

The hazard assessment is a process of identifying the hazards associated with a defined task, and prescribing PPE along with other relevant protection measures that must be employed to minimize the risk from the hazards. Employees who work in an area where there is exposure to hazardous chemicals during use or in foreseeable emergencies will receive hazard communication training at the time of initial assignment and whenever a new physical or health hazard for which they have not been trained is introduced into their work area. Information and training may be designed to cover categories of hazards or specific chemicals. Employees must be informed of:

- the training requirements of the hazard communication standard;
- any operations in their work area where hazardous chemicals are present; and
- the location and availability of this written hazard communication program, including the required hazardous chemical inventory and material safety data sheets required by this program.

Hazard assessments can be organized using three formats: by individual task (e.g., pipetting hazardous liquids), by location (e.g., Chemistry Laboratory Room 409), or by job title (e.g., Chemistry Lab Technician). Any of these formats is acceptable and often will be used in conjunction with each other to provide the safest laboratory work environment possible for employees. The following subsections describe each hazard assessment format in more detail.

3.3.1 Task Evaluation Hazard Assessment

Task evaluation hazard assessments should be conducted for specific tasks such as preparing cement, dilute hydrochloric acid solutions or an ozonolysis reaction and workup. These types of hazard assessments should be written in a very detailed manner. The following describes the steps that should be taken to perform a task evaluation hazard assessment:

- Describe the task.
- List hazards associated with each body part.

- Determine PPE requirements for each hazard.
- List other control measures required such as engineering and administrative controls.

See the OSHS's Forms webpage for the university's Hazard Communication Plan. (www.mtu.edu/oshs/safety-programs/required/hazard-communication/)

3.3.2 Location Evaluation Hazard Assessment

Location evaluation hazard assessments should be conducted for specific areas/laboratories. These types of hazard assessments should be written in a comprehensive manner that includes the majority of hazards present in a specific location (e.g., flammable and corrosive liquids). This type of hazard assessment is the most commonly used in laboratories and should be posted in a location within the lab where it is easily accessed by personnel (e.g., posted near the front door of the lab). If employees perform specific tasks not covered by the laboratory hazard assessment, then it will be necessary to perform another type of hazard assessment such as the task evaluation assessment that does address the specific hazards of that task. The following describes the steps that should be taken to perform a task evaluation hazard assessment:

- Identify the hazards.
- List each task where hazard is present.
- Determine PPE requirements for each task.
- List other control measures required engineering and administrative controls.

See the OSHS's Forms webpage for the university's Hazard Communication Plan. (www.mtu.edu/oshs/safety-programs/required/hazard-communication/)

3.3.3 Job Title Evaluation Hazard Assessment

Job title evaluation hazard assessments should be conducted for specific positions. These types of hazard assessments should be written in a comprehensive manner that includes the majority of hazards that a specific job position (e.g., Animal Care Technician) routinely encounters during the normal course of work. This type of hazard assessment is commonly used for positions where the hazards encountered do not frequently change. If the employee encounters a hazard that is not covered by the job title evaluation hazard assessment, then it will be necessary to perform another type of hazard assessment such as the task evaluation hazard assessment that does address the specific hazards of that task. The following describes the steps that should be taken to perform a task evaluation hazard assessment:

- Identify hazards that the position title may encounter while performing normal duties.

- List each task where hazard is present.
- Determine PPE requirements for each task.
- List other control measures required.

See the OSHS's Forms webpage for the university's Hazard Communication Plan. (www.mtu.edu/oshs/safety-programs/required/hazard-communication/)

3.4 Minimum PPE Requirements for Laboratories

This section details the minimum PPE requirements for all laboratories using hazardous chemicals. These requirements do not apply to labs that involve solely mechanical, computer, laser or other non-ionizing radiation, or electrical operations. The requirements listed do not cover all operations in all laboratories. Some operations and procedures may warrant further PPE, as indicated by the SDS, the SOP for the chemical(s) being used, facility policies, or regulatory requirements. Figure 3.1 illustrates the minimum PPE required when using hazardous chemicals in a laboratory.

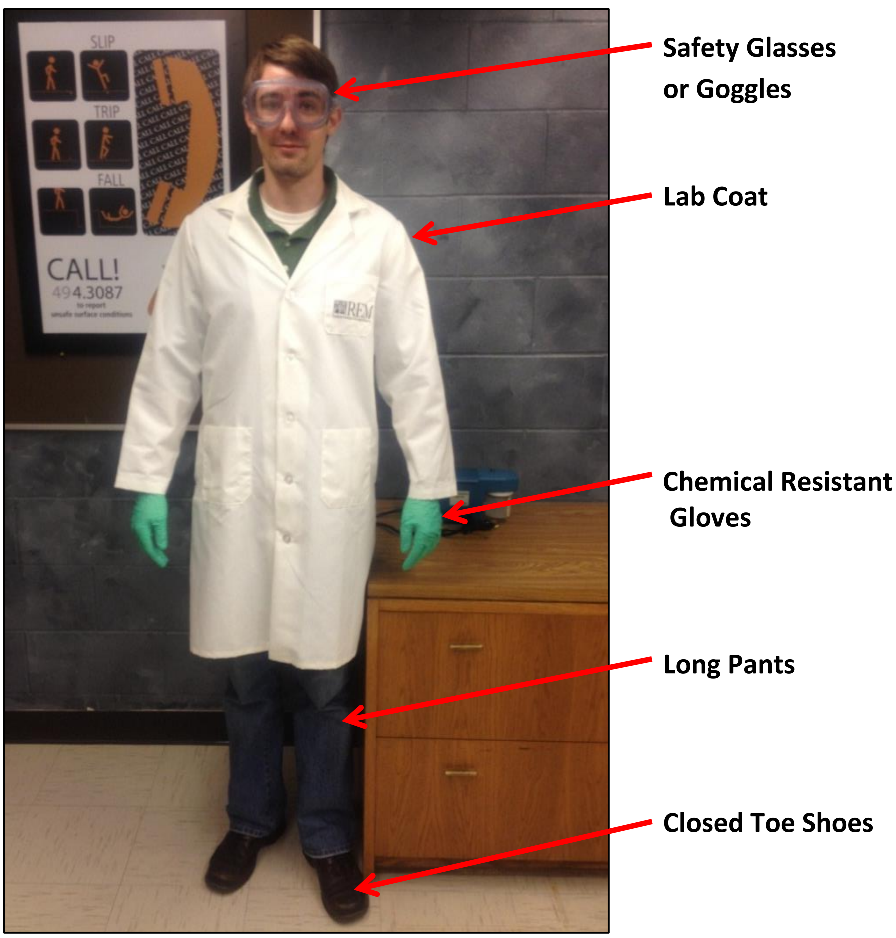


Figure 3.1 – Appropriate PPE for the Laboratory

3.4.1 Head Protection

If there is a serious risk of chemical splash to the head, a chemical-resistant hoodie must be worn. Each affected employee must wear protective helmets when working in areas where there is a potential for injury to the head from falling objects or “bump” hazards.

3.4.2 Hearing Protection

Hearing protection is not typically required in laboratory settings. However, if the lab seems excessively noisy (e.g., operating equipment that is loud, air handling unit is loud) and it is difficult to communicate with co-workers while in the lab, contact OSHS 906-487-2118 for a noise level evaluation.

3.4.3 Respiratory Protection

The use of respirators in the laboratory setting is not typically necessary since all work involving hazardous materials must be conducted in a chemical fume hood whenever possible. When ventilation is not adequate to provide protection against an inhalation hazard, respiratory protective equipment may be necessary. There is a variety of respiratory protective equipment available for use, but no one device will provide protection against all possible hazards. Respirator selection is based on the chemical and process hazard, and the protection factors required. Respirators are not to be used except in conjunction OSHS’s “Respiratory Protection Program”. This program includes a review of the process to ensure that proper equipment is selected for the job, training of all respiratory protective equipment users concerning the methods for proper use and care of such equipment, fitting of respirator users when required, and medical surveillance of respirator users when required. Contact OSHS at 906-487-2118 with questions about the Respiratory Protection Program or visit the OSHS website. (www.mtu.edu/osbs/safety-programs/required/respiratory/)

3.4.4 Eye and Face Protection

Each affected employee must use appropriate eye and face protection equipment when exposed to hazards from hazardous chemical splash, flying debris, or other exposures that may occur in the laboratory. Safety glasses must be worn at all times by all individuals that are occupying the laboratory area unless otherwise designated such as Dillman 110. Splash-proof safety goggles and/or a face shield may be more appropriate depending on the type of work being performed (e.g., transferring hazardous liquids outside of a chemical fume hood or glove box). All eye protection equipment must be American National Standards Institute (ANSI) approved and appropriate for the work being done. Eye and face protection may not be required in the lab if the employee is sitting at a workstation or desk that is away from chemical processes (e.g., working at a desktop computer, having a lab meeting at a table away from hazardous operations).

Eye Protection. Eye protection must be made available to all employees or visitors to laboratories where chemicals are used and stored. Protective eye and face equipment must be used where there is a reasonable probability of injury from hazardous chemicals that can be prevented from such equipment. The minimum acceptable requirements are for hardened glass or plastic safety spectacles. The laboratory supervisor will establish the level of eye protection needed per laboratory activity. Specialized types of eye protection, such as ultraviolet light restricting safety glasses, are available. The following types of eye protection are recommended for use in the laboratory by ANSI: “All eye protective devices must be stamped with "Z87" by the manufacturer if they meet ANSI standards. If the eye protection is not marked, it may not be the most effective protection available.”

Safety glasses with side shields offer minimal protection against flying fragments, chips, particles, sand and dirt. When a splash hazard exists, 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 conditions.

Chemical splash goggles have indirect venting for splash proof sides, which provide adequate protection against splashes. Chemical splash goggles offer the best eye protection from chemical splashes. Safety goggles should not be worn when danger of a splash exists.

Faceshields protect the face and neck from flying particles and splashes. Always wear additional eye protection under faceshields. Ultra-violet light face shields should be worn when working over UV light sources.

3.4.5 Hand Protection

Each affected employee must wear appropriate hand protection when the hands may be exposed to skin contact of hazardous chemicals, cuts, abrasions, punctures, or harmful temperature extremes. Chemical-resistant gloves must be worn while handling any hazardous chemical container; regardless of whether the container is open or closed (it should be assumed that all chemical containers are contaminated). When selecting appropriate gloves, it is important to evaluate the effectiveness of the glove type to the specific hazardous chemical being handled. Some gloves are more suitable for certain hazardous chemicals than others. The SDS for the specific chemical being handled and the glove manufacturer's glove chart must be consulted to select the most appropriate glove. Do not purchase gloves from a manufacturer that does not provide an adequate glove chart. It is recommended that each lab purchase a general purpose disposable nitrile glove (nitrile gloves are typically more versatile and provide resistance to a wider range of chemicals than latex gloves do) with a minimum of a 4 mil thickness that is suitable for general chemical handling. When handling chemicals with harmful temperature extremes such as liquid nitrogen or autoclaves, appropriate protection such as cryogenic gloves or heat-resistant gloves must be worn.

The volume of hazardous chemical being handled should be considered as well. For example, if working with a small volume of a sodium hydroxide solution, disposable chemical-resistant gloves provide adequate protection. But if working with a large volume of sodium hydroxide as with a base bath for instance, a more durable glove such as a butyl rubber should be selected to provide adequate protection.

Hand protection must not be worn outside of the laboratory (e.g., hallways, elevators, offices) to avoid contamination of public areas. Gloves should also be removed prior to handling anything that could likely result in cross-contamination (e.g., light switches, door knobs, elevator controls, water fountains, telephones, computer work stations). Disposable gloves must never be reused and wash hands after using gloves.

3.4.6 Body Protection

Each affected employee must wear protective clothing to protect the body from recognized hazards. All unprotected skin surfaces that are at risk of injury should be covered. Full length pants or 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 are required to be worn while working on, or adjacent to, all procedures using hazardous chemicals (e.g., chemical bottle is open and the chemical is being poured, transferred, pipetted, etc.). Laboratory coats must be appropriately sized for the individual and be fastened (snap buttons are recommended) to their full length. Laboratory coat sleeves must be of a sufficient length to prevent skin exposure while wearing gloves. Flame resistant laboratory coats must be worn when working with pyrophoric materials or flammable liquids greater than 1 liter in volume. It is recommended that 100% cotton (or other non-synthetic material) clothing be worn during these procedures to minimize injury in the case of a fire emergency.

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. **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 for employees to replace contaminated lab coats, or using disposable lab coats.

3.4.7 Foot Protection

Closed toe shoes must be worn at all times when in the laboratory; open toe shoes and/or sandals are not permitted in any circumstance. Each affected employee must wear protective footwear when working in areas where there is a high-risk of objects falling on or rolling across the foot, piercing the sole, and where the feet are exposed to electrical or chemical hazards. If there is a high risk of chemical contamination to the foot (e.g., cleaning up a chemical spill on the floor), then chemical-resistant booties may need to worn as well.

3.4.8 Safety Equipment

Safety Showers. Safety showers provide an immediate water drench of an affected person. MiOSHA has adopted the following ANSI standards for location, design and maintenance of safety showers:

- Showers shall be located within 25 feet of areas where chemicals with a pH of <= 2.0 or >= 12.5 are used. Showers shall be located within 100 feet of areas where chemicals with a pH of > 2 and < 4 or >= 9 and <12.5 are used.

- The location of the shower should be clearly marked, well lighted and free from obstacles, closed doorways or turns.

- Safety showers should be checked and flushed at least annually.

Eye Wash Facilities. Eye wash facilities are required in all laboratories where injurious or corrosive chemicals are used or stored and are subject to the same proximity requirements as safety showers. MiOSHA has adopted the following ANSI standards for location, design and maintenance of emergency eyewash facilities:

- Optimally, those affected must have both hands free to hold open the eye to ensure an effective wash behind the lids. This means providing eye wash facilities that are operated by a quick release system and simultaneously drench both eyes.

- Eye wash facilities must provide the minimum of a 15 minute water supply at no less than 0.4 gallons per minute.

- Eye wash facilities should be flushed out for five minutes at a time, best once per week (acceptable is once per month). A log documenting flushes is recommended.

Please call OSHS regarding specific designs for eye wash facilities.

3.4.9 Ventilation Controls

Ventilation controls are those controls intended to minimize employee exposure to hazardous chemicals by removing air contaminants from the work site. There are two main types of ventilation controls:

- General (Dilution) Exhaust: a room or building-wide system which brings in air from outside and ventilates within. Laboratory air must be continually replaced, preventing the increase of air concentration of toxic substances during the work day. General exhaust systems are not recommended for the use of most hazardous chemicals.

- Local Exhaust: a ventilated, enclosed work space intended to capture, contain and exhaust harmful or dangerous fumes, vapors and particulate matter generated by procedures conducted with hazardous chemicals.

To determine ventilation requirements, assess the SDS. Some SDS terminology, as listed below, may indicate a need for special ventilation considerations beyond general exhaust ventilation:

- ***use with adequate ventilation***
- ***avoid vapor inhalation***
- ***use in a fume hood***
- ***provide local exhaust ventilation***

Proper Use of Local Ventilation Systems: Once a local ventilation system is installed in a work area, it must be used properly to be effective. For use of hazardous chemicals warranting local ventilation controls, the following guidelines should be observed:

- Conduct all operations which may generate air contaminants at or above the appropriate PEL or TLV inside a fume hood.
- Keep all apparatus at least 6 inches back from the face of the hood and keep the slots in the hood baffle free of obstruction by apparatus or containers. Large equipment should be elevated at least two inches off the base and sides of the fume hood, to allow for the passage of air underneath the apparatus.
- Do not use the hood as a waste disposal mechanism except for very small quantities of volatile materials.
- Minimize storage of chemicals or apparatus in the hood.
- Keep the hood sash closed at all times except when the hood is in use.
- Minimize foot traffic and other forms of potential air disturbances past the face of the hood.
- Do not have sources of ignition inside the hood when flammable liquids or gases are present.
- Use sash as a safety shield when boiling liquids or conducting an experiment with reactive chemicals.
- Periodically check the air flow in the hood using a continuous monitoring device or another source of visible air flow indicator. If air flow has changed, contact OSHS for an inspection or Physical Plant for repair.
- The system must be checked prior to each use to assure it is operating. Never work with hazardous chemicals if the required ventilation system is not working. Some hoods are not locally controlled and facilities must contacted to have them turned on. Verify they have been turned on before use.
- Hoods should be inspected annually. After an inspection, hoods are passed or failed for use based on the following criteria:
- The face velocity of air being drawn into the hood at maximum sash height is measured quantitatively in feet per minute (fpm) by a thermoAnemometer (a hot wire). One measurement is taken per square foot of face space and averaged. Hoods must have an average face velocity of 60-150 fpm, depending on their design, with 100 fpm being the ideal average face velocity.
- The turbulence of the air is measured qualitatively by releasing smoke from a smoke tube. The smoke must be captured by the hood, with a minimum of turbulence.
- If the exhaust system does not pass the face velocity test and/or has excessive turbulence, it will be posted as "failed" by the inspector. The supervisor must contact

Physical Plant to have the system repaired before hazardous chemicals can be used in the hood.

- If the exhaust system does pass, the inspector will post the date of inspection and will mark the hood to indicate proper sash position for optimum hood performance. The hood sash should be set at this point for procedures which could generate toxic aerosols, gases or vapors. In general, the sash height should be set at a level where the operator is shielded to some degree from any explosions or violent reactions which could occur and where optimum air flow dynamics are achieved. If a fume hood has no markings regarding sash height or inspection dates, please contact the safety office to arrange for an inspection.
- Certain types of local exhaust systems are not designed for the use of hazardous chemicals. If a local exhaust system's capabilities are not fully understood, check the manufacturers' specifications or call OSHS before using hazardous chemicals in the system.
- Proper use of Ductless Ventilation Systems: Ductless, or portable fume hoods, which employ filtration media, may be an option to conventional local exhaust hoods. Contact OSHS for consultation before acquiring any ductless fume hood.

3.5 Minimum PPE Requirements for Support Staff and Visitors

Support staff (e.g., custodians, maintenance workers) and visitors often must enter laboratories to perform routine tasks such as maintenance or take a tour of the lab. These individuals are present in the laboratory, but are not performing work with or directly adjacent to any work with hazardous chemicals. To be present in the laboratory, the minimum PPE requirements include safety glasses, long pants, and closed-toe shoe. 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 PPE Training Requirements

Laboratory Supervisors must ensure that all employees receive 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;
- What PPE is necessary;
- How to properly don, doff, adjust, and wear PPE;
- The limitations of the PPE; and

- The proper care, maintenance, and useful life of PPE.

Each affected employee must demonstrate an understanding of the training provided, and the ability to use the PPE properly, before performing any work requiring the use of PPE. When the supervisor has reason to believe that an affected employee who has already been trained does not have the understanding and skill required (e.g., employee is seen handling hazardous materials without wearing proper PPE), then the supervisor must ensure the employee is retrained.

Chapter 4: Laboratory Equipment

4.1 Equipment, Apparatus, and Instrument Safety

4.1.1 Centrifuges

The following safety guidelines should be followed when operating centrifuges:

<u>Before centrifugation:</u>

- Centrifuges must be properly installed and operated only by trained personnel.
- Centrifuges cannot be placed in the hallway of a building; they must remain inside of the laboratory.
- Train each operator on proper operating procedures, review the user manual.
- Use only rotors compatible with the centrifuge. Check the expiration date for ultracentrifuge rotors.
- Check tubes, bottles, and rotors for cracks and deformities before each use.

4.1.2 Make sure that the rotor, tubes, and spindle are dry and clean.

- Examine O-rings and replace if worn, cracked, or missing.
- Never overfill centrifuge tubes (don't exceed ¾ full).
- Always cap tubes before centrifugation.
- Always balance buckets, tubes, and rotors properly.
- Check that the rotor is seated on the drive correctly, close the lid on the centrifuge, and secure it.
- When using swinging bucket rotors, make sure that all buckets are hooked correctly and move freely.

<u>During centrifugation:</u>

- Close lids at all times during operation. Never open a centrifuge until the rotor has stopped.
- Do not exceed safe rotor speed.
- The operator should not leave the centrifuge until full operating speed is attained and the machine appears to be running safely without vibration.

- Stop the centrifuge immediately if an unusual condition (noise or vibration) begins and check load balances.

After centrifugation:

- Allow the centrifuge to come to a complete stop before opening.
- Wear new pair of outer gloves (or make sure your existing gloves are clean) to remove rotor and samples. Dirt on the gloves may be transferred resulting in an unbalanced situation. (This is for high speed delicate equipment, not the heavy industrial based centrifuges used for example in Civil and Environmental Engineering)
- Check inside of centrifuge for possible spills and leaks, clean centrifuge and rotor thoroughly if necessary.
- Wash hands after removing gloves.

4.1.3 Stirring and Mixing Equipment

Stirring and mixing devices commonly found in laboratories include stirring motors, magnetic stirrers, and shakers. These devices are typically used in lab operations that are performed in a chemical fume hood, and it is important that they be operated in a way that prevents the generation of electrical sparks. Only spark-free induction motors should be used in power stirring and mixing devices or any other rotating equipment used for laboratory operations. Because stirring and mixing devices, especially stirring motors and magnetic stirrers, are often operated for fairly long periods without constant attention, the consequences of stirrer failure, electrical overload or blockage of the motion of the stirring impeller should be considered as electrical sparks could lead to explosions.

4.1.4 Heating Devices

Laboratories commonly use heating devices such as ovens, hot plates, heating mantles, oil baths, salt baths, sand baths, air baths, hot-tube furnaces, hot-air guns, and microwave ovens. Steam heated devices are generally preferred whenever temperatures of 100 °C or less are required because they do not present shock or spark risks and can be left unattended with assurance that their temperature will never exceed 100 °C. Ensure the supply of water for steam generation is sufficient prior to leaving the reaction for any extended period of time.

A number of general precautions need to be taken when working with heating devices in the laboratory. When working with heating devices, consider the following:

- The actual heating element in any laboratory heating device should be enclosed in such a fashion as to prevent a laboratory worker or any metallic conductor from accidentally touching the wire carrying the electric current.
- If a heating device becomes so worn or damaged that its heating element is exposed, the device should be either discarded or repaired before it is used again.
- The external cases of all variable autotransformers have perforations for cooling by ventilation and, therefore, should be located where water and other chemicals cannot be spilled onto them and where they will not be exposed to flammable liquids or vapors.
- Fail-safe devices can prevent fires or explosions that may arise if the temperature of a reaction increases significantly because of a change in line voltage, the accidental loss of reaction solvent, or loss of cooling. Some devices will turn off the electric power if the temperature of the heating device exceeds some preset limit or if the flow of cooling water through a condenser is stopped owing to the loss of water pressure or loosening of the water supply hose to a condenser.

4.1.5 Distillation and Solvent Purification Systems

The process of thermal solvent distillation is inherently dangerous. If not handled properly, fire, explosion, and/or personnel exposure can result. A few common chemicals distilled in laboratories include tetrahydrofuran, methylene chloride, diethyl ether, toluene, dimethylformamide, benzene, and hexanes. The guidelines below should be followed while thermal distillation of organic solvents is conducted in the lab:

- The thermal solvent distillation system should be installed inside of a chemical fume hood if possible.
- Ensure that all heat generating equipment has a shut-off device installed.
- Ensure that all water connections on the condenser are clamped securely.
- Inspect all glassware for defects before setting them up in the experiment.
- Keep all air and water-sensitive drying agents under inert atmosphere as shown below with a set of distillation stills. Make consistent efforts to not store or use other flammable or hazardous chemicals inside the fume hood where distillation is taking place.

4.1.6 Laboratory Glassware

Broken laboratory glassware is dangerous. Glassware-related injuries ranging from small cuts to multiple stitches and eye damage are common to lab workers. In order to reduce the risk of accidents, the following guidelines should be followed:

- Temperature changes can shatter any laboratory glassware. Never flash-cool glassware with cold water, especially after autoclaving or exposure to any high temperatures.
- Only round-bottomed or thick-walled (e.g., Pyrex) evacuated reaction vessels specifically designed for operations at reduced pressure should be used.
- Inspect glassware for any small imperfections before using. Sometimes a hairline crack may be present and that glassware should then be discarded. Tap the glassware with a pen and listen to the tone to tell if there is a defect. A ringing tone indicates the glassware is fine, while a dull "thud" indicates there is a flaw present.
- Don't keep cracked glassware. If the bottom of a graduated cylinder is chipped or broken, properly dispose of it.
- Always wear appropriate PPE when working with glassware and varying temperatures. Always wear safety glasses.

4.1.7 High Pressure Systems

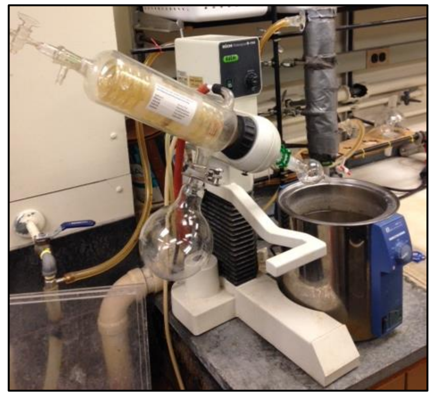
Working with high pressure systems in a laboratory can result in over-pressurization, explosion, and the possible hazards of flying glass, chemical exposure, and fire. All high pressure systems must be set up and operated with careful consideration of potential risks. The following procedures should be followed when working with high pressure systems in the laboratory:

- High-pressure operations should be performed only in pressure vessels appropriately selected for the operation, properly labeled and installed, and protected by pressure-relief control devices.
- Vessels, connecting hoses, and any apparatus must be strong enough to withstand the stresses encountered at the intended operating temperatures and pressures and must not corrode or otherwise react when in contact with the materials it contains.
- All pressure equipment should be visually inspected before each use.
- Must be approved by Supervisor before use.

4.1.8 Vacuum Systems

Vacuum work can result in an implosion and the possible hazards of flying glass, splattering chemicals, and fire. All vacuum operations must be set up and operated with careful consideration of the potential risks. The following guidelines should be followed when using vacuum apparatus in the laboratory:

- Do not allow water, solvents, or corrosive gases to be drawn into vacuum systems. Protect pumps with cold traps and vent their exhaust into an exhaust hood.
- Assemble vacuum apparatus in a manner that avoids strain to the neck of the flask.
- Avoid increasing the gas pressure beyond 7 psi inside glass apparatuses used on vacuum lines since this can result in explosions. Glassware designed for vacuum or pressure operations is rated for specific pressure limits. Some sort of pressure control system should be adopted to release the build-up of pressure such as a mercury bubbler.



- Place vacuum apparatus in such a way that the possibility of being accidentally hit is minimized. If necessary, place transparent plastic around it to prevent injury from flying glass in case of an explosion.
- When using a rotary evaporator, the glass components of the rotary evaporator should be made of Pyrex or similar glass. Glass vessels should be completely enclosed in a shield to guard against flying glass should the components implode. Increase in rotation speed and application of vacuum to the flask whose solvent is to be evaporated should be gradual.
- When using a vacuum source, it is important to place a trap between the experimental apparatus and the vacuum source. The vacuum trap protects the pump and the piping from the potentially damaging effects of the material, protects people who must work on the vacuum lines or system, and prevents vapors and related odors from being emitted back into the laboratory or system exhaust. The following vacuum trapping guidelines should be followed:
    - ❖ Make sure the trap or flask is properly clamped and secured.
    - ❖ Make sure the vacuum hose is connected to the vacuum line, not the gas line to release the vacuum.
    - ❖ To prevent contamination, all lines leading from experimental apparatus to the vacuum source should be equipped with filtration or other trapping device as appropriate.
    - ❖ For particulates, use filtration capable of efficiently trapping the particles in the size range being generated.
    - ❖ For most aqueous or non-volatile liquids, a filter flask at room temperature is adequate to prevent liquids from getting to the vacuum source.
    - ❖ For solvents and other volatile liquids, use a cold trap of sufficient size and cold enough to condense vapors generated, followed by a filter flask capable of collecting fluid that could be aspirated out of the cold trap.
    - ❖ For highly reactive, corrosive, or toxic gases, use a sorbent canister or scrubbing device capable of trapping the gas.

Chapter 5: Safety Equipment

5.1 Laboratory Safety Controls

Laboratory safety controls include engineering controls, administrative controls, and PPE. Elements of these three categories should be used in a layered approach to minimize employee exposure to hazardous chemicals. 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, administrative controls, engineering controls, and PPE must be used to provide the necessary protection. The laboratory employee's responsibility is to follow administrative controls, use engineering controls, and wear PPE correctly and effectively.

5.2 Routes of Exposure

There are four primary routes of exposure in which hazardous substances can enter the body: inhalation, absorption, ingestion, and injection. Of these, the most likely routes of exposure in the laboratory are by inhalation and/or skin absorption. Many hazardous chemicals may affect people through more than one of these exposure modes, so it is critical that protective measures are in place for each of these exposure routes.

5.3 Engineering Controls and Safety Equipment

Exposure to hazardous materials must be controlled to the greatest extent feasible by use of engineering controls. Engineering controls to reduce or eliminate exposures to hazardous chemicals include:

- Substitution with less hazardous equipment, chemicals, or processes (e.g., safety cans for glass bottles);
- Isolation of the operator or the process (e.g., use of a glove box when handling air- or water-sensitive chemicals); and
- Use of forced ventilation systems (e.g., chemical fume hood, biological safety cabinet).

5.3.1 Chemical Fume Hoods

A chemical fume hood is a type of local ventilation installation that is designed to limit exposure to hazardous or toxic fumes, vapors, or dusts. To determine if a chemical is required to be used inside of a chemical fume hood, first check the SDS for that chemical. Statements found in Section 3 on a SDS such as “do not breathe dust, fumes, or vapors” or “toxic by inhalation” indicate the need for ventilation. As a best practice, always use a chemical fume hood for all work involving the handling of open chemicals (e.g., preparing solutions) whenever possible. The following guidelines must be followed at all times:

- Chemical fume hoods must be marked to indicate the proper sash position for optimum hood performance as illustrated in Figure 5.1. The chemical fume hood sash should be positioned at this height whenever working with hazardous chemicals that could generate toxic aerosols, gases, or vapors. In general, the sash height should be set at a level where the operator is shielded to some degree from any splashes, explosions, or other violent reactions which could occur and where optimum air flow dynamics are achieved. Most chemical fume hoods are not intended to be used with the sash fully open. The sash should only be fully opened to add or remove equipment from the chemical fume hood.

Figure 5.1 – Chemical Fume Hood Sash Approved Working Height on right Hood

- Chemical fume hoods should be equipped with a continuous reading monitoring device to indicate adequacy of flow. All lab employees must know how to read and interpret this gauge and check that the chemical fume hood is operating properly before using hazardous chemicals in the fume hood. There are many different types of chemical fume hoods on campus, so it is important that the lab employee understands the specific functions of each chemical fume hood used. If a monitoring device is not available, lab employees should know how to conduct tests to obtain a qualitative estimate of the flow rate, see 5.3.2.

- Only apparatus and chemicals essential to the specific procedure or process should be placed in the chemical fume hood. Extraneous materials from previous experiments should be removed and stored in a safe location outside the chemical fume hood.
- Chemical fume hoods used for experimental work should not be used for chemical or material storage. Chemical fume hoods used for chemical storage should be dedicated to chemical storage. No experimental work should be conducted in storage chemical fume hoods.
- All chemical containers used in chemical fume hoods, including secondary containers (e.g., beakers, flasks, reaction vessels, vials, etc.) must be labeled. If is not practical to label a secondary container that is in process (e.g., reaction vessel, flask), a temporary label can be used. Reaction vessels in chemical fume hoods must be labeled as well. If labeling the vessel itself is not practical, the hood sash or wall may be labeled as illustrated in Figure 5.2.

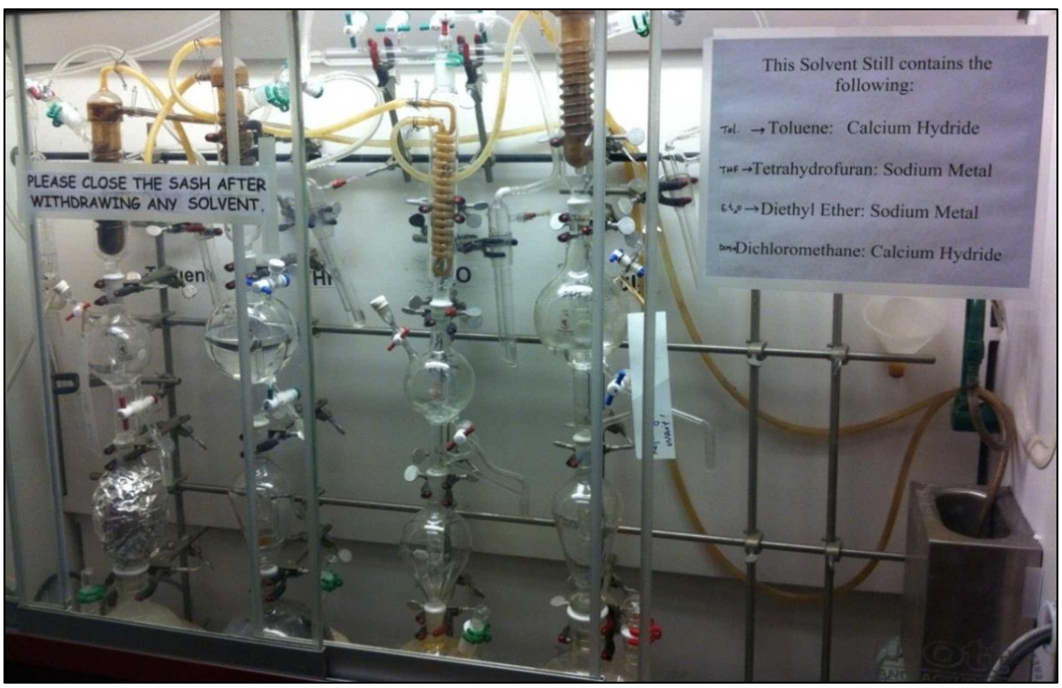


Figure 5.2 – Alternative Labeling of Chemical Fume Hood Reaction Vessels

- Do not allow the vents or air flow baffles to be blocked.
- Never put your head inside of an operating chemical fume hood.

- All chemical fume hoods should be routinely checked for airflow by measuring the face velocity, which should be between 70 – 125 feet per minute. OSHS conducts face velocity readings on a routine basis and records this information on the hood label. Contact OSHS with questions regarding chemical fume hoods 906-487-2118.

5.3.2 How to Verify Adequate Laboratory Chemical Hood Ventilation

Materials

200 g (approximately 250 ml) of dry ice pellets (5 to 10-mm diam)

Shallow bowl, approximately 3-L volume

1 L water at 43 °C (mix hot and cold water as needed to obtain the target temperature)

Thermometer

Procedure

1. Open the **chemical** fume hood sash to simulate actual operation. Position laboratory equipment as close as possible to where it will be used.
2. Place the shallow bowl approximately 15 cm into the **chemical** fume hood and in the center of the sash opening.
3. Add 1 L of the warm water to the bowl.
4. Add the dry ice pellets to the water.
5. After approximately 5 s, observe the vapor flowing from the bowl.
6. Repeat the observation while a colleague walks past or moves around the **chemical** fume hood to simulate actual operation.
7. If vapors are observed escaping the **chemical** fume hood face, the result is a fail; none escaping is a pass.

In the event of a failure or if there is any concern about proper operation, contact appropriate personnel and take corrective action. Adjustment of the sash opening and the baffles and relocation of equipment in the **chemical** fume hood should be considered.

NOTE: In addition, airflow should be measured on an annual basis.

5.3.3 Glove Boxes

A glove box, as illustrated in Figure 5.3, is a sealed container that is designed to allow one to handle material in a defined atmosphere (typically inert). Glove boxes can be used to protect sensitive items inside or the user on the outside, or both. The following recommendations should be followed by all personnel using a glove box:

Figure 5.3 – Glove Box

- All personnel must receive documented training from the Laboratory Supervisor or delegate before any work in a glove box occurs. All trained personnel must understand the design features and limitations of a glove box before use. The 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, atmospheric controls (e.g., controlling oxygen concentrations and moisture), etc.
- Prior to use, a visual glove inspection must be performed. Changing of a glove should be documented (date, manufacturer, model of glove, and person performing change). Gloves should not be used until they fail; they should be changed according to the glove box manufacturer’s recommendations or whenever necessary.

- Plugging ports that are never or infrequently used is recommended. 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 used under the glove box gloves to protect from possible contamination.
- The glove box pressure must be checked every day, before use and immediately after gloves are changed. The pressure check must be documented.
- 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.

5.3.4 Laminar Flow Clean Benches

A laminar flow clean bench, as shown in Figure 5.4, is an enclosed bench designed to prevent contamination of semiconductor wafers, samples, or any particle sensitive device. Air is drawn through a filter and blown in a very smooth, laminar flow towards the user. Therefore it is critical that absolutely no hazardous chemicals, infectious and/or radioactive materials ever be used in a laminar flow clean bench, as the vapors are blown directly towards the user. Applications that involve the use of chemicals should be conducted in chemical fume hoods.

Figure 5.4 – Laminar Flow Clean Bench

5.3.5 Biological Safety Cabinets

A biological (or biosafety) safety cabinet, as shown in Figure 5.5, is an enclosed, ventilated laboratory workspace for safely working with materials contaminated with (or potentially contaminated with) infectious materials. The primary purpose of a biosafety cabinet is to serve as a means to protect the laboratory worker and the surrounding environment from pathogens. All exhaust air is filtered as it exits the biosafety cabinet, removing harmful particles. Biological safety cabinets are not designed to be used with chemical applications so the use of chemicals should be kept to a minimum. Applications that involve the use of chemicals should be conducted in chemical fume hoods.

Figure 5.5 – Biological Safety Cabinet

5.3.6 Safety Showers and Eyewash Stations

All laboratories using hazardous chemicals must have immediate access to safety showers and eye wash stations. Safety showers must have a minimum clearance of 24 inches from the centerline of the spray pattern in all directions at all times. Identify the safety station with a highly visible sign and maintain an unobstructed path to it. All lab personnel must be aware of the location and know how to properly use the safety shower and eyewash stations. If lab personnel are exposed to a hazardous chemical, they should dial 911 (or someone else in the lab that is not exposed should dial 911) and use the safety shower and/or eye wash unit for 15 minutes or until emergency response have personnel arrive and begin treatment. If an uninjured individual is present, this person should assist with the decontamination of the affected individual. In the event of a fire or chemical spill, the affected person should immediately remove clothing and then go to the shower or remove the clothing while under the shower.

All eyewash stations must be flushed (see Section 3.4.8) by laboratory personnel on a weekly basis to ensure proper working order. This will keep the system free of sediment and prevent bacterial growth from reducing performance. OSHS performs annual inspections of all campus safety shower and eyewash stations. This inspection evaluates the basic mechanical functionality of each station. Any deficiencies are repaired either by OSHS staff or by Michigan Tech Physical Facilities maintenance staff. If the safety shower or eye wash unit becomes inoperable, notify your building attendant immediately.

5.3.7 Fire Extinguishers

All fire extinguishers should be mounted on a wall in an area free of clutter. Each fire extinguisher on campus is inspected on an annual basis by OSHS. All laboratory personnel should be familiar with the location, use, and classification of the extinguishers in their laboratory. Ensure that the fire extinguisher being used is appropriate for the type of material on fire before attempting to extinguish any fire.

A major hazard one can face in the chemical laboratory is that of fires. Please familiarize yourself with the location and types of fire extinguishers and fire alarm pull stations. In the event of a fire, do not put yourself in danger to extinguish the fire.

If there is a major fire, pull the fire alarm located usually located near exits. This will alert campus security who will then see which building and which floor the alarm went off on. They will then attempt to contact someone in the building and also send someone over to assess the damage. If it is a serious fire, they will then at this stage call the fire department. In light of this and after you have reached safety, i.e., outside the building (or in the process of reaching safety), call 911 and request the immediate dispatch of an emergency response, i.e., the fire department or ambulance.

The 911 phone call is answered by a dispatch service located in Neganee MI which dispatches emergency response services for the entire UP. Therefore, call 911 after you have reached safety.

If you dial 906-487-2216 this is a nonemergency phone. This can be used in case of locked doors or if you see someone behaving in a suspicious manner in the building. Do not dial this number for fires. Use 911.

If it is a small (i.e., a fire contained to a small garbage bin in size or one that you cannot extinguish within 5 seconds using a fire extinguisher) fire you feel you can control, do not pull the fire alarm. Extinguish the fire and be sure to then fill out the safety report. If you extinguish the fire, it is entirely possible that the fire extinguishing material will be distributed all over the lab and may destroy sensitive equipment contained in the lab. Your department and the departmental CHO may be able to provide you with more specific instructions regarding fires. The Chemistry Department sponsors fire training every two or so years. This consists of a trained expert giving a lecture on safety and the opportunity to put out a simulated fire. If you do extinguish the fire, you must still call 911 to report the incident since it is possible depending on the nature of the incident, flare ups may occur.

Implement the PASS method when putting out a fire:

STEP 1: PULL. Pull the pin. This will also break the tamper seal.
STEP 2: AIM. Aim low, pointing the extinguisher nozzle (or its horn or hose) at the base of the fire. Note: Do not touch the plastic discharge horn on CO2 extinguishers; it could get very cold and may damage skin.
STEP 3: SQUEEZE. Squeeze the handle to release the extinguishing agent.
STEP 4: SWEEP. Sweep from side to side at the base of the fire until it appears to be out. Watch the area. If the fire re-ignites, repeat steps 2 through 4.

If you hear the fire alarm sounding, leave the building immediately. Do not return to your office and close the door. Do not use elevators and assist handicapped persons to leave the building if possible. Building marshalls (each department or building should have person(s) to satisfy the role of a building marshall(s)) need to check the building and secure the perimeter for access by the emergency response services. These Building Marshalls should also indicate when it is safe to re-enter the building.

It is important to recognize the various types of fires and methods to extinguish them.

Class A Fires: Combustible solids, paper, rubber, plastics. Combustion can result in release of toxic gases.

The most convenient method is to use water. Can also use dry chemical extinguisher, and CO2 but these result in spreading of the ash over a large area.

Class B Fires: Solvent fires.

These pose the greatest risk, especially in organic chemistry and solvent extraction labs. A measure of the flammability of the liquid is given by "flash point" which is defined as the temperature at which a liquid gives rise to ignitable vapors. A liquid with a flash point < 15 °C is regarded as dangerously flammable.

Flash Point of Common Solvents:

Pentane	– 40 °C	Ethyl acetate	– 4.4 °C
Diethyl ether	– 45 °C	Toluene	4 °C
Carbon disulfide	– 30 °C	Acetonitrile	2 °C
Hexane	– 7 °C	Methanol	11 °C
Acetone	– 18 °C	1,4-dioxane	12 °C
isopropyl alcohol	12 °C	methylene chloride	none
Tetrahydrofuran	– 21 °C	Ethanol	12 °C

The **flash point** of a material is defined as the temperature at which an ignition source 1 cm from the surface of the liquid will cause ignition. The standard method is defined by ASTM and most flash points are measured in a "closed cup" flashpoint tester. Discrepancies/disagreements are found in the literature for some substances, but the values are usually fairly close.

Dichloromethane has upper and lower explosion limits! While generally regarded as nonflammable, and although no flashpoint can be measured by the standard method, dichloromethane (methylene chloride) has known explosive limits in air mixtures at 100°C and above, and is known by firefighters to give flammable/explosive mixtures with air if there is a high energy ignition source or an enriched oxygen content.

Carbon disulfide has a very low auto ignition point of 100 °C. The vapors can ignite up on contact with a hot water bath !! Avoid use of CS_2! If the fire is contained in a beaker or a small vessel, it can often be extinguished by covering the vessel with a wire gauze or addition of sand or dry ice. If the fire is in a larger vessel or has spread, dry ice is very effective. Dry chemical extinguisher is also useful. CO2 extinguishers produce a jet of foam which can result in overturning of the vessel and sometimes aid in spreading of the fire! Water should not be used to extinguish solvent fires. If you are handling flammable materials it pays to have a container of sand to quickly throw on top of the fire.

Class C Fires: Electrical equipment: Never use water for these fires even if the main is turned off.

Many equipment store charge essentially in capacitors. If power cannot be turned off, dry chemical or inert gas must be used.

Class D Fires: Metal (K, Na, Mg, Li, Al) and Metal hydrides (NaH, KH, $LiAlH_4$, etc)

These fires can not be extinguished using water, CO2 or volatile hydrocarbons. Inert powder (sand or talc) must be used. It is best to use Metal X extinguishers.

Some Common Fire Sources in the Lab:

A. Open Flames: Open flames should almost never be used in the lab, especially in the organic chemistry lab. If a Bunsen burner is used, it should be turned off when not in use.

B. Sparks: Volatile and flammable solvents should not stored in open containers nears sources of sparks which include vacuum pumps, drying ovens, thermostats etc.

C. Oxygen cylinders: A leaking oxygen cylinder can lead to an increase in oxygen concentration in the atmosphere which will cause a dangerous fire if a flammable substance and an ignition source are present. All compressed oxygen cylinders should be checked for leaks periodically.
D. Sodium residues: Sodium residue should never be destroyed by addition of water: even if there is only very small quantities. Large quantities are best destroyed by slow addition of 2-propanol to the sodium contained in a round-bottomed flask equipped with a water cooled reflux condenser. Smaller quantities (1-2 g) can be destroyed by very cautious addition of methanol using a similar set-up.

E. Organometallics: These pose a serious fire risk. They must always be handled in an inert atmosphere.

Table 5.1 summarizes the fire classification system, which should be used to determine the most suitable fire extinguisher for a particular area. Recall that laboratory personnel are not required to extinguish fires that occur in their work areas and should not attempt to do so unless:

- It is a small, contained fire that can be quickly and safely extinguished (e.g., small trash can sized fire);
- Appropriate training has been received and the individual feels the fire can be safely extinguished; and
- It is necessary to extinguish a fire in order to exit an area (e.g., fire is blocking an exit).

Remember that if a fire occurs in the laboratory and is extinguished by lab personnel, the Fire Department must still be contacted immediately by dialing 911.

Table 5.1 – Fire Classifications System

Classification	Fire Type
Class A	Ordinary fire (wood and paper)
Class B	Flammable liquids and gases
Class C	Electric fire
Class D	Combustible metal fire
Class K	Kitchen fire

5.3.8 Fire Doors

Many laboratories may contain fire doors as part of the building design. These doors are an important element of the fire containment system and should remain closed unless they are on a magnetic self-closure or other automated self-closing system. Never disable an automatic door closure device (e.g., placing a block under the door). If you are unsure of whether a door is fire rated or not, contact OSHS at 906-487-2118 and a staff member will come to the area to evaluate the specific door in question.

Chapter 6: Chemical Management

6.1 Chemical Storage Requirements

Proper storage of chemicals is an essential component to a laboratory safety program. Improper chemical storage practices can cause undesired chemical reactions, which may form hazardous products that can lead to employee exposure or possibly fires and property damage. All lab employees should carefully read each chemical's SDS and container label before deciding how to store a chemical, as these will often indicate any special storage requirements that may be necessary. The following subsections describe chemical storage requirements in more detail.

6.1.1 General Chemical Storage

The following general chemical storage guidelines must be followed in all laboratories:

- Each chemical in the laboratory must be stored in a specific location and returned there after each use. Acceptable chemical storage locations may include flammable cabinets, corrosive cabinets, laboratory shelves, or appropriate laboratory refrigerators or freezers.
- Chemical containers must be in good condition and appropriate for the chemical that they contain and be free from exterior contamination.
- Fume hoods should not be used as permanent chemical storage areas, unless designated as such. Not only does this create potentially unsafe conditions by having extraneous chemicals stored near chemical reactions and processes, excess chemical bottles in the hood may also seriously impair the ventilating capacity of the hood. Only chemicals being used in the process or experiment being conducted in the hood are allowed to be stored in the hood and should be removed when the process or experiment is complete. The Department of Civil and Environmental Engineering restricts storage to chemical storage rooms and only permits lab storage for 4-6 weeks. Other departments on campus may have more regulations regarding chemical storage.
- Chemicals should not be permanently stored on bench tops. Avoid storing any chemical containers on the floor. Under no circumstance should chemical containers, or anything else, be stored in aisle ways, corridors, or in front of doors.
- Hazardous liquids should not be stored on shelves above eye-level unless there is a SOP detailing safe handling procedures.
- Chemicals should be stored at an appropriate temperature and humidity level and never be stored in direct sunlight.

- Periodic cleanouts of expired or unneeded chemicals should be conducted to minimize the volume of hazardous chemicals stored in the laboratory.
- Always follow the chemical manufacturer's storage instructions, if provided.

6.1.2 Flammable Liquids Storage

Flammable liquids include any liquid with a flash point no greater than 93 °C (200 °F). The following guidelines for storing flammable liquids must be followed in all laboratories:

- Flammable and combustible liquids should be stored in flammable storage cabinets, as shown in Figure 6.1, whenever possible. No more than 10 gallons of flammable liquid is permitted to be stored outside of a flammable storage cabinet in research laboratories of 700-1500 sq ft unless it is stored in a flammable safety can equipped with a spring-loaded lid and an internal screen as shown in Figure 6.2.
- Domestic refrigerators or freezers must never be used to store flammable liquids. Flammable liquids can only be stored in refrigerators or freezers that are designed for flammable materials (most refrigerators are not intended for flammable storage).
- Flammable liquids must be stored in well-ventilated areas free from ignition sources.
- Some organic solvents (e.g., diethyl ether) have a shelf-life and can form organic peroxides over time while in storage. These "peroxide formers" must be dated when received from the chemical manufacturer and disposed of once expired. If any time-sensitive chemicals are found to be past the manufacturer's expiration date, they must be submitted to OSHS for hazardous waste disposal immediately. See Section 19.1.7 for a list of commonly found organic solvents that potentially form organic peroxides.

Figure 6.1 – Flammable Storage Cabinet

Figure 6.2 – Flammable Safety Can

6.1.3 Compressed Gases Storage

Compressed gases are defined as gases that are contained in a receptacle at a pressure not less than 280 kPA at 20 °C or as a refrigerated liquid. The following guidelines for storing compressed gases must be followed in all laboratories:

- Compressed gas cylinders (cylinders) must be stored in a secure, well ventilated location, and in an upright position at all times.
- All cylinders should be handled as if full and should never be completely emptied.
- Cylinders that are not in use (meaning that the cap is on) must be secured and have the safety cap. Multiple cylinders may be secured together (gang-chained), only if they are capped (not in use). Only capped cylinders can be secured with a single restraining device (gang chained) as shown in Figure 6.3.
- Cylinders that are in use, meaning there is a regulator attached, must be individually secured by a chain or strap as shown in Figure 6.4. Cylinder valves and regulators should be protected from impact or damage.

Figure 6.3 – Not In-Use Cylinders

Figure 6.4 – In-Use Cylinder

6.1.4 Reactive Materials Storage

Reactive materials include explosives, pyrophorics, self-heating and self-reacting compounds, and water-reactives. Many reactive materials are also toxic and are dissolved or immersed in a flammable solvent (e.g., lithium alkyl compounds dissolved in diethyl ether, sodium metal immersed in mineral oil). Other common hazards often associated with reactive chemicals include corrosivity, teratogenicity, or organic peroxide formation. The following guidelines for storing reactive materials must be followed in all laboratories:

- The amount of reactive materials stored in the lab must be kept to a minimum. Any expired or unnecessary reactive materials must be properly disposed of as hazardous waste.
- All reactive materials must be clearly labeled with the original manufacturer's label, which should have the chemical name, hazard labels, and pictograms. The label should not be defaced in any way.
- All reactive materials should be placed into secondary containment as a best management practice.
- Suitable storage locations for reactive materials include inert gas-filled desiccators or glove boxes, flammable storage cabinets that do not contain aqueous or other incompatible chemicals, or intrinsically safe refrigerators or freezers that also do not contain aqueous or other incompatible chemicals. If possible, store all reactive chemicals in a small flammable cabinet dedicated only for reactives. Signs should be posted to indicate their presence and unique hazards as shown in Figure 6.5.

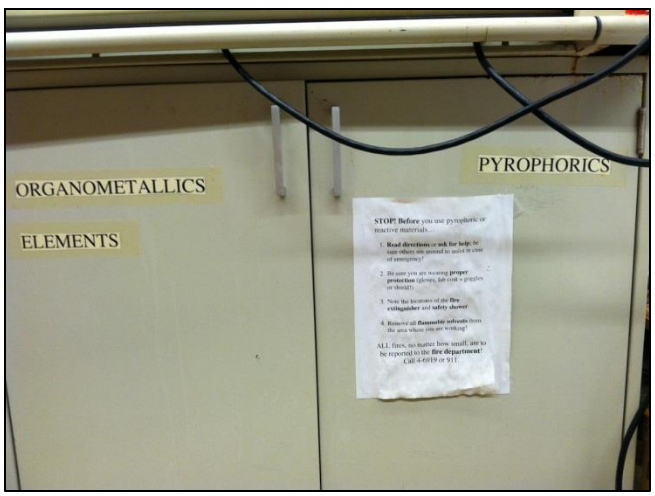


Figure 6.5 – Reactive Chemicals Storage

- Many reactive materials are water and/or air reactive and can spontaneously ignite on contact with air and/or water. Therefore, reactives must be handled under an inert atmosphere and in such a way that rigorously excludes air and moisture.
- If reactive materials are received in a specially designed shipping, storage, or dispensing container (such as the Aldrich Sure-Seal packaging system), ensure that the integrity of that container is maintained. Ensure that sufficient protective solvent, oil, kerosene, or inert gas remains in the container while reactive materials are stored.

6.1.5 Acutely Toxic Materials Storage

Acutely toxic materials are defined as substances that may be fatal or cause damage to target organs as the result of a single exposure or exposures of short duration. The following guidelines for storing acutely toxic materials must be followed in all laboratories:

- Suitable storage locations for acutely toxic materials include desiccators, glove boxes, flammable storage cabinets that do not contain incompatible chemicals (primarily strong acids), or non-domestic refrigerators or freezers. These locations should be clearly posted.
- Acutely toxic materials should be stored in secondary containment at all times as a best management practice.
- If possible, store all acutely toxic materials in a cabinet dedicated only for acutely toxic materials. Signs should be posted to indicate their presence and unique hazards.
- The amount of acutely toxic material stored in the lab should be kept at a minimum. Any expired or unnecessary materials must be properly disposed of as hazardous waste.
- All acutely toxic materials should be clearly labeled with the original manufacturer's label, which should have the chemical name, hazard labels, and pictograms. The label should not be defaced in any way.

6.1.6 Corrosive Materials Storage

Corrosive materials are defined as substances that cause destruction of living tissue by chemical corrosion at the site of contact and can be either acidic or basic (caustic). The best storage method for corrosive materials is inside of a corrosive storage cabinet or lab cabinet where acids and bases are segregated at all times. Acids must also be segregated from chemicals where a toxic gas would be generated upon contact with an acid (e.g., reactive cyanide compounds). Organic acids (e.g., acetic acid, formic acid) must be stored away from oxidizing acids (e.g., nitric acid, perchloric acid), as these types of acids are incompatible with each other. Segregation can be achieved either by physical distance (preferred method) or by secondary containment as shown in Figure 6.6.

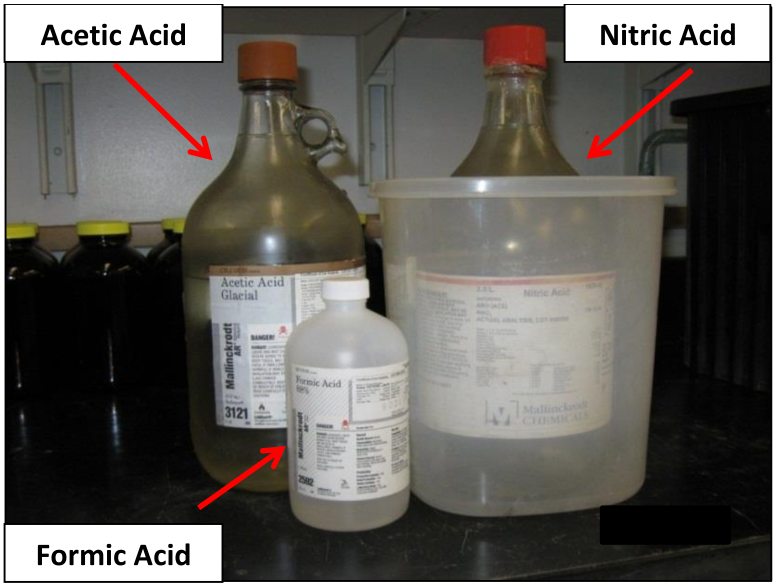


Figure 6.6 – Segregation Using Secondary Containment

6.1.7 Oxidizers and Organic Peroxide Storage

Oxidizing materials are defined as substances which, while in itself are not necessarily combustible, may generally by yielding oxygen, cause, or contribute to the combustion of other material. An organic peroxide is an organic substance which contains the bivalent -O-O- structure and may be considered a derivative of hydrogen peroxide, where one or both of the hydrogen atoms have been replaced by organic radicals. The following guidelines for storing oxidizers and organic peroxides must be followed in all laboratories:

- Oxidizers (e.g., hydrogen peroxide, sodium nitrate) and organic peroxides (e.g., methyl ethyl ketone peroxide, benzoyl peroxide) must be stored in a cool, dry location and kept away from combustible materials such as wood, pressboard, paper, and organic chemicals (e.g., organic solvents and organic acids).
- If possible, store all strong oxidizing agents in a chemical cabinet dedicated only for oxidizers.
- The amount of oxidizers and organic peroxides stored in the lab should be kept at a minimum.
- All material must be clearly labeled; the original manufacturer's label with the chemical name, hazard labels, and pictograms should not be defaced or covered.

6.1.8 Refrigerators and Freezers Chemical Storage

A number of general precautions need to be taken when storing chemicals in refrigerators and/or freezers in the laboratory. When working with freezers or refrigerators, the following procedures must be followed:

- Domestic refrigerators or freezers must never be used to store flammable liquids. Flammable liquids are only allowed to be stored in refrigerators or freezers that are designed for flammable materials.
- Lab refrigerators or freezers must never be used to store food or beverages for consumption. Lab refrigerators/freezers should be posted with a sign that states “No Food or Drink”.
- All chemicals stored in a refrigerator or freezer must be labeled.
- Ensure that the chemicals stored in a refrigerator or freezer are compatible with each other.
- There must not be any open chemicals in a refrigerator or freezer. All containers must be completely sealed or capped and safely stored.
- Chemicals should be allowed to warm to room temperature before sealing to prevent pressure buildup.
- Shelves in refrigerators or freezers should all have suitable plastic trays for secondary containment in the refrigerator and freezer compartments. If plastic trays are not available, liquid chemicals should be placed in secondary containers to contain spills.
- Remember that power outages and technology failures can cause internal temperatures to rise, which can impact chemical contents. Be aware of unusual odors, vapors, etc., when opening the refrigerator or freezer.
- An inventory should be posted on the refrigerator door.
- Chemical refrigerator or freezers should be located away from laboratory exits.
- Refrigerators and freezers should be cleaned-out and manually defrosted as necessary.
- When defrosting a freezer, consideration should be taken regarding potential chemical contamination of the water. If the water draining from a defrosted refrigerator is suspected to chemically contaminated, contact OSHS at 906-487-2118 for further assistance.

6.2 Cryogenic Liquids Safety

A cryogenic liquid is defined as a liquid with a normal boiling point below -150 °C (-240 °F). The most common cryogenic liquid used in a laboratory setting is liquid nitrogen. By definition, all cryogenic liquids are extremely cold. Cryogenic liquids and their vapors can rapidly freeze human tissue and can also pose an asphyxiation hazard if handled in confined spaces. The following precautions should be taken when handling cryogenic liquids:

- Use and store cryogenic liquids in well ventilated areas only, i.e, rooms that have either continuously operating fume hoods or vents to remove accidental release of large volumes of gas. Ventilation here does not refer to fans which merely circulate the air inside a room.
- Wear appropriate PPE while handling cryogenic liquids. Proper PPE for handling cryogenic liquids includes chemical splash goggles, a face shield, cryogenic-safe gloves, long sleeves, long pants, and closed-toe shoes.
- Cryogenic liquids will vent (boil off) from their storage containers as part of normal operation. Containers are typically of a vacuum jacketed design to minimize heat loss. Excessive venting and/or an isolated ice build-up on the vessel walls may indicate a fault in the vessel's integrity or a problem in the process line. A leaky container should be removed from service and taken to a safe, well-ventilated area immediately.
- All systems components piping, valves, etc., must be designed to withstand extreme temperatures.
- Pressure relief valves must be in place in systems and piping to prevent pressure build up. Any system section that could be valved off while containing cryogenic liquid must have a pressure relief valve. The pressure relief valve relief ports must be positioned to face toward a safe location.
- Transfer operations involving open cryogenic containers, such as Dewars must be done slowly, while wearing all required PPE. Care must be taken not to contact non-insulated pipes and system components.
- Open transfers will be allowed only in well-ventilated areas.
- Do not use a funnel while transferring cryogenic liquids.
- Use tongs or other similar devices to immerse and remove objects from cryogenic liquids; never immerse any part of your body into a cryogenic liquid.

6.3 Nanoparticle Safety

The American Society of Testing and Materials (ASTM) Committee on Nanotechnology has defined a nanoparticle as a particle with lengths in two or three dimensions between 1 and 100

nanometers (nm). Nanoparticles can be composed of many different base materials and may be of different shapes including: nanotubes, nanowires, and crystalline structures such as fullerenes and quantum dots. Nanoparticles present a unique challenge from an occupational health perspective as there is a limited amount of toxicological data currently available for review. However, some studies have shown that existing exposure control technologies have been effective in reducing exposure to nanoparticles. Refer to the Nanoparticle Safety and Health Guidelines at the National Institutes of Health for detailed procedures and guidance regarding the safe handling of nanoparticle.
(www.ors.od.nih.gov/sr/dohs/Documents/Nanotechnology%20Safety%20and%20Health%20Program.pdf)

6.4 Sharps Handling Safety

Sharps are defined as items capable of puncturing, cutting, or abrading the skin such as glass or plastic pipettes, broken glass, test tubes, petri dishes, razor blades, needles, and syringes with needles. Sharps are often contaminated with hazardous chemicals and/or infectious agents, so multiple hazards are often encountered. Employees that routinely work with sharps must be aware of the risk of being punctured or lacerated. It is important for these employees to take precautions and properly handle sharps in order to prevent injury and potential disease transmission. These employees should use appropriate PPE (e.g., puncture-resistant gloves), tools, barrier protection, sharps waste containers, and engineering controls to protect themselves. At Michigan Tech, “Sharps” fall under the domain of the Biological Safety officer available at 906-487-2131.

Chapter 7: Housekeeping

Housekeeping is an important element to a laboratory safety program. A clean, well-maintained lab improves safety by preventing accidents and can enhance the overall efficiency of the work being performed.

7.1 Essential Guidelines

The following laboratory housekeeping guidelines should be followed:

1. All doorways and hallways must be free of obstructions to allow clear visibility and exit. The laboratory should be uncluttered without excessive storage of materials that could cause or support a fire (e.g., paper, cardboard, flammable liquids, etc.).
2. Fire protection sprinklers must be unobstructed; a minimum of 18 inches of clearance is required below the sprinkler head. If the laboratory does not have fire protection sprinklers, there must be a minimum of 24 inches of clearance below the ceiling.
3. Do not store items that block fire extinguishers or eyewash and safety shower stations.
4. Do not store items in front of electrical boxes/panels in the lab.
5. A routine cleaning schedule should be established. All work surfaces should be kept as clean as possible. All potentially chemically contaminated work area surfaces (e.g., chemical fume hood deck, countertops) should be cleaned routinely (e.g. daily, weekly).
6. For operations where spills and contamination are likely (e.g., agarose gel electrophoresis/ethidium bromide applications), cover work spaces with a bench paper or liner. The soiled bench paper should be changed on a routine basis or as needed.
7. All chemical spills must be cleaned up immediately. Refer to Chapter 8 of the CHP for detailed chemical spill cleanup procedures.
8. Do not allow materials to accumulate in laboratory hoods and remove used tissues, foil, gloves, or other unnecessary objects immediately after use. The safety of the workspace and the hood ventilation may be compromised when excessive chemicals and equipment are kept in hoods.
9. Ensure that all waste (e.g., trash, chemically contaminated waste, etc.) is placed in the appropriate containers. Do not overfill waste containers.
10. All equipment should be cleaned and returned to storage after each use.
11. Equipment should be stored in a safe and orderly manner that prevents it from falling.
12. Chemical containers must be clean, properly labeled, and returned to storage upon completion or usage. Avoid storing liquids above eye level.

13. Do not store heavy or frequently used items on top shelves. Locate items used daily close to the work area.

7.2 Chemical Inventories

It is a prudent practice to develop and maintain a chemical inventory. Taking a routine chemical inventory can reduce the number of unknown chemicals and the tendency to stockpile chemicals. OSHS recommends that all laboratories take a chemical inventory at least annually. Depending on the type of chemicals being used and stored in a laboratory, OSHS may require that a chemical inventory be prepared for a room, work unit, or department (e.g., Department of Homeland Security Chemical Facility Anti-Terrorism Standards Inventory) on a routine basis.

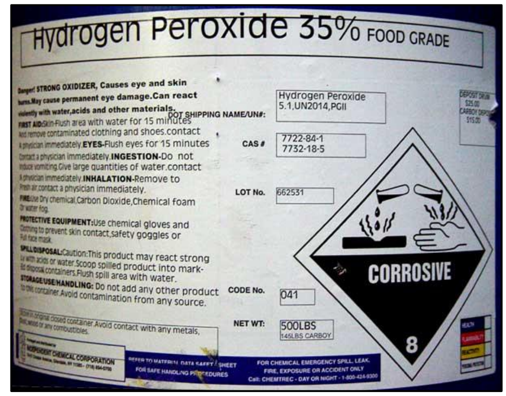
7.3 Safety Data Sheets

The SDS provides comprehensive information that is imperative for the safe handling of hazardous chemicals. Carefully read the label and SDS and make sure that you understand the information provided in this document before using a chemical. In some cases it may be necessary to do additional research. The Laboratory Supervisor should be consulted if necessary.

It is important that all lab employees have access to SDS for all hazardous chemicals that are stored in the lab. Access can mean storing hard copies of SDS in the lab or some other easily accessible location (e.g., departmental main office), or can mean storing electronically by a means that is also accessible to all lab personnel (e.g., shared network drive, MSDS online). To obtain a copy of a SDS, contact the chemical manufacturer. Many manufacturers' SDS can be found online at OSHS's SDS webpage or other websites such as Siri SDS Index. The links to these resources are included below:

- OSHS SDS Search (www.mtu.edu/research/resources-for/safety/)
- Siri MSDS Index (hazard.com/msds/)
- Sigma-Aldrich Product Search (www.sigmaaldrich.com/united-states.html)

7.4 Chemical Labeling Requirements



Every chemical container present in the laboratory, whether hazardous or not, must be properly labeled. All secondary chemical containers (e.g., wash bottles, beakers, flasks, sample vials, etc.) must also be properly labeled. Avoid using abbreviations, chemical formulae, or structure unless there is a complete and up-to-date legend (e.g., MeOH = Methanol) prominently posted in the lab. Most chemicals come with a manufacturer label that contains all of the necessary information, so care should be taken to not damage or remove these labels. It is recommended that each bottle also be dated when received and when opened to assist in determining which chemicals are expired and require proper disposal. The owner's name or initials must be indicated. Detailed information and strategies for the labeling of research samples is discussed in Section 7.6 of the CHP. These same strategies can be used when labeling secondary chemical containers as well.

7.5 Chemical Segregation

All chemicals must be stored according to chemical compatibility. Once segregated by chemical compatibility, they can then be stored alphabetically. Information regarding chemical compatibility can be found in the SDS, primarily in Part 7, "Handling and Storage" and Part 10, "Stability and Reactivity" see Figure 11.1 in Section 11.6.1. If unsure of proper segregation procedures, contact the Laboratory Supervisor for assistance. Chemical segregation can be achieved by either isolation (e.g., organic solvents stored in a flammable cabinet), physical distance (e.g., acids and bases are stored on opposite sides of a chemical storage room), or secondary containment (e.g., placing oxidizing acids such as nitric acid into a secondary containment to segregate from organic acids such as formic acid as shown in Figure 6.6). In the most general terms, proper segregation can be achieved by:

- Storing acids away from bases and toxics;
- Storing oxidizers away from organic chemicals; and
- Storing reactive and acutely toxic materials away from all other chemicals.

Table 7.1 illustrates a more detailed chemical compatibility logic that can be used for chemical storage. Hazard classes marked by an X need to be segregated from each other (e.g., Acid, inorganic must be segregated from Base, inorganic). Contact OSHS at 906-487-2118 with questions regarding chemical segregation.

Table 7.1 – Chemical Compatibility Chart

	Acid, inorganic	Acid, organic	Acid, oxidizer	Base, inorganic	Base, organic	Oxidizer	Toxic, inorganic	Toxic, organic	Reactive	Organic solvent
Acid, inorganic				X	X		X	X	X	
Acid, organic			X	X	X	X	X	X	X	
Acid, oxidizer		X		X	X		X	X	X	X
Base, inorganic	X	X	X						X	
Base, organic	X	X	X			X			X	
Oxidizer		X			X			X	X	X
Toxic, inorganic	X	X	X						X	
Toxic, organic	X	X	X			X			X	
Reactive	X	X	X	X	X	X	X	X		X
Organic solvent			X			X			X	

7.6 Research Samples and Chemicals Developed in the Lab

Research samples and chemicals developed in the lab (samples) must be managed responsibly. Samples often accumulate in labs for years and are difficult to identify and dispose of and can create unsafe and non-compliant conditions if not managed properly. The following requirements apply to samples developed in the laboratory:

- All samples must be kept closed except when in use. Storage in beakers or flasks should be temporary. If temporarily storing samples in beakers or flasks, a cork, Parafilm®, or some other closure device must be used.
- All samples must be labeled with the chemical name, date the sample was developed/received, and the name of generator. Chemical structure or a labeling system that is only known to lab personnel is not acceptable as the only means of labeling samples. Abbreviations can be used as a labeling system as long as an up-to-date legend is posted in the lab.

- Samples should be disposed of within 6 months unless actively being used for analysis. Stockpiling unusable samples in not an acceptable practice. All samples that are no longer necessary must be properly disposed of in a timely manner using OSHS's hazardous waste program.
- Samples must be stored according to compatibility and the primary hazard class; this should be done to the best of your ability considering the properties that are known or assumed such as toxicity.
- If the hazard(s) of a sample are unknown, the Laboratory Supervisor must attempt to determine whether it is hazardous or not. Assume all samples are toxic unless otherwise demonstrated. This can be accomplished by literature review or reviewing the hazards of other similar compounds. At a minimum, the Laboratory Supervisor should be able to determine if a chemical is flammable, corrosive, oxidant, or reactive. Call OSHS at 906-487-2118 for assistance with identifying the hazards of samples.
- If samples are consolidated for storage (e.g., vial boxes), it is not always necessary to label every sample container. For example, a box containing sample vials which are all in the same hazard class (e.g., miscellaneous pharmaceutical compounds considered to be toxic) can have one label on the outside of the box stating "Miscellaneous Toxic Pharmaceutical Compounds" or a similar description. A label such as the one shown in Figure 7.1 can be used to identify consolidated samples, and should only be used on a temporary basis. This type of information communicates the hazards to emergency responders, as well as gives OSHS the information necessary for proper disposal. A listing of smaller sized labels is on the following page.
- If the chemical substance is 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.

Chemical Description			
Employee Name		Date	
Circle the hazards that apply			
Flammable	Reactive	Oxidizer	Corrosive
Toxic	Explosive	Irritant	Non-hazardous
Other:			

Figure 7.1 – Example Temporary Sample Container Label

Chemical Description			
Employee Name		Date	
Circle the hazards that apply			
Flammable	Reactive	Oxidizer	Corrosive
Toxic	Explosive	Irritant	Non-hazardous
Other:			

Chemical Description			
Employee Name		Date	
Circle the hazards that apply			
Flammable	Reactive	Oxidizer	Corrosive
Toxic	Explosive	Irritant	Non-hazardous
Other:			

Chemical Description			
Employee Name		Date	
Circle the hazards that apply			
Flammable	Reactive	Oxidizer	Corrosive
Toxic	Explosive	Irritant	Non-hazardous
Other:			

Chemical Description			
Employee Name		Date	
Circle the hazards that apply			
Flammable	Reactive	Oxidizer	Corrosive
Toxic	Explosive	Irritant	Non-hazardous
Other:			

Chemical Description			
Employee Name		Date	
Circle the hazards that apply			
Flammable	Reactive	Oxidizer	Corrosive
Toxic	Explosive	Irritant	Non-hazardous
Other:			

Chemical Description			
Employee Name		Date	
Circle the hazards that apply			
Flammable	Reactive	Oxidizer	Corrosive
Toxic	Explosive	Irritant	Non-hazardous
Other:			

Chemical Description			
Employee Name		Date	
Circle the hazards that apply			
Flammable	Reactive	Oxidizer	Corrosive
Toxic	Explosive	Irritant	Non-hazardous
Other:			

Chemical Description			
Employee Name		Date	
Circle the hazards that apply			
Flammable	Reactive	Oxidizer	Corrosive
Toxic	Explosive	Irritant	Non-hazardous
Other:			

Chemical Description			
Employee Name		Date	
Circle the hazards that apply			
Flammable	Reactive	Oxidizer	Corrosive
Toxic	Explosive	Irritant	Non-hazardous
Other:			

Chemical Description			
Employee Name		Date	
Circle the hazards that apply			
Flammable	Reactive	Oxidizer	Corrosive
Toxic	Explosive	Irritant	Non-hazardous
Other:			

Chemical Description			
Employee Name		Date	
Circle the hazards that apply			
Flammable	Reactive	Oxidizer	Corrosive
Toxic	Explosive	Irritant	Non-hazardous
Other:			

Chemical Description			
Employee Name		Date	
Circle the hazards that apply			
Flammable	Reactive	Oxidizer	Corrosive
Toxic	Explosive	Irritant	Non-hazardous
Other:			

7.7 Laboratory Self-Inspections

OSHS performs laboratory inspections for various purposes (e.g., routine building safety and compliance inspections). However, the Laboratory Supervisor or a qualified designee should also inspect the laboratory for compliance with the requirements of the CHP at a minimum on an annual basis. Lab personnel have a much greater understanding of the unique hazards and issues that are encountered in their individual lab than OSHS does. The goal of these inspections is to identify and correct unsafe and non-compliant conditions that could potentially result in an injury to lab personnel or a fine from a regulatory agency (e.g., open hazardous waste container). All deficiencies found during the inspection must be reviewed and corrected. In general the following elements should be performed during these inspections:

- Housekeeping practices should be reviewed. Chemicals should be stored appropriately and labeled. Evidence of spills (incident reports) and/or chemical contamination should be cleaned. All glassware and equipment should be stored appropriately, etc.
- Hazard assessments should be updated if process changes have occurred. For example, the lab is now performing organic synthesis (or water treatment) and working with organometallic compounds.
- Training records should be updated and documented if new lab personnel have not yet been trained or if any processes have changed.
- Excess or outdated chemicals should be properly disposed of by OSHS.
- Safety supplies such as PPE and spill containment equipment should be replenished if necessary.

A recommended template to use during laboratory self-inspections is the Self-Audit Checklist, which can be found in Section 11.2.3 of this document

7.8 Laboratory Ergonomics

Many tasks in laboratories require repetitive motions which may lead to cumulative trauma injuries of the body, these effects can be long term. Tasks like pipetting, weighing multiple samples, standing at the bench or hood and using microscopes for long periods of time can cause physical stress. Even time compiling data at a computer poses potential physical problems. Ergonomics is the study of interaction of the human body with the work environment. Ergonomics strives to fit the job to the body through proper body positioning, posture, movement, tools, workplace layout and design. Parts of the body commonly affected by poor ergonomics include: neck, shoulders, back, hands, wrists, elbows, legs, and feet.

OSHS has resources available to improve ergonomic conditions and help reduce cumulative trauma injuries to laboratory workers. Often simple adjustments are all that is required to improve conditions. Refer to the OSHS website special link for detailed information regarding OSHS's laboratory ergonomics program. (https://uwaterloo.ca/safety-office/programs-and-procedures/ergonomics/office-ergonomics)

7.9 Laboratory Electrical Safety

7.9.1 Training

Laboratory employees shall be trained to understand the specific hazards associated with electrical energy. See the written Electrical Safety Manual prepared by OSHA for more detailed information. (https://www.osha.gov/dte/grant_materials/fy09/sh-18794-09/electrical_safety_manual.pdf)

Employees who need access to operate circuit breakers and fused switches in electrical panels may require additional training to be designated by their supervisor as qualified for the task. Electrical outlets have three connections, one live, the other the return and then the ground. The reason why some electrical cords have one prong larger than the other is to ensure that the switch controlling the instrument shuts off the live feed. If you do not insert the electrical cord in the proper way (assuming the outlet is properly wired) then the on/off switch on the instrument will be hooked up to the return. Under these circumstances you could potentially act as a grounding source if you touch the instrument and be electrocuted. One should check that the outlet is properly wired by means of plugging in a receptacle tester.

7.9.2 Portable Electrical Equipment and Extension Cords

The following requirements apply to the use of cord-and-plug-connected equipment and flexible cord sets (extension cords):

- Extension cords may only be used to provide temporary power and must be used with Ground Fault Circuit Interrupter (GFCI) protection during maintenance and construction activities and in damp or wet locations.
- Portable cord and plug connected equipment and extension cords must be visually inspected before use for external defects such as loose parts, deformed and missing pins, or damage to outer jacket or insulation, and for possible internal damage such as pinched or crushed outer jacket. Any defective cord or cord-and-plug-connected equipment must be removed from service and no person may use it until it is repaired and tested to ensure it is safe for use.
- Extension cords must be of the three-wire type. Extension cords and flexible cords must be designed for hard or extra hard usage. The rating or approval must be visible.
- Portable equipment must be handled in a manner that will not cause damage. Flexible electric cords connected to equipment may not be used for raising or lowering the equipment.
- Extension cords must be protected from damage. Sharp corners and projections must be avoided. Flexible cords may not be run through windows or doors unless protected from damage, and then only on a temporary basis. Flexible cords may not be run above ceilings or inside or through walls, ceilings or floors (secured with duct tape), and may not be fastened with staples or otherwise hung in such a fashion as to damage the outer jacket or insulation.
- Extension cords used with grounding type equipment must contain an equipment-grounding conductor; the cord must accept a three-prong, or grounded, plug. Operating equipment with extension cords without a grounding plug is prohibited.
- Attachment plugs and receptacles may not be connected or altered in any way that would interrupt the continuity of the equipment grounding conductor. Additionally, these devices may not be altered to allow the grounding pole to be inserted into current connector slots. Clipping the grounding prong from an electrical plug is prohibited.
- Flexible cords may only be plugged into grounded receptacles. Adapters that interrupt the continuity of the equipment grounding connection may not be used.
- All portable electric equipment and flexible cords used in highly conductive work locations, such as those with water or other conductive liquids, or in places where employees are likely to contact water or conductive liquids, must be approved for those locations.
- Employee's hands must be dry when plugging and unplugging flexible cords and cord and plug connected equipment if energized equipment is involved.
- If the connection could provide a conducting path to the employee’s hands (e.g. if a cord connector is wet from being immersed in water), the energized plug and receptacle connections must be handled only with insulating protective equipment.

- Lamps for general illumination must be protected from breakage, and metal shell sockets must be grounded.
- Temporary lights must not be suspended by their cords unless they have been designed for this purpose.
- Extension cords are considered to be temporary wiring, and must also comply with the section on “Requirements for Temporary Wiring” in this program.

7.9.3 Temporary Wiring Requirements

Temporary electrical power and lighting installations 600 volts or less, including flexible cords, cables and extension cords, may only be used during and for renovation, maintenance, repair, or experimental work. The following additional requirements apply:

- Ground-fault protection (e.g. GFCI) must be provided on all temporary-wiring circuits, including extension cords, used for construction or maintenance activities.
- In general, all equipment and tools connected by cord and plug must be grounded. Listed or labeled double insulated tools and appliances need not be grounded.
- Receptacles must be of the grounding type.
- Flexible cords and cables must be of an approved type and suitable for the location and intended use. They may not be used as a substitute for the fixed wiring, where run through holes in walls, ceilings or floors, where run through doorways, windows or similar openings, where attached to building surfaces, or where concealed behind building walls, ceilings, floors, rugs or carpeting .
- Suitable disconnecting switches or plug connects must be installed to permit the disconnection of all ungrounded conductors of each temporary circuit.
- Lamps for general illumination must be protected from accidental contact or damage, either by elevating the fixture above 8 feet above the floor or other working surface or by providing a suitable guard. Hand lamps supplied by flexible cord must be equipped with a handle of molded composition or other approved material and must be equipped with a substantial bulb guard.
- Flexible cords and cables must be protected from accidental damage. Sharp corners and projections are to be avoided. Flexible cords and cables must be protected from damage when they pass through doorways or other pinch points.

7.9.4 Wet or Damp Locations

Work in wet or damp work locations (i.e., areas surrounded or near water or other liquids) should not be performed unless it is absolutely critical. Electrical work should be postponed until the liquid can be cleaned up. The following special precautions must be incorporated while performing work in damp locations:

- Only use electrical cords that have GFCIs;
- Place a dry barrier over any wet or damp work surface;
- Remove standing water before beginning work. Work is prohibited in areas where there is standing water;
- Do not use electrical extension cords in wet or damp locations; and

Keep electrical cords away from standing water.

Chapter 8: Emergency Procedures for Accidents and Spills

8.1 Basic steps for emergency and spill response

Releases of hazardous substances that pose a significant threat to health and safety or that, by their very nature, require an emergency response regardless of the circumstances surrounding the release or the mitigating factors are emergency situations. The following definitions designate an emergency situation:

The situation is unclear to the person causing or discovering the spill.
The release requires evacuation of persons.
The release involves or poses a threat of fire, suspected fire, explosion or other imminent danger
Conditions that are Immediately Dangerous to Life and Health (IDLH)

High levels of exposure to toxic substances.

The person(s) in the work area is uncertain they can handle the severity of the hazard with the personal protective equipment (PPE) and response equipment that has been provided and/or the exposure limit could easily be exceeded. Conversely, releases that do not pose significant safety or health hazards to person(s) in the immediate vicinity or to the person(s) cleaning releases, do not have the potential to become emergencies within a short time frame are not emergency situations.
The following situations ARE NOT emergency situations:

- The person causing or discovering the release understands the properties and can make an informed decision as to the exposure level.

- The release can be appropriately cleaned up by the lab personnel using authorized (certified commercially available) spill kits. Sand does not constitute a spill kit.

- The materials are limited in quantity, exposure potential, or toxicity and present minor safety or health hazards to persons in the immediate work area or those assigned to clean up the activity.

- Incidental releases of hazardous substances that are routinely cleaned up by OSHS or trained custodians from outside the immediate release area need not be considered an emergency.

8.1.1 Chemical Spills

Chemical spills in the laboratory can pose a significant risk to human health and the environment. All lab personnel must be trained on how to properly respond to chemical spills in order to minimize risk. In general, chemical spills can be placed into one of two categories: non-emergency chemical spills, or emergency chemical spills.

8.1.1.1 Non-Emergency Chemical Spill Procedures

Non-emergency chemical spills are generally defined as less than 1 liter, do not involve a highly toxic or reactive material, do not present a significant fire or environmental hazard, and are not in a public area such as a hallway. These spills can be cleaned up by properly trained lab personnel using conventional lab PPE (e.g., safety glasses/goggles, lab coat, gloves) and the lab spill kit. In general, when a non-emergency spill occurs in the lab the area around the spill should be isolated, everyone in the lab should be made aware of the spill, and the spilled material should be absorbed and collected using either pads or some other absorbent material such as oil dry or kitty litter. Decontamination of the spill area should be conducted using an appropriate solvent (soap and water is often the most effective). Proper PPE should be worn at all times and only trained personnel should conduct the cleanup. Additionally, review the SDS(s) (specifically Section 3.1.1, “Accidental Release Measures”) to obtain chemical-specific cleanup information.

Notes and Precautions: The range and quantity of hazardous substances used in laboratories require pre-planning to respond safely to chemical spills. The cleanup of a chemical spill should only be done by knowledgeable and experienced personnel who have received appropriate training. Spill kits with instructions, absorbents, reactants, and protective equipment should be available to clean up minor spills. A minor chemical spill is one that the laboratory staff is capable of handling safely without the assistance of safety and emergency personnel. A major chemical spill requires active assistance from emergency personnel.

WHAT TO DO?

- Alert people in immediate area of spill.
- Wear protective equipment, including safety goggles, gloves, and long-sleeve lab coat.
- Avoid breathing vapors from spill.
- Confine spill to small area.
- Do not wash spill down the drain.
- Use appropriate kit to neutralize and absorb inorganic acids and bases. Collect residue, place in container, and dispose as chemical waste.

- For other chemicals, use appropriate kit or absorb spill with vermiculite, dry sand, or diatomaceous earth. Collect residue, place in container and dispose as chemical waste.
- Clean spill area with water.

8.1.1.2 Emergency Chemical Spill Procedures

Emergency chemical spills are generally defined as greater than 1 liter, involve a highly toxic or reactive compound, present an immediate fire or environmental hazard, or require additional PPE (e.g., respirator) and specialized training to properly cleanup. The following procedures should be followed in the event of an emergency chemical spill:

WHAT TO DO?

- Cease all activities and immediately evacuate the affected area (make sure that all personnel in the area are aware of the spill and also evacuate).
- Attend to injured or contaminated persons and remove them from exposure. If chemical exposure has occurred to the skin or eyes, the affected personnel should be taken to the nearest safety shower and eyewash station.
- If spilled material is flammable, turn off ignition and heat sources. Don’t light Bunsen burners or turn on other switches.
- Close doors to affected area.
- Dial 911, which will initiate both the Michigan Tech Police and Fire Department response, if the situation is, or could become an emergency (e.g., chemical exposure has occurred, a fire or explosion has occurred).
- The fire alarm should be pulled, which will initiate building evacuation, if any of the following occurs:
- A fire and/or explosion has occurred (or there is a threat of fire and/or explosion);
- The large spill (which is either highly toxic or presents an immediate fire or environmental hazard) is in a public area such as a hallway;
- Toxic vapors are leaving the area where the spill has occurred, such as seeping from the laboratory into the hallway or neighboring rooms;
- You are unsure of the hazards and feel that the spill could be harmful to building occupants.
- Ensure that no one else is allowed to enter the area until the spill has been properly cleaned up by the Fire Department.
- Have person knowledgeable of incident and laboratory assist emergency personnel.

8.1.1.3 Procedures for chemical spill on body

- Remove contaminated clothing at once and flood exposed area with running water from faucet or safety shower for at least 15-minutes.
- Make sure the chemical has not accumulated inside shoes.
- Obtain immediate medical attention.
- Report the incident to the Principal Investigator.
- See other sections of the CHP for guidelines on handling spills.

8.1.1.4 Procedure for hazardous material splashed in eye

- Immediately rinse eyeball and inner surface of eyelid with water continuously for at least 15-minutes.
- Forcibly hold your eye open to ensure effective washing behind the eyelids. In case glass or other foreign objects enter the eye, do not rub the eye.
- Obtain immediate medical attention.
- Report the incident to the Principal Investigator.

8.1.2 Mercury Spills.

For very small spills, less than 1 cc, such as a broken thermometer, use a trapped vacuum line attached to a tapered glass tube, similar to a medicine dropper, to pick up mercury droplets.

- Do not use a domestic or commercial vacuum cleaner.
- Cover small droplets in accessible areas with one of the following:
- sodium polysulfide solution
- powdered sulfur
- silver metal compounds
- dry ice to freeze the mercury droplets
- Place residue in container for hazardous waste collection.
- For large spills, i.e. greater than 1 cc, contact the Michigan Tech's OSHS 906-487-2118 for spill cleanup, instructions or assistance.

8.1.3 Spill Kits.

Each laboratory should have a spill response kit available for use. Lab spill kits can either be purchased from a vendor or created by lab personnel, but each spill kit should be equipped to handle small spills of the most common hazards in the laboratory. The kit should be equipped with response and cleanup materials such as:

- Absorbent materials such as pads, booms, oil dry or kitty litter, booms, or pillows
- Neutralizing agents (e.g., Neutrasorb®) for acids and/or bases if high volume of acids and/or bases are stored in the laboratory
- Containers such as drums, buckets, and/or bags to containerize spilled material and contaminate debris generated during the cleanup process (enough for 2 gallon spill).
- PPE such as gloves, safety glasses and/or goggles, lab coat or apron, chemical-resistant booties
- Caution tape or some other means to warn people of the spill
- scooper

Most spills greater than 1 liter in volume require assistance from trained personnel from OSHS at 7-2118.

Some sorbents are chemically specific. The best sorbents are those which can be used to clean up all types of chemical spills. Check absorbents in spill kits for their absorbency range.

Each laboratory's spill kit should be kept in a readily accessible location and each employee should be trained on how to use the spill kit. The chemistry departmental spill kits are located on the southern end of the 6th floor. The code is 31-21-11. Report any use so that stock can be replenished.

8.1.4 Biological Spill

Notes and Precautions: Biological spills outside biological safety cabinets could generate aerosols that can be dispersed in the air throughout the laboratory. These spills are to be taken seriously if they involve microorganisms that require Biosafety Level (BL) 2 or 3 containment, since these agents may have the potential for transmitting disease by infectious aerosols. To reduce the risk of inhalation exposure in such an incident, occupants should leave the laboratory **immediately**. The laboratory **should not** be re-entered to decontaminate and clean up the spill for at least 30-minutes. During this time, the aerosol will be removed from the laboratory by the exhaust air ventilation system. Appropriate protective equipment is particularly important in cleaning up spills involving microorganisms that require either BL2 or BL3 containment. This equipment includes lab coat with long sleeves, back-fastening gown or jumpsuit, disposable gloves, disposable shoe covers, and safety goggles and mask or full face shield. Use of this equipment will prevent contact with contaminated surfaces, and protect eyes and mucous membranes from exposure to splattered materials.

SPILL INVOLVING A MICROORGANISM REQUIRING **BL1** CONTAINMENT

- Wear disposable gloves.
- Soak paper towels in disinfectant and place over spill area.
- Place towels in plastic bag for disposal.
- Clean spill area with fresh towels soaked in disinfectant.

SPILL INVOLVING A MICROORGANISM REQUIRING **BL2** CONTAINMENT

- Alert people in immediate area of spill.
- Put on protective equipment.
- Cover spill with paper towels or other absorbent materials.
- Carefully pour a freshly prepared 1:10 dilution of household bleach/water around the edges of the spill and then into the spill. Avoid splashing.
- Allow a 20-minute contact period.
- Use paper towels to wipe up the spill, working from the edges to the center.
- Clean spill area with fresh towels soaked in disinfectant.
- Place towels in a plastic bag and decontaminate in an autoclave.

SPILL INVOLVING A MICROORGANISM REQUIRING **BL3** CONTAINMENT

- Attend to injured or contaminated persons and remove them from exposure.
- Alert people in the laboratory to evacuate.
- Close doors to affected area.
- Call PSPS at 9-1-1.
- Have person knowledgeable of incident and laboratory assist emergency personnel.

PROCEDURES FOR BIOLOGICAL SPILL ON BODY

- Remove contaminated clothing and vigorously wash exposed area with soap and water for 3-minutes.
- Obtain immediate medical attention.
- Report the incident to the Principal Investigator.
- See other sections of the CHP for guidelines on handling spills.

8.1.5 Non-Emergency Situation - Spill.

If the spill is less than one liter and the chemical involved is of low toxicity and a low flammable hazard, handle it in the following manner:

- If there are questions about proper spill response techniques, call OSHS at 906-487-2118.
- Locate the spill kit.
- Choose the proper protective equipment:
- Always wear gloves and protective eye wear
- Use additional protective equipment such as an apron, coveralls, or boots.
- Use a fitted respirator if there is an inhalation hazard above the permissible exposure limit.
- Confine or contain the spill.
- For non-reactive spills:
- Cover liquid spills with spill kit absorbent and scoop into a plastic disposal bag.
- Sweep solid materials into a dust pan and place in a sealed container.
- Dispose of waste as normal trash as long as substance is non-volatile, non-hazardous.
- For reactive or potentially reactive spills:
- Cover liquid spill with spill kit absorbent and scoop into an appropriate disposal container.
- Wet mop dry substances to avoid spreading hazardous dust, provided it is non-water reactive.
- If spilled chemical is a volatile solvent, transfer disposal bag to a hood for evaporation of solvent.
- Follow the Michigan Tech Waste Disposal Guide for disposal.

8.1.6 Emergency Situation - Fire.

As described above in section 1, the following steps are basic protocol for handling a fire or fire-related emergency situation in the laboratory:

- Pull the fire alarm.
- Call 911 from a safe location (use your best judgement as to a safe location).
- Notify the unit emergency coordinator Rudy Luck at 370-7405.
- Evacuate (i.e., evacuate after pulling the alarm and then complete the steps).

8.1.7 Additional Considerations

Small fires (those confined to a specific, small area or piece of equipment where flames cannot easily reach other combustibles) can be extinguished without evacuation. However, an immediate readiness to evacuate is essential in the event the fire cannot be controlled. Fire extinguishers should be used only by trained personnel. All lab workers should be trained in the use of fire extinguishers. Call OSHS to set up a fire extinguisher training program.

- Never enter a room that is smoke filled.
- Never enter a room containing a fire without a backup person.
- Never enter a room if the top half of the door is warm to touch.
- Report any problems with fire alarms, fire extinguishers, or other fire protection devices to the Facility Director.

IF YOU DISCOVER FIRE ON YOUR FLOOR:

- Manually activate the fire alarm system, if available.
- Immediately exit the building, closing doors behind you (DO NOT USE ELEVATORS).
- Call 9-1-1.

ONCE FIRE ALARM IS ACTIVATED:

- Walk to the nearest exit (DO NOT USE ELEVATORS).
- Assist persons with special needs.
- Notify fire personnel if you suspect someone is trapped inside the building.
- Gather outside at a designated assembly area, and do not attempt to re-enter the building until instructed to do so by PSPS or OSHS.

PROCEDURES FOR SMALL FIRES

- Alert people in the lab and, if there is any chance you may not be able to put out the fire, activate alarm or call 9-1-1 and report the fire.
- Smother the fire or use the correct fire extinguisher (Only if you are trained and it can be done without risk to safety and health):
  - ❖ Carbon dioxide for type B (flammable liquids) or type C (electrical) fires.
  - ❖ Dry powder – ABC for type A (ordinary combustibles), type B (flammable liquids), or type C (electrical) fires.
  - ❖ Water for type A (ordinary combustibles) fires.
  - ❖ Dry powder – D for type D (burning metals) fires.

- If it is an electrical fire, first turn the power off at the main electrical panel.
- Always maintain an accessible exit.
- Avoid smoke and fumes.
- Report the fire to the Principal Investigator.

PROCEDURES FOR MAJOR FIRES OR EXPLOSIONS

- Alert people in the area to evacuate.
- Activate nearest fire alarm. Call 9-1-1 and report the fire. Give exact location and extent of fire and any special circumstances that could be hazardous, such as chemicals or faulty equipment. If unsafe to call from lab, go elsewhere to call.
- Assist any who need help to evacuate, if it can be done safely. If someone's clothing is on fire, roll the person around on the floor or drench the person in a safety shower.
- Close doors to confine the fire.
- Evacuate to a safe area or exit the building through a stairwell; do not use elevator. Pre-plan your evacuation route, plus an alternate. If your immediate evacuation would result in a hazardous situation and if you are not in immediate danger from the incident, stay just long enough to put your area in a safe condition.
- Have a person knowledgeable of the incident and lab assist emergency personnel.
- Account for each person in your work area. Report anyone who is missing to fire or police personnel.
- Do not reenter the building (even if the fire alarm bell/horns stop) until you are advised to do so by the PSPS, OSHS, or Department Chair.
- If the authorities, members of the press, or others approach you with questions, please refer them to the University Fire Marshall or the Department Chair for answers.
- If the fire or explosion is in a halon protected room, leave the room immediately, closing all windows and doors.
- Report the fire to the Principal Investigator and the Department Chair.

IF TRAPPED IN A ROOM:

- Wet and place cloth material around and under the door to prevent smoke from entering the room.
- Close as many doors as possible between you and the fire.
- Be prepared to signal someone outside, but DO NOT BREAK GLASS until absolutely necessary (outside smoke may be drawn into the room).

IF CAUGHT IN SMOKE:

- Drop to hands and knees and crawl toward exit.
- Stay low, as smoke will rise to ceiling level.
- Breathe shallowly through nose and use a filter such as a shirt or towel.

IF FORCED TO ADVANCE THROUGH FLAMES (which should be a last resort):

- Hold your breath.
- Move quickly.
- Cover your head and hair with a blanket or large coat.
- Keep your head down and your eyes closed as much as possible.
- USING A FIRE EXTINGUISHER: If you have been trained and it is safe to do so, you may fight small fires with a fire extinguisher. Fire extinguisher instructions: Use the "PASS" method. Pull safety pin from handle. Aim at base of fire. Squeeze the trigger handle. Sweep from side to side at base.
- PROCEDURES FOR CLOTHING ON FIRE:
- Roll the person around on the floor to smother the flames, or drench the person with water if a safety shower is immediately available.
- Obtain immediate medical attention.
- Report the incident to the Principal Investigator.

8.2 Power Outages.

If emergency lighting and fire alarms ARE NOT operable, evacuate the building after the following steps have been taken:

- Place lids on all open containers of volatile chemicals
- Lower the sash on chemical fume hoods
- Shut down all equipment (leave cooling water and purge gases on as necessary)
- Turn off ignition sources
- Secure or isolate reactions that are underway (boiling liquid on a hot plate, distillations)
- Close fire doors
- Take your books, coats, purse/wallet, keys, etc.
- Lock outside door to lab
- In anticipation of possible power outages, do the following:
- Have a flashlight conveniently located or other emergency lighting
- Make sure that all emergency contact numbers on the door are accurate and updated

Chapter 9: Chemical Waste

9.1 Introduction

Hazardous waste is generally defined as waste that is dangerous or potentially harmful to human health or the environment. Hazardous waste regulations are strictly enforced by both the Environmental Protection Agency (EPA) and the Michigan Department of Environmental Quality. The Laboratory Supervisor is responsible for managing the hazardous waste program in a safe and compliant manner. No chemical waste should be poured down the drain or discarded in the trash unless it is certain that doing so does not violate hazardous waste regulations or the wastewater treatment plant's requirements (see Section 9.7 of this chapter for information and guidance for acceptable sink disposal practices).

Hazardous wastes can be liquid, solid, gas, or sludge. They can be discarded chemicals or mixtures generated from research and teaching operations, commercial products (e.g., cleaning fluids or pesticides), or by-products of manufacturing processes. All hazardous waste falls into one of the following categories:

- Characteristic Wastes: includes wastes that are ignitable, corrosive, reactive, or toxic (D-listed).
- Listed Wastes: includes wastes from common manufacturing and industrial processes (F-listed), wastes from specific industries (K-listed), and wastes from commercial chemical products (U- and P-listed).
- Universal Waste: includes certain batteries (primarily rechargeable batteries such lithium, nickel-cadmium, nickel metal hydride, and mercury oxide), mercury-containing equipment (e.g., thermometers, thermostats), and certain lamps (e.g., fluorescent bulbs). Note: alkaline batteries and incandescent bulbs are not considered Universal Wastes and can be legally disposed of as trash.
- Mixed Waste: hazardous waste mixed with radioactive waste.

EPA-regulated hazardous waste should not be mistaken for biological or radiological wastes. A more detailed definition of hazardous waste, including the D, F, P, and U lists, is provided in OSHS website www.mtu.edu/oshs/safety-programs/required/waste-disposal/.

9.2 Waste Identification and Labeling

All chemical constituents in a hazardous waste container must be identified by knowledgeable laboratory personnel. Not only is this required by the EPA, it also ensures that waste can be properly characterized and disposed of by OSHS. If there is uncertainty about the composition of a waste stream resulting from an experimental process, laboratory employees must consult the Laboratory Supervisor for assistance. In most cases, careful documentation and review of all chemical products used in the experimental protocol will result in accurate waste stream characterization. Additionally, review SDSs (specifically Chapters 3 and 4) to obtain information about hazardous constituents and characteristics.

All waste should be properly labeled as soon the first drop of waste enters a waste container. Containers must be labeled and clearly marked with words that describe the contents of the waste and the words "Hazardous Waste". Hazardous waste should be listed completely on the label provided by OSHS in a percentage format as shown in Figure 9.1. Listing accurate percentages is not as important (+ 5% is acceptable and constituents less than 1% can be listed as “trace”) as listing all of the chemicals that makeup the waste. If a chemical is found in the laboratory and the composition is unknown, it should be assumed to be hazardous and labeled as “Hazardous Waste – awaiting proper characterization”.

Michigan Tech
Michigan Technological University

Request for Collection of Waste Chemicals

Requested by: Date:

Department/Office/Division: Telephone:

Location of Waste Chemicals: Building: Room:

Please specify the location of the waste chemicals within the room.

	Chemical Name / Description	EPA Waste ID No.*	Physical State**	Quantity	Container size
X					
X					
X					
	Add More Chemicals				

* Refer to EPA hazardous waste tables in the MTU hazardous waste disposal procedures or contact OSHS
** Indicate whether waste is solid, liquid, gas, or sludge.

To submit your request for waste chemical pickup:
Save a copy of this form and then submit as an E-mail attachment to: wastepickup-l@mtu.edu

Figure 9.1 – Michigan Technological University Hazardous Waste Label

9.3 Waste Storage Requirements

Hazardous waste containers in Michigan Tech laboratories are stored in satellite accumulation area (SAA). SAAs are used to manage hazardous waste in laboratories and shops because doing so provides safe and effective means to accumulate hazardous waste before removal by OSHS. Additionally, SAAs provide the least restrictive regulatory option for the accumulation and storage of hazardous waste containers. The following SAA rules must be followed at all times when managing hazardous waste in a laboratory:

- All waste must be stored in containers.
- Containers must be in good condition and compatible with the waste they contain (no corrosive waste in metal containers).
- Containers must be kept closed at all times except when adding or removing waste.

CAUTION
Hazardous Waste Satellite Accumulation Area

- Containers must be labeled or clearly marked with words that describe the contents of the waste (e.g., liquid chromatography waste) and the words "Hazardous Waste".
- Containers must be stored at or near the point of generation and under the control of the generator of the waste (wastes should remain in the same room they were generated in). A central waste collection room should not be established.
- The waste storage volume should never exceed 55 gallons per SAA.
- Containers should be segregated by chemical compatibility during storage (e.g., acids away from bases, secondary containment can be used as a means of segregation).
- Avoid halogenated and non-halogenated wastes in the same waste container.
- Avoid mixing incompatible waste streams in the same container (e.g., acids with bases, oxidizers with organic solvents) that will potentially create an exothermic reaction in the waste container. If mixing waste streams does create heat, allow the container to vent and cool in a chemical fume hood before sealing to avoid over pressurization of the container as illustrated in Figure 9.2.
- Collect all highly toxic, reactive, mercury and any exotic wastes (e.g., dioxin compounds, PCBs, controlled substances) separately even if they are chemically compatible with other waste streams. Failing to do so can result in costly disposal fees (e.g., mixing mercury with an organic solvent waste means that the entire waste stream must be treated as mercury waste).
- All spills and leaks should be cleaned up immediately.
- Identification of SAAs is not required by the EPA, but it is recommended as a good practice.

Figure 9.2 – Container Failure Due to Mixing Incompatible Waste Streams

9.4 Waste Containers

OSHS does not provide containers to campus. It is the responsibility of the generator of the waste to provide containers. Usually the original container of the main component of the waste can be used (e.g., 4-liter glass jar, 5-gallon green metal solvent can). Michigan Tech ChemStores also offers waste containers such as 20-liter carboys as shown in Figure 9.3 for sale.

If requested, reusable hazardous waste storage containers of 5 gallons or larger may be returned to the generator's area. Mark the container clearly with "Return to", the building, and room number as illustrated in Figure 9.4. Containers unsuitable for reuse will be properly disposed of and not returned.

Figure 9.3 – 20 Liter Carboy

Figure 9.4 – Reusable Waste Container

The University's policy for the disposal of empty containers is implemented to protect Michigan Tech facilities and the Physical Facilities Buildings and Grounds staff when removing trash. Please remember that some chemical residues have the potential to mix with other incompatible residues in the dumpster or compactor causing a reaction or fire. In addition, sealed containers may become pressurized during compaction, which may result in residues spraying onto workers. Please keep the following procedures and information in mind when disposing of empty containers:

- Triple rinse empty containers with a solvent capable of removing the original material.
- Collect the rinsate for disposal through OSHS.
- Either remove the label or mark it up with a black marker.
- Remove any cap that may cause the container to become pressurized when compacting.
- Take these containers to the designated area beside the dumpster outside your building.
- Try to break glass containers by hurling them into the large garbage dumpster bins. This is to prevent people from reusing the containers.
- If unable to remove residual hazardous materials from containers, submit these to OSHS for pickup using the Hazardous Materials Pickup Request Form.

9.5 Waste Disposal Procedures

OSHS provides pickup services for all chemical waste generated on the main Michigan Tech campus. A Hazardous Materials Pickup Request form must be completed and submitted by the generator of the waste to initiate pickup services. Once the pickup request has been processed, OSHS staff will come to your lab to pick up the waste. Average turnaround time is 3-5 days.

The following procedures must be followed in order to have hazardous waste removed from campus locations:

1. Prior to pick up, all waste must be placed in a designated area within the room where the waste was generated.
2. All waste must be placed in an appropriate container(s).
3. All containers must be capped and labeled, see Figure 9.1.
4. Complete and submit a Hazardous Materials Pickup Request form (Figure 9.1). Visit the OSHS's Forms webpage http:/www.mtu.edu/oshs/safety-programs/required/waste-disposal/waste_chemical_collection_request_form to find the online Hazardous Material Pickup Request submission form.

For further information regarding hazardous waste disposal, call OSHS at 906-487-2118 or visit the OSHS website. (www.mtu.edu/oshs/)

9.6 Unknown Chemical Waste

Unknown chemicals are a serious problem in laboratories. Mysterious chemicals are often stored in labs for years before lab personnel notice the unidentified items. However, steps can be taken to assist with proper management of unknowns. Unknown chemicals must be properly identified according to hazard class before proper disposal. The hazards that should be noted include: corrosive, flammable, oxidizer, reactive, toxic, and radioactive. The following subsections describe in detail how to properly manage unknown chemicals.

9.6.1 Labeling Unknown Chemicals

Until the unknown chemical can be properly identified by either lab staff or OSHS, the container should be labeled with a Hazardous Waste Disposal Tag. The following information should be written on the label: "Unknown hazardous chemical, awaiting proper characterization by REM" as illustrated in Figure 9.5.

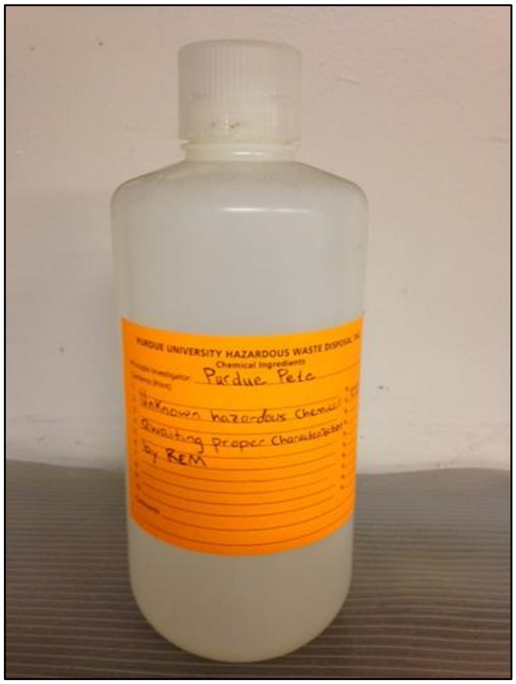


Figure 9.5 – Properly Labeled Unknown Waste

9.6.2 Identifying Unknown Chemicals

Every effort should be made by laboratory personnel to identify unknown chemicals. Here are a few steps that can be taken to help this effort:

1. Ask other laboratory personnel if they are responsible for, or can help identify the unknown chemical.
2. The type of research conducted in the laboratory can be useful information for making this determination. Eliminating certain chemicals as a possibility helps narrow the problem as well. This is especially important for mercury, PCB, or dioxin compounds because they must be managed separately from other hazardous waste.
3. For trade products, contact the manufacturer or search online to obtain an SDS. OSHS staff can assist you in finding an SDS.

9.6.3 Removing Unknown Chemicals from the Work Area

If it is not possible to identify the material, a "Hazardous Waste" label should be placed on the container as described above in Section 9.6.1 and a Hazardous Materials Pickup Request form should be submitted which describes all of the available information (e.g., 4-liter container of clear liquid). Call OSHS at 906-487-2118 if you have a question about an unknown.

9.6.4 Preventing Unknown Chemicals

Here are a few tips that will help prevent the generation of unknown chemicals:

- Label all chemical containers, including beakers, flasks, vials, and test tubes. The label should be placed on the container, not the cap to avoid accidental mislabeling.
- Immediately replace labels that have fallen off or that are deteriorated.
- Label containers using chemical names. Do not use abbreviations, structure, or formulae.
- Archived research samples are often stored in boxes containing hundreds of small vials. Label the outside of the box with the chemical constituents paying special attention to regulated materials such as radioactive material, organic solvents, heavy metals and other toxics. If the samples are nonhazardous, label them as such.
- Submit frequent Hazardous Materials Pickup Request Forms to reduce the amount of chemicals in your laboratory.
- Employees should dispose of all of their waste before leaving/graduating from Michigan Tech. The lab and/or department should come up with a system to ensure that all faculty, staff, and students properly dispose of hazardous waste, including unwanted research samples, before employees leave.

9.7 Sink and Trash Disposal

No chemical waste should be poured down the drain or discarded in the trash unless it is certain that doing so does not violate hazardous waste regulations or the wastewater treatment plant's discharge requirements. In order to ensure improper disposal does not occur, the detailed instruction and guidelines for acceptable sink disposal is provided in the Michigan Technological University Hazardous Waste Disposal Guidelines, www.mtu.edu/oshs/safety-programs/required/waste-disposal/. Please contact OSHS at 906-487-2118 for further information regarding non-hazardous chemical waste disposal.

9.8 Sharps Waste

Sharps are items capable of puncturing, cutting, or abrading the skin such as glass or plastic pipettes, broken glass, test tubes, petri dishes, razor blades, needles, and syringes with needles. Sharps waste contaminated with hazardous chemicals must be placed into puncture resistant containers (e.g., sharps container, plastic or metal container with lid) and properly labeled. All chemically contaminated waste should be inventoried on a Hazardous Materials Pickup Request form and sent to OSHS for proper disposal.

Clean uncontaminated broken glassware and plastic sharps should be placed in a corrugated cardboard box or other strong disposable container. Do not exceed 20 pounds. When ready for disposal, the box should be taped shut and prominently labeled as "Sharp Objects/Glass – Discard" or similar wording. A "Safe for Disposal" label should also be affixed to the outside of the container. Contact your Physical Facilities Building Services department for specific non-hazardous waste disposal instructions. More detail regarding sharps, including biologically contaminated sharps, can be found at the found in the OSHS Sharps and Infectious Waste Handling and Disposal Guidelines. (www.mtu.edu/research/administration/integrity-compliance/pdf/MTU%20Exposure%20Control%20Plan_05-21-2012.pdf)

9.9 Liquid Chromatography Waste

Liquid chromatography (LC) is an analytical technique used to separate, identify, quantify, and purify individual components of a mixture. This technique is very common in biological and chemical research. The most common type of LC at Michigan Tech is High Performance Liquid Chromatography (HPLC). Michigan Tech has numerous LC instruments located in laboratories all over campus. Because organic solvents (e.g., methanol, acetonitrile) are commonly used in the process, most LC waste is regulated by the EPA as hazardous waste. Consequently, all containers collecting LC waste must remain closed while the LC unit is in operation. It is neither acceptable to place a waste line running from the LC unit into an open waste container nor is it acceptable to use foil or Parafilm® as a means of closure as shown in Figure 9.6.

Open Waste		**Foil**	**Parafilm®**
			

Figure 9.6 – Improper LC Waste Collection Practices

One of the following practices must be employed in order to comply with hazardous waste regulations for LC waste collection systems:

- Purchase an engineered container and/or cap designed for LC waste collection. Figure 9.7 shows several examples of acceptable solutions for proper LC waste collection that can be purchased.

Safety Cans	**Ported Cap** (No Threads)	4 Port (threaded) Cap	Solvent Bottle Cap
			

Figure 9.7 – Proper LC Waste Collection Options for Purchase

- An existing cap can be modified by the research lab for LC waste collection. To modify an existing cap, a hole can be drilled into a cap. The diameter of the hole should be similar to the diameter of the waste line; there should be a tight fit between the container opening and waste line. In addition, a hole should be drilled to accommodate any exhaust filter or air valve tube that may be required. It is recommended that either a 4-liter container or 5-gallon carboy be used for waste collection. The modified cap should be replaced with a regular, unmodified cap once the container is full and ready for OSHS pickup.

Chapter 10: Training

Effective training is crucial to a successful laboratory safety program. Laboratory Supervisors must actively participate in the training process to ensure that all lab employees are effectively trained before any work with hazardous materials occurs. This chapter details the minimum training requirements for all Michigan Tech laboratories. It should be noted that depending on the type of research being conducted and associated hazards, there may be additional training requirements that are not detailed in this chapter. For more information, contact OSHS at 906-487-2118 or visit the OSHS Training guides www.mtu.edu/oshs/safety-programs/guides.

10.1 CHP Training

As discussed in Chapter 1 of the CHP, all laboratory employees (graduate students, lab technicians/managers, post-docs, visiting scientists, etc.) must receive documented CHP training before any work with hazardous materials occurs. The Laboratory Supervisor is responsible for providing CHP training. Initial CHP training should include the following:

- Review the lab-specific CHP in its entirety. Selected material from the Appendix section of the CHP may be required.
- Review lab-specific hazard assessments
- Review lab-specific SOPs
- Review any other lab-specific protocol or requirements

Refer to Section 11.3.1 for the CHP Lab-Specific Training Certification form, which must be used to document having read the CHP.

10.1.1 Annual CHP Refresher Requirements

After receiving the initial documented CHP training, all lab employees must receive annual CHP refresher training as well. This annual refresher training can be a condensed version of the initial CHP training, but should include at least the following elements:

- Review of the lab-specific hazard assessments (review of PPE requirements)
- Review of the lab-specific SOPs
- Review of any additional lab-specific rules and requirements
- Review of chemical spill and lab emergency procedures

10.2 PPE Training

As discussed in Chapter 3 of the CHP, Laboratory Supervisors must ensure that all lab employees receive documented PPE training before any work with hazardous materials occurs. Document PPE training using the Certification of Training form (Appendix A of the CHP). Each lab employee must be trained to know at least the following:

- When PPE is necessary
- What PPE is necessary
- How to properly don, doff, adjust, and wear PPE
- The limitations of the PPE
- The proper care, maintenance, and useful life of PPE

Each affected employee must demonstrate an understanding of the training provided, and the ability to use the PPE properly, before performing any work requiring the use of PPE.

10.3 Laboratory Safety Courses

The Michigan Tech Department of Chemistry offers a graduate level, one credit Spring-semester course (CH6800) that covers the fundamentals of laboratory chemical safety practices. CH6800 includes a strong focus on learning how to find, read, interpret and use the information in safety data sheets, chemical labels, and other printed chemical safety information. Other topics covered include fire protection/prevention, electrical safety, laser and ionizing radiation safety, machine safety (pumps, autoclaves, centrifuges), and non-PPE safety equipment (hoods, extinguishers, fire protection systems and building elements, general ventilation, showers, eyewashes), and an understanding of administrative controls, engineering controls, and how to select, use, maintain and decide to retire/replace PPE necessary for laboratory work with chemicals. Regulatory agency familiarity and compliance topics including MiOSHA, EPA, DOT, and NRC are also included. CH 6800 is open to all departments and is a required course for some departments. All graduate students working in a laboratory environment are strongly encouraged to take CH 6800.

Other departments on campus also provide safety training via courses or modules. Chemical Engineering provide a three credit hour course (CM4310) to their undergraduates Chemical Process Safety/Env which entails the following: “A study of the technical fundamentals of chemical process safety and designing for the environment. Includes toxicology, industrial hygiene, source models, fires and explosions, relief systems, hazard identification, risk assessment, environmental fate and transport, hazardous waste generation, pollution prevention, and regulatory requirements."

Chemical Engineering also has a one credit hour graduate level course (CM 5310) entitled Laboratory Safety which "provides the technical and cultural background necessary to operate and manage a safe Laboratory."

Civil & Environmental Engineering provides a "training program" in the form of a module available on Canvas for students to engage in Chemical Hygiene Training.

10.4 OSHS Researcher's Guide

The CHP focuses on work with hazardous chemicals in the laboratory. However, other common types of hazards are present in many research labs as well (e.g., biological hazards, lasers, etc.). OSHS has developed various Guides as a tool to assist researchers with compliance and training requirements for a broad range of common hazards and regulatory programs found in the laboratory. Visit the OSHS website for more detailed information. (www.mtu.edu/oshs/safety-programs/guides/)

Chapter 11: Safety Rules and Regulations

11.1 Laboratory Management Plan

An effective laboratory management plan is essential to operating a safe lab environment. Requirements on topics such as lab housekeeping, chemical inventories, proper handling, storage, segregation, and labeling of chemicals, and equipment safety must be established and known by all laboratory personnel. This chapter details how laboratories should be managed at Michigan Tech.

11.2 Laboratory Safety Guidelines

All laboratory employees must have a good understanding of the hazards associated with the chemicals being used and stored in the lab. Basic factors such as the physical state (gas, liquid, or solid) of the chemical and the type of facilities and equipment involved with the procedure should be considered before any work with hazardous materials occurs.

11.2.1 Laboratory Safety Considerations

Many factors are involved is laboratory safety. Asking and answering the following questions will help address many of the factors that should be considered when it comes to laboratory safety.

- Is the material flammable, explosive, corrosive, or reactive?
- Is the material toxic, and if so, how can I be exposed to the material (e.g., inhalation, skin or eye contact, accidental ingestion, accidental puncture)?
- What kind of ventilation do I need to protect myself?
- What kind of PPE (e.g., chemical-resistant gloves, respirator, and goggles) do I need to protect myself?
- Will the process generate other toxic compounds, or could it result in a fire, explosion, or other violent chemical reaction?
- What are the proper procedures for disposal of the chemicals?
- Do I have the proper training to handle the chemicals and carry out the process?
- Are my storage facilities appropriate for the type of materials I will be using?
- Can I properly segregate incompatible chemicals?
- What possible accidents can occur and what steps can I take to minimize the likelihood and impact of an accident? What is the worst incident that could result from my work?

11.2.2 General Laboratory Safety Rules

It is extremely important that all laboratory safety rules are known and followed by lab personnel. Not only is it important that the rules are understood and followed, it is also important that the Laboratory Supervisor enforce all lab safety rules. A culture of safety must be adopted by all employees before a lab safety program can be successful. The following general laboratory safety rules should be followed at all times:

- Prior to beginning work in the lab, be prepared for hazardous materials emergencies and know what actions to take in the event of an emergency. Plan for the worst-case scenario. Be sure that necessary supplies and equipment are available for handling small spills of hazardous chemicals. Know the location of safety equipment such as the nearest safety shower and eyewash station, fire extinguisher, spill kit, and fire alarm pull station.
- In the Chemistry Department, do not work alone in the laboratory if you are working with high hazard materials (e.g., acutely toxics, reactives, or processes that involve handling a large volume of flammable materials, > 1 liter). Other departments may have more restrictions and may not allow for individual work in labs. Check with your CHO.
- If working with a high-hazard chemical, ensure that others around you know what you are working with and understand the potential hazards.
- Limit access to areas where chemicals are used or stored by posting signs and/or locking doors when areas are unattended.
- Purchase the minimum amount of hazardous materials necessary to efficiently operate the laboratory.
- Ensure that adequate storage facilities (e.g., chemical storage rooms, flammable safety cabinets) and containers are provided for hazardous materials. Ensure that hazardous materials are properly segregated by chemical compatibility.
- Ensure that ventilation is adequate for the chemicals being used. Understand how chemical fume hoods function and be able to determine if the hood is not functioning properly.
- **Ensure that air always flows from the hallway into your lab and not the reverse.**
- Use good personal hygiene practices. Keep your hands and face clean; wash thoroughly with soap and water after handling any chemical.
- Smoking, drinking, eating, and the application of cosmetics are forbidden in areas where hazardous chemicals are in use. Confine long hair and loose clothing.
- Never smell or taste a hazardous chemical. Never use mouth suction to fill a pipette.
- When using equipment that creates potential hazards (e.g., centrifuge), ensure that the equipment is being used following the manufacturer’s guidelines and instructions. If equipment requires routine maintenance (e.g., HEPA filters need to be changed), ensure the maintenance is performed by a qualified individual.
- Use required PPE as instructed by the PPE Policy detailed in Chapter 6.

11.2.3 Chemistry Department Safety Inspection Form

Inspector's Name___Room____________________Date_________________

A. TRAINING ASSESSMENT				
1	Has the department identified all pertinent training for their personnel?	O YES	O NO	O NA
2	Are the training records up-to-date?	O YES	O NO	O NA
3	Is the Chemical Hygiene Plan available and do personnel know where to find it?	O YES	O NO	O NA
4	Have all personnel been trained in the Chemical Hygiene Plan?	O YES	O NO	O NA
5	Have all personnel received specific laboratory safety training?	O YES	O NO	O NA
6	Is there a "Right-To-Know" bulletin posted in the department?	O YES	O NO	O NA
B. SIGNS AND INFORMATION				
1	Are special hazard signs in place (i.e. laser, cryogenic hazards, biohazards)?	O YES	O NO	O NA
2	Are lab doors labeled and information up-to-date?	O YES	O NO	O NA
3	Are the emergency phone numbers posted on the laboratory door?	O YES	O NO	O NA
4	Do all personnel know how to obtain SDS?	O YES	O NO	O NA
C. STANDARD OPERATING PROCEDURES				
1	Are standard operating procedures established and available?	O YES	O NO	O NA
D. EMERGENCY EQUIPMENT				
1	Are extinguishers in designated locations and are these locations labeled?	O YES	O NO	O NA
2	Are extinguishers accessible and free from obstructions?	O YES	O NO	O NA
Safety Showers and Eyewashes:				
1	Are showers/eyewashes labeled, accessible, and free from obstruction?	O YES	O NO	O NA
E. PROTECTIVE EQUIPMENT				
Personal Equipment:				
1	Are safety glasses with side shields worn as required?	O YES	O NO	O NA
2	Are substantial shoes worn with no sandals or open toes?	O YES	O NO	O NA
3	Is protective clothing worn while working at benches?	O YES	O NO	O NA
4	Are gloves selected and worn according to hazard?	O YES	O NO	O NA
5	Disposable gloves are not reused?	O YES	O NO	O NA
6	Are chemical splash goggles/face shields worn when appropriate?	O YES	O NO	O NA
Other Equipment:				
1	Is proper protective equipment in place (shields, guards, warning signs, etc.)	O YES	O NO	O NA
2	Is secondary containment used for Hg use and storage?	O YES	O NO	O NA
General Housekeeping:				
1	Are aisles and exits free from obstructions?	O YES	O NO	O NA
2	Are benches/shelves overloaded with unused equipment/chemicals?	O YES	O NO	O NA
3	Are combustibles stored within three feet of the ceiling?	O YES	O NO	O NA
4	Is damaged glassware used (i.e. broken or chipped)?	O YES	O NO	O NA
5	Is lab apparatus properly assembled and used in a safe manner?	O YES	O NO	O NA
6	Is the lab free of food and beverages?	O YES	O NO	O NA
F. COMPRESSED GAS				
1	Are cylinders properly secured in an upright position?	O YES	O NO	O NA
2	Are stored cylinders tightly capped and kept to a minimum?	O YES	O NO	O NA
3	Are flammable materials stored a minimum of 20 ft from oxygen cylinders?	O YES	O NO	O NA
4	Are regulators, connections, and tubing in good condition?	O YES	O NO	O NA
G. ELECTRICAL EQUIPMENT				
Refrigerators and Freezers:				
1	Are only flammable storage refrigerators/freezers used to store flammables?	O YES	O NO	O NA
2	Are refrigerators/freezers which are not rated as "flammable storage" clearly labeled "NO FLAMMABLES ALLOWED"?	O YES	O NO	O NA

3	Are refrigerators labeled "CHEMICAL USE ONLY" or "FOOD USE ONLY" and used accordingly?	O YES	O NO	O NA
4	Is the interior sound and free of chemical spills or contamination?	O YES	O NO	O NA
5	Are containers stored stoppered and/or tightly closed?	O YES	O NO	O NA
General Equipment:				
1	Is electrical apparatus equipped with ground plugs or properly grounded?	O YES	O NO	O NA
2	Are extension cords in good condition and free of any splices?	O YES	O NO	O NA
3	Are extension cords for temporary use only and not overloaded?	O YES	O NO	O NA
4	Are electrical panels free from obstruction?	O YES	O NO	O NA
5	Are appliances properly grounded?	O YES	O NO	O NA
H. HAZARDOUS SUBSTANCES				
Chemical Storage:				
1	Has chemical inventory been updated annually?	O YES	O NO	O NA
2	Are chemical containers labeled, capped, and in good condition?	O YES	O NO	O NA
3	Is the storage of chemicals on, above, or next to a desk avoided?	O YES	O NO	O NA
4	Are all chemicals stored below "eye level"?	O YES	O NO	O NA
5	Are chemicals segregated by hazard (organics away from oxidizers, flammables away from acids)?	O YES	O NO	O NA
6	Is the flammable/combustible liquid total less than 10 gallons outside an NFPA approved flammables cabinet?	O YES	O NO	O NA
7	Are flammables/conbustibles kept away from heat, ignition, flames, etc?	O YES	O NO	O NA
8	Are peroxide forming reagents dated when opened?	O YES	O NO	O NA
9	Are peroxide forming reagents disposed of or tested after the expiration date?	O YES	O NO	O NA
10	Is chemical storage kept to a minimum?	O YES	O NO	O NA
Solvent Storage:				
1	Is excess solvent stored in approved safety cans or solvent storage cabinets and not placed high on shelving?	O YES	O NO	O NA
2	Are safety cans/wash bottles properly labeled?	O YES	O NO	O NA
3	Are Bunsen burners used in chemical hoods?			
Infectious/Chemical Waste:				
1	Are waste containers labeled and chemical compositions identified?	O YES	O NO	O NA
2	Is waste stored in secondary containment?	O YES	O NO	O NA
3	Is a chemical spill kit available?	O YES	O NO	O NA
4	Are hazardous wastes container lids closed securely?	O YES	O NO	O NA
5	Are sharps and broken glass waste in a labeled, puncture-proof container?	O YES	O NO	O NA
6	Are hazardous wastes not stored beyond 365 day limit?	O YES	O NO	O NA
7	Has the self audit been conducted annually?	O YES	O NO	O NA
Laboratory Hoods/Local Exhaust				
1	Do hood sashes open/close properly and is glass intact?	O YES	O NO	O NA
2	Is hood free of excess chemical storage/equipment?	O YES	O NO	O NA
3	Are hood sashes down (panels closed) when not accessing?			
I. VACUUM EQUIPMENT				
1	Are vacuum pump belt guards in place?	O YES	O NO	O NA
2	Are glass Dewar's wrapped or shielded?	O YES	O NO	O NA
3	Are protective shatterproof shields in place when vacuum equipment is used?	O YES	O NO	O NA
4	Are glass desiccators under vacuum stored in metal guards or shielded?	O YES	O NO	O NA

11.3 Safety Responsibilities

Everyone working at the University has the right to expect safety and the responsibility to help assure safety for themselves and others. Everyone has an important role in safety. The following illustrate areas of responsibility for safety at Michigan Tech.

- **Michigan Tech's President and Board of Trustees** are responsible for providing safe research facilities and for directing resources as needed to support necessary facility improvements and administrative functions of safety management at Michigan Tech.
- **The Departmental Unit** has similar responsibilities to support safety in departmental laboratories and off-site research, and to help provide resources as needed to assure student, staff, and faculty safety. The following departments (Biological Sciences, Biomedical Engineering, Chemical Engineering, Chemistry, Civil & Environmental Engineering, Geological/Mining Engineering & Sciences, Material Science & Engineering, Electrical & Computer Engineering, Mechanical Engineering-Engineering Mechanics, Physics, School of Forestry Resources and Environmental Science, Social Sciences, and, Visual and Performing Arts) should have selected Chemical Hygiene or Safety Officers whose function and role is described above in Section 1.5.6.
- **The Principal Investigators** are responsible for determining, implementing, and documenting appropriate safety policies and procedures in accordance with the Chemical Hygiene Plan. This includes the following activities:
  - ❖ List safety program personnel.
  - ❖ Complete and update chemical inventories annually.
  - ❖ Write a Lab-Specific SOP for each hazardous chemical or laboratory process that is not already included in the general Chemical Hygiene Plan.
  - ❖ Maintain SOP documentation, submit copies to OSHS and use it to train employees.
  - ❖ Perform routine periodic inspections of their research operations. Promptly correct problem areas and document all inspections and follow-up actions.
  - ❖ Discuss safety issues during regular research group meetings. Notes from these meetings can be used to document safety awareness and action.
  - ❖ Track safety related correspondence.
- **The Main Hygiene Officers (HO)** for each laboratory research group are the group's Principal Investigator, or a qualified person designated by the Principal Investigator who is sufficiently familiar with safety procedures and the operations and materials used in the lab.
- **Supervisory Laboratory Staff** are responsible for assisting in the development and enforcement of safe policies and procedures in the laboratories.

- **All Personnel in Laboratories** and in potentially hazardous situations outside of laboratories, are responsible for learning and following safe work practices.
- **Michigan Tech's OSHS** is responsible for providing training, inspections, and exposure monitoring as needed, for certification of laboratory fume hoods and biosafety cabinets and to otherwise assist in implementation of the Chemical Hygiene Plan.
- **The OSHS Director** is responsible for advising and assisting the faculty and research staffs in matters of safety.
- **Michigan Tech's Public Safety and Police Services (PSPS)** is responsible for emergency efforts within the University, including campus police and security, ambulances, and fire-fighting personnel, and for maintaining fire safety equipment.
- **The Chemical Hygiene and Lab Specific Training Form** shown in Section 11.3.1 must be completed and signed for every employee (professor, postdoc, research associate, student) conducting experiments in a research capacity (i.e., not for course work) at Michigan Tech. The document should be given to your departmental Hygiene Officer and should be sent electronically to OSHS at kjpuuri@mtu.edu

11.3.1 Chemical Hygiene Plan and Lab Specific Training Form

Name____MTU. #___________________________
Position____Supervisor________________________
Employee Signature_______________________________Date_____________________________

With my signature above, I certify that I have read the Chemical Hygiene Plan for Michigan Tech.

1. **By Chemical Hygiene Officer**

Right-to-Know Law
Laboratory Specific Standard Operating Procedures
Chemical Procurement, Storage, Handling
PPE Labeling
Waste Handling Housekeeping Engineering Controls Permit
System Emergency Action Plan
Training Completed by__________________________________Date_______________
(Signature acknowledges that the above topics have been adequately communicated)

2. **By Laboratory Supervisor**

Introduction to operations where chemical and physical hazards are present/types of hazards encountered.
Required work practices
PPE
Emergency procedures
Detection of chemical hazards
Location and training on SOP(s), SDS(s), and CHP Labeling system
Training Completed by__________________________________Date_______________
For Building/Room Number____
Training Completed by__________________________________Date_______________
For Building/Room Number____
Training Completed by__________________________________Date_______________
For Building/Room Number____
Employee Signature____________________________________Date_______________
(Signature acknowledges that the above topics have been adequately communicated)

3. **Review and Testing** (by Chemical Hygiene Officer) **Conducted biennially**

Review work practices and procedures
Answer employee questions
Test
Review and Testing Completed by____________________________________Date___________
Employee Signature____Date___________

A PDF version of this completed form must be filed with OSHS. Send email to kjpuuri@mtu.edu.

11.3.2 Incident Report

In order to report an incident involving personal injury, illness or exposure to a hazardous material, please fill out the online form located at www.mtu.edu/oshs/injury-reporting/injury-form/. All incidents, however minor, must be reported.

11.4 Administrative Controls

Administrative controls are procedural measures which can be taken to reduce or eliminate hazards associated with the use of hazardous materials. Administrative controls include the following:

- Ensuring that employees are provided adequate documented training for safe work with hazardous materials
- Careful planning of experiments and procedures with safety in mind. Planning includes the development of written SOPs and hazard assessments (discussed in detail in Chapter 6) for safe performance of the work
- Restricting access to areas where hazardous materials are used
- Using safety signs or placards to identify hazardous areas (designated areas)
- Labeling all chemicals
- Substitution of toxic materials with less toxic materials, when possible
- Good housekeeping and good personal hygiene such as routine hand washing and regular decontamination of areas that are possibly chemically contaminated such as bench-tops and fume hoods
- Prohibiting eating and drinking where chemicals are used or stored

11.4.1.1 Generic Signs.

Every laboratory shall have the following signs visibly posted:

1. The Michigan Right-to-Know law poster (www.michigan.gov/documents/dleg/wsh_cet2105_219990_7.pdf), listing the location of SDSs for all hazardous chemicals used in the laboratory. Emergency contact numbers (two names, preferably the P.I., head technician or a graduate student) shall be posted on the external doorway to the lab. These names and numbers shall be updated when personnel change. In case of an emergency, responders need this information to contact knowledgeable personnel about specific laboratory hazards. If a laboratory has 10

gallons or more of a flammable liquid, the main doorway to the lab shall have a flammable liquid sticker visibly posted on it. This is an aid to fire response personnel.

2. For the Chemistry department, the department's safety committee general knowledge safety information posters should also be displayed. This is illustrate in Section 11.8.1.1. A form of this document which can be edited to suit specific lab needs is available from the chemistry department main office.

11.4.1.2 Restricted Access And Designated Areas.

Facilities containing certain hazards must have warning signs posted at the designated area of the laboratory where the hazard exists, and at the entrance way to the laboratory. Any areas placarded as such are restricted access, designated areas and have certain standards regarding training and use by employees. Such hazards include:

- MiOSHA Class A carcinogens
- HIV and HBV research laboratories and production facilities*
- Biological agents that require Biosafety Level 2 or higher*
- Radioisotopes*
- Other chemical hazards will be dealt with on a case-by-case basis, with consultation from OSHS.

11.4.1.3 Storage Areas.

Chemicals should be stored according to compatibility as designated by hazard classes. Particularly hazardous chemicals should be stored and handled with extreme care. When ordering chemicals that are unfamiliar, review the SDS before purchase so that use and storage guidelines are understood. Assure that the following areas are labeled and chemicals are stored appropriately:

- Carcinogens
- Corrosives
- Flammable Liquids
- Flammable Solids
- Oxidizers
- Perchloric Acid

11.5 Chemical Classification Systems

Chemical classification systems are designed to communicate hazards. The three most widely used classification systems are the OSHA Globally Harmonized System for Classifying and Labeling Chemicals (recently adopted and implemented under the OSHA Hazard Communication Standard), the National Fire Protection Association (NFPA) system of classifying the severity of hazards, and the Department of Transportation (DOT) hazard classes. These classification systems are used by chemical manufacturers when creating safety data sheets and chemical labels, therefore it is important that Michigan Tech lab employees understand the basic elements of each classification system.

11.6 Globally Harmonized System for Classifying Chemicals

The Globally Harmonized System (GHS) is a world-wide system adopted by OSHA (https://www.osha.gov/dsg/hazcom/ghs.html) for standardizing and harmonizing the classification and labeling of chemicals. The objectives of the GHS are to:

- Define health, physical, and environmental hazards of chemicals;
- Create classification processes that use available data on chemicals for comparison with the defined hazard criteria (numerical hazard classification is based on a 1 – 5 scale, 1 being the most hazardous and 5 being the least hazardous); and
- Communicate hazard information, as well as protective measures, on labels and Safety Data Sheet (SDS), formerly known as Material Safety Data Sheets (MSDS).

11.6.1 Safety Data Sheets

The SDS provides comprehensive information that is imperative for the safe handling of hazardous chemicals. Laboratory personnel should use the SDS as a resource to obtain information about hazards and safety precautions. SDSs cannot provide information for hazards in all circumstances. However, the SDS information enables the employer to develop an active program of worker protection measures such as training on hazard mitigation. Chemical manufacturers are required to use a standard format when developing SDSs. The SDS will contain 16 headings which are illustrated in Figure 11.1.

1.	**Identification** includes product identifier; manufacturer or distributor name, address, phone number; emergency phone number; recommended use; restrictions on use.	**9.**	**Physical and chemical properties** lists the chemical's characteristics.
2.	**Hazard(s) Identification** includes all hazards regarding the chemical; required label elements.	**10.**	**Stability and reactivity** lists chemical stability and possibility of hazardous reactions.
3.	**Composition/information on ingredients** includes information on chemical ingredients; trade secret claims.	**11.**	**Toxicological information** includes routes of exposure; related symptoms, acute and chronic effects; numerical measures of toxicity.
4.	**First aid measures** includes important symptoms/ effects, acute, delayed; required treatment.	**12.**	**Ecological information***
5.	**Firefighting measures** lists suitable extinguishing techniques, equipment; chemical hazards from fire.	**13.**	**Disposal considerations***
6.	**Accidental release measures** lists emergency procedures; protective equipment; proper methods of containment and cleanup.	**14.**	**Transport considerations***
7.	**Handling and storage** lists precautions for safe handling and storage, including incompatibilities.	**15.**	**Regulatory information***
8.	**Exposure controls/personal protection** lists OSHA's Permissible Exposure Limits (PELs); Threshold Limit Values (TLVs); appropriate engineering controls; personal protective equipment (PPE).	**16.**	**Other information,** includes the date of preparation or last revision.

**Figure 11.1 – GHS Required Sections of a Safety Data Sheet. ***Note: Since other Agencies regulate this information, OSHA will not be enforcing Sections 12 through 15(29 CFR 1910.1200(g)(2)).

An example of an SDS sheet for benzene is available at the following by clicking here. Take the time to read and examine all aspects of the SDS sheets before using any chemical. You are expected to have read these sheets before using chemicals and will be asked to demonstrate this during unannounced lab inspections.

11.6.2 Chemical Labeling

The GHS standardized label elements, which are not subject to variation and must appear on the chemical label, contain the following elements:

- Symbols (hazard pictograms) are used to convey health, physical and environmental hazard information, assigned to a GHS hazard class and category;
- Signal Words such as "Danger" (for more severe hazards) or "Warning" (for less severe hazards), are used to emphasize hazards and indicate the relative level of severity of the hazard assigned to a GHS hazard class and category;

- Hazard statements (e.g., “Danger! Extremely Flammable Liquid and Vapor”) are standard phrases assigned to a hazard class and category that describe the nature of the hazard; and
- Precautionary statements are recommended measures that should be taken to minimize or prevent adverse effects resulting from exposure to the hazardous chemical.

GHS also standardizes the hazard pictograms that are to be used on all hazard labels and SDSs. There are 9 pictograms that represent several defined hazards, and include the harmonized hazard symbols which are intended to convey specific information about each hazard. Figure 11.2 illustrates these GHS hazard pictograms.

		
Carcinogen, Respiratory Sensitizer, Reproductive Toxicity, Target Organ Toxicity, Mutagenicity	**Flammable, Pyrophoric, Self-Heating, Emits Flammable Gas, Organic Peroxide**	**Irritant, Dermal Sensitizer, Acute Toxicity (harmful), Narcotic Effects**
		
Gas Under Pressure	**Corrosive**	**Explosive, Organic Peroxide, Self-Reactive**
		
Oxidizer	**Environmental Toxicity**	**Acute Toxicity (Severe)**

Figure 11.2 – GHS Hazard Pictograms

GHS labeling requirements are only applicable to chemical manufacturers, distributors, and shippers of chemicals. GHS labeling requirements are not required for chemicals being stored in a laboratory. However, since most chemicals stored in the laboratory have been purchased from a chemical manufacturer, the GHS labeling and pictogram requirements are very relevant and must be understood by laboratory employees. Figure 11.3 illustrates the GHS label format showing the required elements.

ACETONE

PRODUCT IDENTIFIER

Code:
Product Name:

SUPPLIER IDENTIFICATION

Company Name:
Street Address:
City: State:
Postal Code:
Phone Number:

PRECAUTIONARY STATEMENTS

Keep away from heat, sparks, open flames, hot surfaces – No smoking.
Avoid breathing dust, fumes, gas, mist, vapors, and spray.
IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
Repeated exposure may cause skin dryness and cracking.
In Case of Fire: Use water spray, alcohol-resistant foam, dry chemical, or carbon dioxide.
First Aid: Move out of dangerous area. Consult a physician. If inhaled, move person to fresh air. If not breathing, give artificial respiration. In case of skin contact, wash with soap and plenty of water. In case of eye contact, rinse thoroughly with plenty of water for at least 15 minutes. If swallowed, do not induce vomiting. Never give anything by mouth to an unconscious person. Rinse mouth with water, consult a physician.

HAZARD PICTOGRAMS

SIGNAL WORD

Danger

HAZARD STATEMENT

Highly flammable liquid and vapor.
Causes mild skin irritation.
Causes serious eye irritation.
May cause drowsiness or dizziness.

Figure 11.3 – GHS Label Format

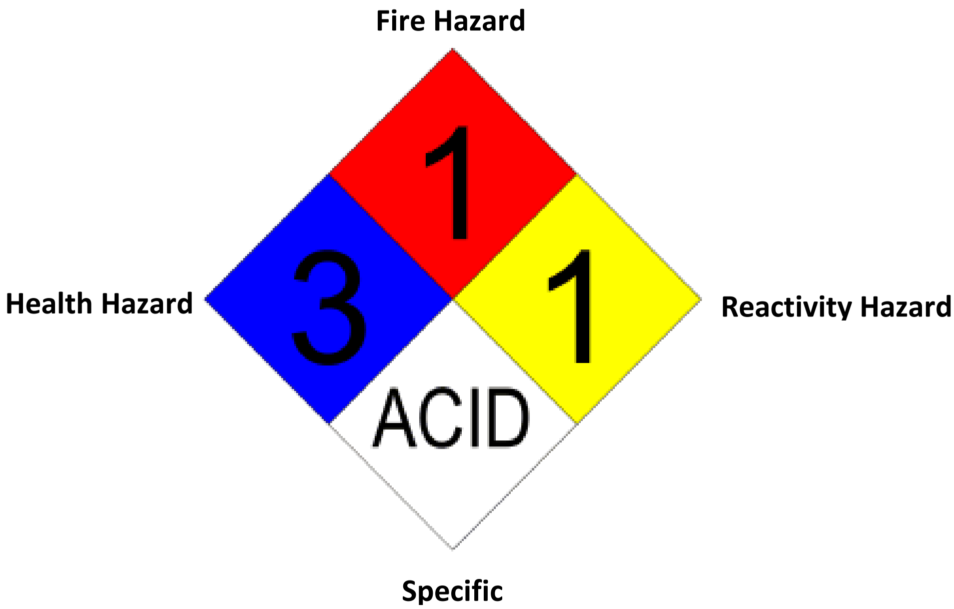
As mentioned earlier, one of the objectives of GHS was to create a quantitative hazard classification system (numerical hazard classification is based on a 1 – 5 scale, 1 being the most hazardous and 5 being the least hazardous) based on physical characteristics such as flash point, boiling point, lethal dose of 50% of a population, reactivity, etc. Table 11.1 illustrates how the numerical hazard classification works for flammable liquids. More detailed information on GHS can be found on the OSHA website. (https://www.osha.gov/dsg/hazcom/ghs.html)

Table 11.1 – GHS Hazard Classification System for Flammable Liquids

Category	Criteria	Pictogram	Signal Word	Hazard Statement
1	Flash point < 23 °C Boiling point ≤ 35 °C		Danger	Extremely flammable liquid and vapor
2	Flash point < 23 °C Boiling point > 35 °C		Danger	Highly flammable liquid and vapor
3	Flash point ≥ 23 °C and < 60 °C		Warning	Flammable liquid and vapor
4	Flash point ≥ 60 °C and ≤ 93 °C		Warning	Combustible liquid
5	There is no Category 5 for flammable liquids			

11.7 National Fire Protection Association Rating System

The NFPA system uses a diamond-shaped diagram of symbols and numbers to indicate the degree of hazard associated with a particular chemical. This system was created to easily and quickly communicate hazards to first responders in the event of an emergency situation. These diamond-shaped symbols are placed on chemical containers to identify the degree of hazard associated with the specific chemical or chemical mixture. The NFPA system is a common way to identify chemical hazards and should be understood by laboratory employees. The NFPA 704 numerical rating system is based on a 0 – 4 system; 0 meaning no hazard and 4 meaning the most hazardous (note: this in contrast to the GHS system where 1 is the most hazardous and 4 is the least hazardous). Figure 11.4 illustrates the NFPA hazard rating system and identifies both the hazard categories and hazard rating system.



Health Hazard	Fire Hazard	Reactivity Hazard	Specific Hazard
4 - Deadly	**4** - FP* < 73° F	**4** - May Detonate	**ACID** Acid
3 - Extreme Danger	**3** - FP < 100° F	**3** - Shock/Heat May Detonate	**ALK** Alkali
2 - Hazardous	**2** - 100° F < FP < 200° F	**2** - Violent Chemical Change	**COR** Corrosive
1 - Slightly Hazardous	**1** - FP > 200° F	**1** - Unstable if Heated	~~**W**~~ No Water
0 – Normal Material	**0** - Will Not Burn		Radioactive

Figure 11.4 – NFPA Hazard Rating System

11.8 Department of Transportation Hazard Classes

The DOT regulates the transportation of all hazardous materials in the United States, and defines a hazardous material as any substance that has been determined to be capable of posing an unreasonable risk to health, safety, or property when transported in commerce. There are several methods that can be employed to determine whether a chemical is hazardous for transport, a few of which included:

- Reviewing the DOT Hazardous Materials Table (49 CFR 172.101);
- Reviewing the SDS, specifically Section 2: Hazard(s) Identification and Section 14: Transport Information, for the chemical being shipped, as detailed in Section 18.4.1 of the CHP;

- Reviewing the chemical label and looking for hazard information detailed above in Section 11.6.1 of the CHP; and
- Understanding the chemical and physical properties of the chemical.

All hazardous chemicals must be properly labeled by the chemical manufacturer or distributor before transportation occurs. Chemical containers stored in laboratories are not required to be labeled per DOT standards; however the DOT 9 hazard classes are often seen on chemical containers and are discussed in Section 14 of GHS-formatted SDSs. The DOT 9 hazard classes are illustrated below in Figure 11.5. It should be noted that Figure 11.5 only lists the primary hazard classes, the sub classes (e.g., Organic Peroxides, DOT Class 5.2) were omitted for stylistic purposes.

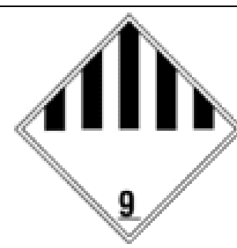
		
DOT Class 1 **Explosives**	**DOT Class 2** **Compressed Gases**	**DOT Class 3** **Flammable Liquids**
		
DOT Class 4 **Flammable Solids**	**DOT Class 5** **Oxidizers**	**DOT Class 6** **Poisons**
		
DOT Class 7 **Radioactive Materials**	**DOT Class 8** **Corrosives**	**DOT Class 9** **Miscellaneous**

Figure 11.5 – NFPA Hazard Rating System

11.8.1 Required Laboratory Postings

The following forms and labels are required to be posted by most campus laboratories:

- The Laboratory Information door posting (Section 11.8.1.2) is required for all laboratories. (www.michigan.gov/documents/dleg/wsh_cet2105_219990_7.pdf)
- The Certification of Hazard Assessment form is required for all laboratories. Detailed information regarding the hazard assessment process is presented in Section 3.3 of the CHP.
- The Carcinogens, Reproductive Toxins, or Extremely Toxic Chemicals label (Toxic Chemicals Label), which is illustrated in Figure 11.6 is required if a lab uses or stores any chemicals on the list linked below. The definitions for these chemicals are from DOT regulations as defined in Title 49 of the Code of Federal Regulations Part 173 (49CFR173) Subpart D. The toxic chemical form is also available at (www.mtu.edu/oshs/safety-programs/required/emergency-response/emergency-response-poster)

11.8.1.1 Chemistry Department Safety Poster

MichiganTech

Chemistry Department Safety Information

All chemicals used at work, even "household" chemicals, should be considered potentially hazardous.

Always understand the hazards of the chemical. Strive to minimize exposure to chemicals.

Chemicals can enter the body through various paths:

- **Lungs**: inhaling dusts, fumes, vapors, or gases;
- **Skin**: chemicals coming in contact with skin;
- *Do not store or put chemicals on your desks within the labs.*
- **Digestive system**: ingesting chemicals.

Effects of chemical exposure:

- **Acute**: immediate outcomes upon exposure; and/or
- **Chronic**: outcome from repeated exposure over longer duration.
- **Don't assume you aren't being exposed just because you don't experience immediate health outcomes**: it may take days, months, years, to see chronic effects.

How to use chemicals safely:

- Material Safety Data Sheet (MSDS or SDS): always read these first to learn about how to use the chemical safely and the hazards of the chemical;
- Substitution: use a less hazardous chemical to do the job if possible;
- Ventilation: use ventilation or work in a well-vented area when using or generating inhalation hazards (volatile chemicals, toxic gases from reaction, etc.);
- Storage: segregate incompatible chemicals and protect flammable chemicals from ignition sources;
- Hygiene: wash your hands after use and prevent chemicals from getting on your clothes;
- Use lab coats, appropriate gloves and wear safety glasses at all times in the lab
- Labeling and signage: always label containers with their content and hazards
- Work practices: when using chemicals try to work so that exposure is minimized.

Selecting the proper Personal Protective Equipment (PPE) when working with chemicals:

Gloves

- Rubber, chemical-resistant material;
- Nitrile offer the widest range of compatibilities, but...
- ALWAYS consult with the MSDS to determine which glove to wear;
- **Do not use gloves to turn door knobs, open doors or to push elevator buttons.**

Eye Protection

- Safety glasses – when splashing and vapors are not a concern;
- Goggles – when splashing is not a concern, but vapors are;
- Face shields – when splashing is a concern;
- Use face shields with goggles when splashing and vapors are a concern.

Body Protection (Lab Coats)

- Use to prevent contact to skin or clothes;
- Protect clothes to prevent "carrying home" chemicals from the job;
- Remove or change before leaving the work area.

Room Specific Instruction:

- Learn where the safety and first-aid equipment is located. This includes fire extinguishers, showers and eye-wash stations.
- Notify the instructor immediately in case of an incident, however minor. A report must be given to the chemistry office. Use the report form available at the website given below.
- Know how to collect and dispose of waste solvents.
- Avoid clutter and keep the work area clean. **Do not store food on hallway floors.**
- Always immediately clean and store used glassware and equipment.
- Transport chemicals in the elevators and hallways with safety containers to contain spills from accidental breakage.

Tips for using PPE:

- Store PPE where they won't be exposed to chemicals.
- Never reuse single use PPE (dust masks, disposable gloves, etc.).
- Discard reusable PPE when they show even the slightest sign of degradation.
- Grossly contaminated PPE should be discarded.
- Inspect PPE before using to find holes, degradation, or wear.
- You should always be using the appropriate PPE when handling chemicals.

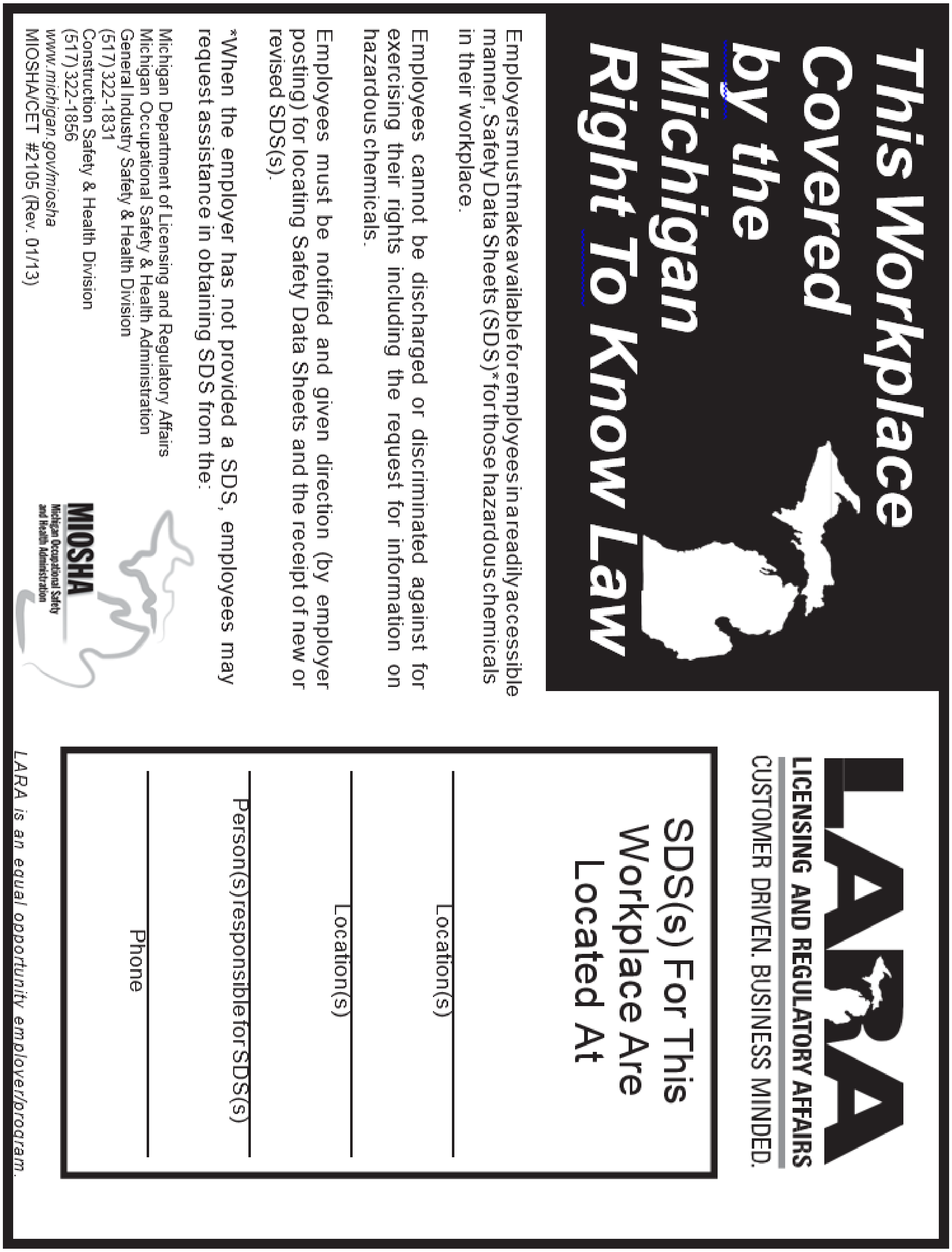
For further information:

Please review the Required Safety Programs and Hazard Communication Plan on the Occupational Safety and Health Services website given below and on the chemistry department's website at mtu.edu/chemistry/labs/safety/.

Personal Protective Equipment and Hazard Communications training is required for all Lab Workers.

Occupational Safety and Health Services; Room 322, Lakeshore Center
906 487 2118 Call 911 in case of emergency
http://www.mtu.edu/oshs/

11.8.1.2 Door Posting Sign From MiOHSA



Room#

Building Name and Number

Department of

Additional Information (optional)

In Case of Emergency: Dial 911

For Emergency Responder Use

Hazards *Mark only those hazards present above listed threshold amounts*

- Flammable/Combustible Liquids (total amount greater than 1 gallon)
- Corrosive Liquids (total amount greater than 1 gallon)
- Water Reactive Chemicals (total amount greater than 10 grams)
- Elemental Mercury (total amount greater than 10 ml)
- Biohazards
- Unsealed Radioactive Materials
- Other (specify)

Compressed Gas Cylinders

- Toxic Gas (poisonous by inhalation)
- Corrosive Gas
- Oxidizing Gas
- Flammable Gas
- Non-flammable Gas or Inert Gas

None of the Above Hazards are Present in this Location

Emergency Contact Information

For Information Contact:	Office Phone	After hours Phone

Are you using MSDSonline to manage Safety Data Sheets? Yes No

Figure 11.6 – Toxic Chemicals Label

- The Abbreviations and Chemical Formulas list is required for all labs that use abbreviations and/or chemical formulas as a means to label chemical containers, including secondary containers such as beakers, flasks, and vials. This list, which can be found on the OSHS website, is not all inclusive and any abbreviations not listed must be added by laboratory personnel. (www.mtu.edu/oshs/safety-programs/required/waste-disposal/descriptions.html)

There are several other lab postings that may also be required that are not discussed in the CHP, particularly if radioisotopes and/or biological agents are used in the lab. This information should be obtained by reviewing the Radiation Safety Manual and/or Biological Safety Manual. Additional information regarding lab postings and labels can be found on the OSHS website. www.mtu.edu/oshs/

Chapter 12: Laboratory Design and Ventillation

The best way to prevent exposure to airborne substances is to prevent their escape into the working atmosphere by use of hoods and other ventilation devices.

The dictates of the OSHA Laboratory Standard **29 CFR 1910.1450** stipulate:

12.1 The Laboratory Facility

12.1.1 Design

The laboratory facility should have:

(a) An appropriate general ventilation system with air intakes and exhausts located so as to avoid intake of contaminated air;
(b) Adequate, well-ventilated stockrooms/storerooms;
(c) Laboratory hoods and sinks;
(d) Other safety equipment including eyewash fountains and drench showers;
(e) Arrangements for waste disposal.

12.1.2 Maintenance.

Chemical-hygiene-related equipment (hoods, incinerator, etc.) should undergo continual appraisal and be modified if inadequate.

12.1.3 Usage.

The work conducted and its scale must be appropriate to the physical facilities available and, especially, to the quality of ventilation.

12.1.4 Ventilation—

(a) General laboratory ventilation. This system should: Provide a source of air for breathing and for input to local ventilation devices; it should not be relied on for protection from toxic substances released into the laboratory; ensure that laboratory air is continually replaced, preventing increase of air concentrations of toxic substances during the working day; direct air flow into the laboratory from non-laboratory areas and out to the exterior of the building.

(b) Hoods. A laboratory hood with 2.5 linear feet of hood space per person should be provided for every 2 workers if they spend most of their time working with chemicals;

each hood should have a continuous monitoring device to allow convenient confirmation of adequate hood performance before use. If this is not possible, work with substances of unknown toxicity should be avoided or other types of local ventilation devices should be provided.

(c) Other local ventilation devices. Ventilated storage cabinets, canopy hoods, snorkels, etc. should be provided as needed. Each canopy hood and snorkel should have a separate exhaust duct.

(d) Special ventilation areas. Exhaust air from glove boxes and isolation rooms should be passed through scrubbers or other treatment before release into the regular exhaust system. Cold rooms and warm rooms should have provisions for rapid escape and for escape in the event of electrical failure.

(e) Modifications. Any alteration of the ventilation system should be made only if thorough testing indicates that worker protection from airborne toxic substances will continue to be adequate.

(f) Performance. Rate: 4-12 room air changes/hour is normally adequate general ventilation if local exhaust systems such as hoods are used as the primary method of control.

(g) Quality. General air flow should not be turbulent and should be relatively uniform throughout the laboratory, with no high velocity or static areas; airflow into and within the hood should not be excessively turbulent; hood face velocity should be adequate (typically 60-100 linear feet per minute, (lfm)).

(h) Evaluation. Quality and quantity of ventilation should be evaluated on installation, regularly monitored (at least every 3 months), and reevaluated whenever a change in local ventilation devices is made.

12.2 Michigan Tech policy

With the OSHA recommendations stated in Section 12.1, Michigan Tech believes that the best way to prevent exposure to airborne substances is to prevent their escape into the working atmosphere by the use of hoods and other ventilation devices. University facilities must adhere to the following concepts which are based on the NRC recommendations concerning chemical hygiene in laboratories (1910.1450 App A):

(a) Toxic or corrosive chemicals that require vented storage should be stored in vented cabinets instead of in a chemical hood.

(b) Solvent storage cabinets must be checked frequently to see that there are no obnoxious smells generated within. Containers that are not properly sealed and leaking vapors should be checked and sealed tightly with electrical tape if necessary.

(c) Chemical waste should not be disposed of by evaporation in a chemical hood.

(d) Keep chemical hood areas clean and free of debris at all times.

(e) Solid objects and materials, such as paper, should be prevented from entering the exhaust ducts as they can reduce the air flow.

(f) Chemical hoods should be maintained, monitored and routinely tested for proper performance.

(g) Drains at the back of fume hoods must be checked periodically for blockages.

Our laboratory ventilation systems should include the following characteristics and practices:

(a) Heating and cooling should be adequate for the comfort of workers and operation of equipment. Before modification of any building HVAC, the impact on laboratory or hood ventilation should be considered, as well as how laboratory ventilation changes may affect the building HVAC.

(b) A negative pressure differential should exist between the amount of air exhausted from the laboratory and the amount supplied to the laboratory to prevent uncontrolled chemical vapors from leaving the laboratory.

(c) Local exhaust ventilation devices should be appropriate to the materials and operations in the laboratory.

(d) The air in chemical laboratories should be continuously replaced so that concentrations of odoriferous or toxic substances do not increase during the workday.

(e) Laboratory air should not be recirculated but exhausted directly outdoors.

(f) Air pressure should be negative with respect to the rest of the building. Local capture equipment and systems should be designed only by an experienced engineer or industrial hygienist.

(g) Ventilation systems should be inspected and maintained on a regular basis. There should be no areas where air remains static or areas that have unusually high airflow velocities.

Before work begins, laboratory workers should be provided with proper training that includes how to use the ventilation equipment, how to ensure that it is functioning properly, the consequences of improper use, what to do in the event of a system failure or power outage, special considerations, and the importance of signage and postings.

Chapter 13: Exposure Monitoring

13.1 Control measures

The lab supervisor should implement control measures to reduce employee exposure to hazardous chemicals. The three types of control measures are:

Administrative Controls: methods of controlling employee exposures to contaminants by job rotation, work assignment or time periods away from contaminant. Examples include Standard Operating Procedures, Chemical Hygiene Plans and Safety Manuals.

Engineering Controls: methods of controlling employee exposures by modifying the source or reducing the quantity of contaminants released into the work environment. Examples include fume hoods and biosafety cabinets.

Personal Protective Equipment: personal safety equipment designed for secondary employee protection from hazardous chemicals. Examples include gloves and lab coats.

Note: MiOSHA R 325.51105 regarding air contaminants, states that engineering controls and administrative controls shall first be determined and implemented when feasible. When such controls are not feasible to achieve full compliance, protective equipment or any other protective measures shall be used to keep the exposure of employees to air contaminants within the limits prescribed in the rule.

MiOSHA requires control measures when the following circumstances are met:

- Whenever employees use hazardous chemicals.
- Whenever employee exposures exceed the action level (or, in the absence of an action level, the Permissible Exposure Limit, the published exposure limit or the Threshold Limit Value).
- Upon addition of new chemicals or changes in procedures.
- Other situations should be dealt with on a case-by-case basis. Please consult OSHS for assistance in establishing control measures.

The following general control measures are recommended for use in most situations requiring the use of hazardous chemicals:

- Use the following primary methods for detecting exposures:
- Determine the source of exposure.

- Determine the path the contaminant follows to reach the employee.
- Determine the employee's work pattern and use of personal protective equipment.
- Change one or more of the above pathways to reduce or eliminate exposure.
- Substitute less harmful chemicals for more harmful chemicals whenever possible.
- Change or alter processes to minimize exposure.
- Isolate or enclose a process or work operation to reduce the number of employees exposed (for example, use a fume hood).
- Use wet methods to reduce the generation of dust.
- Use local exhaust ventilation (hoods) at point of generation or dispersion of contaminants and use dilution (general) ventilation to reduce air contaminants.
- Practice good housekeeping procedures to reduce unnecessary exposures.
- Use training and education as primary administrative controls for reducing exposures.

Use special control methods such as shielding and continuous monitoring devices to control exposures in special situations.

Chapter 14: Compressed Gas Safety

14.1 Compressed Gas Cylinder Safety

Compressed gas storage requirements are discussed above in Section 6.1.3. However, there are additional important safety requirements for use of compressed gases in laboratories detailed below:

- Gas cylinder connections and fittings must be inspected frequently for deterioration.
- Never use a leaking, corroded, or damaged cylinder and never refill compressed gas cylinders.
- When stopping a leak between cylinder and regulator, always close the valve before tightening the union nut.
- The regulator must be replaced with a safety cap when the cylinder is not in use.
- The safety cap must be in place when a gas cylinder is moved. For large gas cylinders (>27 inches), an approved gas cylinder cart should be used.
- The cylinder must be strapped to the cart and the protective cap must be in place before moving the cylinder. A cylinder should never be moved or transported without the protective cap. The proper way to move a large gas cylinder is illustrated in Figure 14.1.
- Never dispense from a cylinder if it is on a gas cylinder cart.

Figure 14.1 – Gas Cylinder Cart

A few compressed gas cylinders have a shelf-life and can become more hazardous as time goes on. It is extremely important that these chemicals are identified and managed properly. If any time-sensitive gases are found to be past the manufacturer’s expiration date, they must be submitted to OSHS for hazardous waste disposal immediately. The following is a list of time-sensitive compressed gases:

- Hydrogen Fluoride, anhydrous
- Hydrogen Bromide, anhydrous
- Hydrogen Sulfide, anhydrous
- Hydrogen Cyanide, anhydrous
- Hydrogen Chloride, anhydrous

The compressed gases listed above have a shelf-life provided by the manufacturer that must be strictly followed. There have been numerous incidents involving these compounds related to storage past the expiration date. For example, hydrogen fluoride (HF) and hydrogen bromide (HBr) cylinders have a shelf-life of one to two years, depending on the vendor. Over time, moisture can slowly enter the cylinder, which initiates corrosion. As the corrosion continues, HF and/or HBr slowly react with the internal metal walls of the cylinder to produce hydrogen. The walls of the cylinder weaken due to the corrosion, while at the same time the internal pressure increases due to the hydrogen generation. Ultimately, these cylinders fail and create extremely dangerous projectiles and a toxic gas release. Figure 14.2 shows a 30-year old HF lecture bottle cylinder that exploded in a University of Michigan laboratory in 2011.

Figure 14.2 – HF Cylinder Incident at University of Michigan in 2011

Chapter 15: Medical Consultation and Examination

15.1 Injuries, Illnesses, and Medical Examinations

Employees must notify their Laboratory Supervisor of all injuries and illnesses regardless of the magnitude. The Laboratory Supervisor must ensure that a First Report of Injury form is completed. Employees should report to a Michigan Tech approved occupational medical provider if medical attention is required. If the injury is serious and presents an emergency situation, dial 911 and emergency responders (Michigan Tech Police or Portage Ambulance) will respond and transport the patient to a local hospital emergency room. For more information regarding the First Report of Injury reporting process, visit the OSHS webpage (www.mtu.edu/oshs/injury-reporting/injury-form/)

Departments must provide all employees who work with hazardous chemicals 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;
- Where exposure monitoring reveals an exposure level routinely above the action level (or in the absence of an action level, the permissible exposure limit) for an OSHA 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; and
- 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 examination. All medical examinations must be performed by or under the direct supervision of a licensed medical care provider and must be provided without cost to the employee.

15.2 Injury and illness

For urgent medical treatment, under current Michigan Tech policies and procedures, affected employees must seek care from the Emergency Room at Portage Hospital at 200 Michigan Avenue, in Hancock 906-483-1000.

The supervisor or instructor must ensure the appropriate injury report forms are completed.

If you have any questions regarding injury and illness procedures, contact your supervisor, instructor or the Michigan Tech Department of Police and Public Safety.

Minor First Aid

First Aid Kits. First aid kits are not recommended except for remote operations where emergency care is not readily available. If a unit desires a first aid kit, it must be maintained with essential supplies at all times. See a General Stores Catalog for a list of essential supplies.

Do not dispense or administer any medications, including aspirin. Do not put any ointments or creams on wounds or burns. Use cool water. The SDS contains specific first aid information for a given chemical.

15.3 Medical consultations and examinations

Health assessments prior to work assignment for new employees will be performed under the following conditions:

- When conditions specified by the Exposure to Health Risks form (available from OSHS) are met, the employee must send the completed form to the Michigan Tech Occupational Safety and Health Services and then schedule an appointment for a medical examination prior to work assignment. Note that there are separate forms for full-time employees and student employees.

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

- When an employee develops signs or symptoms associated with a hazardous chemical to which the employee may have been exposed in the laboratory, the employee must be provided an opportunity to receive an appropriate examination.

- Where exposure monitoring reveals an exposure level routinely above the action level (or in the absence of an action level, the Permissible Exposure Limit) for an OSHA 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 consultations 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 direct supervision of a licensed physician and must be provided without cost to the employee, without loss of pay and at a reasonable time and place.

The unit shall provide the following information to the physician:

- 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.
- A description of the signs and symptoms of exposure that the employee is experiencing, if any. The unit shall obtain a written opinion from the examining physician 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 by the physician of the results of the consultation or medical examination and any medical condition that may require further examination or treatment.
- The written opinion of the physician shall not reveal specific finding of diagnoses unrelated to occupational exposure.

Appendix A: Biological Safety

A.1 Requirements

In order to be in compliance with this chapter of your CHP the following items must be completed.

- Write and implement an Exposure Control Plan, *if necessary*
- Document Bloodborne Pathogens training by OSHS
- Initiate Hepatitis B Vaccine Program
- Document exposures
- Maintain housekeeping schedule

A.2 MiOSHA Bloodborne Pathogens Standard

The purpose of the bloodborne pathogens standard is to reduce or eliminate the risk of occupationally acquired infections from human-derived products such as blood, tissues, and other body substances. In order to be in compliance with this standard that can be found in MiOSHA Part 554, Rule 325.70001, all laboratories that work with blood or other potentially infectious materials must have a written exposure control plan. To prevent occupational exposure to potentially infectious bloodborne pathogens, all laboratories must apply *Universal Precautions*. Universal Precautions is a method of infection control in which the following materials are to be treated as if known to be infectious:

- Blood products, semen, vaginal secretions
- Saliva in dental settings
- Any body fluid that is contaminated with blood
- Any body fluid of unknown source
- Unfixed tissues or organs
- HIV or HBV containing cells or cultures
- Blood, organs or other tissues from experimental animals infected with BBP
- Introduction of human-derived materials, i.e., tumor cells into animals

In addition to Universal Precautions, the rule mandates specific items that must be addressed to minimize occupational exposure to bloodborne pathogens. These items include:

- Written Exposure Control Plan
- Exposure Determination

- Hepatitis B Vaccine Program
- Medical Policies
- Training Program
- Workplace Practice Controls (PPE, Housekeeping)
- Biohazardous Waste Handling

Perhaps the best advice and guidance in the relatively complex area of biological hazards management can be obtained from contacting the Biosafety Officer: **Biosafety Officer, OSHS** Mr. David Dixon Phone: 906-487-2131.

General background information, the basic principles of biosafety, and an explanation of the biosafety "levels" as applied to facilities and hazard control can be found in the Center for Disease Control (CDC) – National Institutes of Health (NIH) guidance document "Biosafety in Microbiological and Biomedical Laboratories Manual." This information, as a minimum, must be understood by all persons working in laboratories with biohazards and should be part of training for all such persons.

A.3 Terms and Definitions

Bloodborne Pathogens (BBP) are pathogenic microorganisms that are present in human blood and can cause disease to humans. These pathogens include, but are not limited to, hepatitis B virus (HBV) and human immunodeficiency virus (HIV). **Contaminated** means the presence; or the reasonably anticipated presence; of human blood or other potentially infectious materials on an item or surface. **Contaminated Laundry** means laundry that has been soiled with human blood or other potentially infectious materials or may contain sharps. Contaminated **Sharps** means any contaminated object that can penetrate the skin. **Decontaminated** means the use of physical or chemical means to remove, inactivate, or destroy bloodborne pathogens on a surface or on an item to a point where they are no longer capable of transmitting infectious particles and the surface of the item is rendered safe for handling, use, or disposal. **Exposure Incident** means a specific eye, mouth, other mucous membranes, non-intact skin, or parenteral contacts with human blood or potentially infectious materials that result from the performance of a researcher's duties. **Occupational Exposure** occurs when U of M employees' skin, eye, or mucous membrane has come in contact with human blood or potentially infectious materials as a result of performing their professional duties. **Universal Precautions** is an approach to infection control. According to the concept of Universal Precautions, all human blood and certain human body fluids are treated as if known to be infectious for HIV, HBV, and other bloodborne pathogens.

A.4 Written Exposure Control Plan

Exposure Control Plans apply to all research personnel with occupational exposure to human blood or other potentially infectious materials. Exposure Control Plans (ECP) are designed to eliminate or minimize exposure to human bloodborne infectious agents. The ECP must be accessible to employers as well as reviewed and updated annually. MiOSHA provides a "template" or model document for the preparation of an ECP for Bloodborne Pathogen compliance. This document can be downloaded from the MiOSHA website at: https://www.osha.gov/Publications/osha3186.pdf

A.5 Exposure Determination and Post-Exposure Evaluation

In the event of exposure to human blood or blood products, research personnel should immediately flush the affected area with copious amounts of water and seek medical attention at the branch of the Portage at the SDC as soon as possible and report that they have received an occupational injury of a potentially infectious nature. Following an exposure incident, a free, confidential medical evaluation and follow-up will be offered. The evaluation and follow-up will include the following elements:

- Documentation of the routes of exposure(s), and the circumstances under which the incident occurred.
- If possible, identification of the source.
- If consent is granted and the source can be identified, the HIV/HBV antibody status of the source. If consent is not granted, it will be established that legally required consent cannot be obtained.
- An exposed individual's blood will be collected and tested for HIV/HBV status as soon as feasible and after written consent is obtained.
- Follow-up on the exposed person will include: offering 6-month antibody or antigen serologic testing, counseling, illness reporting and safe and effective post-exposure prophylaxis.

A.6 Hepatitis B Vaccine Program

OSHS strongly recommends that all research personnel who have the potential for occupational exposure to bloodborne pathogens take advantage of the hepatitis B vaccine program. Hepatitis B vaccinations are available, at no cost, for all research personnel who have occupational exposure or have been involved in an exposure incident. Research personnel who decline to accept the vaccination will be required to sign a statement of declination. Follow-up hepatitis B virus (HBV) antibody titer testing is also available to research personnel at no cost. To arrange for vaccination or follow-up, call Michigan Tech's OSHS at 906-487-2118 for an appointment. It may also be possible to get these vaccinations at the Western UP Health Department, 540 Depot Street Hancock, MI, phone 906-482-7382. Research personnel who plan to work with human blood or other potentially infectious body fluids must notify their supervisor if they have not received Bloodborne Pathogens training or have not been offered a vaccination for hepatitis B virus.

A.7 Medical Policies

The University will maintain a record for thirty (30) years for any personnel with occupational exposure in accordance with 29 CFR 1910.20. The record will include a copy of the employee's hepatitis B vaccination status, results of examinations, medical testing and follow-up procedures, and the written opinions and information provided by the health care professional.

A.8 Training Program

The Principal Investigator will maintain a record of training for each researcher with occupational exposure. The record will include the date of training, the contents of the training, the names and qualifications of the persons conducting the training, and the job title of the researcher. All training records will be maintained for three years from the date training occurred. Bloodborne Pathogen Training conducted by OSHS is required for all employees who may potentially be exposed to bloodborne pathogens.

A.9 Biohazardous Waste

- Sharps*** –** Dispose of sharps such as needles, contaminated broken glass and scalpels in labeled, hard-walled sharps containers that are available from OSHS.
- Solids*** –** Place solid waste such as laboratory coats in special biohazardous waste containers available from OSHS.
- Liquids*** –** If disinfected with bleach, blood and blood products can be poured down the drain. If the biohazardous liquid waste contains other chemicals besides bleach, manifest as chemical waste.
- Autoclaved **Waste –** Place waste that will be autoclaved in clear autoclave bags that have a color change indicator that shows waste has been autoclaved. Do not put sharps or standing liquids in autoclave bags. This autoclaved waste can then be disposed with normal, uncontaminated waste.
- Call for pick-up by OSHS (906-487-2131).

A.10 Work Practices and Controls

A.10.1 Housekeeping

- Clean and disinfect all equipment and working surfaces after the completion of procedures or immediately after overt contamination. A solution of l0% (volume/volume) commercial bleach and water is an effective disinfectant. Other commercially available cleaning solutions are available from scientific supply companies.
- Decontaminate equipment that requires servicing prior to servicing or shipping.
- Label equipment as “contaminated”, if it cannot be decontaminated prior to service.
- Remove protective coverings as soon as feasible when they become overtly contaminated.

A.10.1.1 Additional Biological Disinfectants

Liquid Disinfectants noted by NIH (National Institutes of Health) (www.nih.gov/od/ors/ds/pubs/biodecontamination/biodecon1.html):

- 2% Glutaraldehyde (aqueous)
- 2% Hydrogen peroxide (stabilized)
- 1-8% Formaldehyde (aqueous)
- Iodophors (30-50 mg. of free iodine per liter; 70-150 mg of available iodine per liter)
- Chlorine compounds (500-5,000 mg of free chlorine per liter)
- 70% Alcohol (ethyl or isopropyl)
- 0.5% Iodine and 70% alcohol
- 0.5-3% Phenolic compounds (aqueous)
- 0.1-0.2% Quaternary ammonium compounds (aqueous)

From the ORCBS (Michigan State University) website (www.ehs.msu.edu/biological/programs_guidelines/biosafety_manual/Biosafety_Manual.pdf): There are many different liquid disinfectants available under a variety of trade names. In general, these can be categorized as halogens, acids or alkalines, heavy metal salts, quaternary ammonium compounds, aldehydes, ketones, alcohols, and amines. Unfortunately, the most effective disinfectants are often very aggressive (corrosive) and toxic. Some of the more common ones are discussed below:

Alcohols: Ethyl or isopropyl alcohol in concentration of 70% to 90% are good general-use disinfectants. However, they evaporate fast and therefore have limited exposure time. They are less active against non-lipid viruses and ineffective against bacterial spores. Concentrations above 90% are less effective.

Formalin: Formalin is 37% solution of formaldehyde in water. Dilution of formalin to 5% results in an effective disinfectant. Formaldehyde is a human carcinogen and creates respiratory problems at low levels of concentration.

Glutaraldehyde: This compound although chemically related to formaldehyde, is more effective against all types of bacteria, fungi, and viruses. Vapors of glutaraldehydes are irritating to the eyes, nasal passages and upper respiratory tract. They should be used always in accordance with the instructions on the label and the appropriate personal protective equipment.

Phenol and Phenol Derivatives: Phenol based disinfectants come in various concentrations ranging mostly from 5% to 10 %. These derivatives including phenol have an odor, which can be somewhat unpleasant. Phenol itself is toxic and appropriate personal protective equipment is necessary during application. The phenolic disinfectants are used frequently for disinfection of contaminated surfaces (e.g., walls, floors, bench tops). They effectively kill bacteria including Mycobacterium tuberculosis, fungi and lipid-containing viruses. They are not active against spores or non-lipid viruses.

Quaternary Ammonium Compounds ("Quats"): Quats are cationic detergents with strong surface activity. They are acceptable for general-use disinfectants and are active against Gram-positive bacteria and lipid-containing viruses. They are less active against Gram-negative bacteria and are not active against non-lipid-containing viruses. Quats are easily inactivated by organic materials, anionic detergents or salts of metals found in water. If Quats are mixed with phenols, they are very effective disinfectants as well as cleaners. Quats are relatively nontoxic and can be used for decontamination of food equipment and for general cleaning.

Halogens (Chlorine and Iodine): Chlorine-containing solutions have broad spectrum activity. Sodium hypochlorite is the most common base for chlorine disinfectants. Common household bleach (5% available chlorine) can be diluted 1/10 to 1/100 with water to yield a satisfactory disinfectant solution. Diluted solutions may be kept for extended periods if kept in a closed container and protected from light. However, it is recommended to use freshly prepared solutions for spill clean-up purposes. Chlorine-containing disinfectants are inactivated by excess organic materials. They are also strong oxidizers and very corrosive. Always use appropriate personal protective equipment when using these compounds. At high concentrations and extended contact time, hypochlorite solutions are considered cold sterilants since they inactivate bacterial spores. Iodine has similar properties to chlorine. Iodophors (organically bound iodine) are recommended disinfectants. They are most often used as antiseptics and in surgical soaps and are relatively nontoxic to humans.

A.10.2 Engineering Controls

- Perform all work that may create an aerosol in a biological safety cabinet.

A.10.2.1 Biological Safety Cabinet (BSC) Guide

OSHS provides many services to ensure laminar flow hoods and biological safety cabinets (BSC) operate as intended. The BSC is designed to prevent employee exposure to biohazardous agents, prevent a release to the environment, and minimize contamination of research materials. Services OSEH provides include:

- Annual certification and maintenance on modern Class II biological safety cabinets with readily available parts.
- Training, education, selection, and placement evaluations, technical assistance, and laboratory design review.
- Review and revise the Biological Safety Cabinets Guideline as needed.
- In order for a BSC to work correctly, laboratory personnel must be trained in its proper use. Staff should be made aware of the OSEH Guideline and its contents available at www.oseh.umich.edu/pdf/guideline/guidbsc.pdf. Some key components of the guideline are summarized below. CONTACT PERSON For each biological safety cabinet a designated contact person must be identified. This facilitates communication necessary for the annual inspection, routine maintenance and other functions that OSEH performs. OSHS must be contacted at 906-487-2131 whenever there is a change in the contact person.

A.10.2.2 Annual Certification

OSHS will arrange an appointment and notify the contact person by campus mail of the date and time the biological safety cabinet will be certified. If the assigned date is not convenient, call 906-487-2131 to arrange a new time. All items including clamps and hoses must be removed and surfaces must be wiped down with a disinfectant. Refer to Section 7.10.2.1 for a suitable disinfectant.

A.10.2.3 New Installations and Relocations

Please Contact OSHS at 906-487-2131 for a site evaluation and for certification of a new and relocated BSC. Prior to relocating a BSC, OSHS must be notified two weeks in advance. OSEH will then send a decontamination form to the contact person to be completed and returned. The form will be evaluated by the Biological Safety Officer to determine if decontamination of the biological safety cabinet is necessary. The form will be returned to occupant following review. The form must be attached to BSC prior to relocation of the BSC.

A.10.2.4 Placement

The placement of a biological safety cabinet within a laboratory is very important for its proper performance. All biological safety cabinets must have a twelve-inch clearance from the ceiling and on both sides so they can be properly serviced and certified. Make sure biological safety cabinets are placed away from doors, windows, supply vents, or high traffic areas. Make sure the cabinet is level. If the cabinet is not, the airflow can be affected. To ensure proper placement, please contact OSHS at 906-487-2131 to arrange a site evaluation.

A.10.2.5 Helpful Hints on the Use of Biological Safety Cabinets

START-UP PROCEDURE

- Many manufacturers recommend leaving the cabinet running at all times with the sash at the recommended operating height. This is usually 8 or 10-inches. Check your owner's manual for the correct window height, as the proper operating position is not variable on these units. If the sash is positioned too high, the user is more likely to contaminate themselves and their work. If the sash is positioned too low, the unit is starved for airflow creating the likelihood of product contamination.
- Never completely close the window sash with the motor running. This may cause the motor to burn out and will force room air to contaminate the work area. If the cabinet has been turned off, turn the blower switch to ON and do not use the cabinet for at least five minutes to allow time for room air to be removed from the cabinet. Make sure you have airflow, either by listening for blower sound or by feeling the airflow with your fingers. If your cabinet has a pressure indicator make sure it does not read zero.
- If your cabinet is equipped with an ultraviolet (UV) light, turn it off and turn on the fluorescent light before beginning work. It is important to avoid hazardous exposure of skin and eyes to UV light. Make sure the drain valve is closed and wipe down the interior of the cabinet with a disinfectant. Wipe down all the interior surfaces of the BSC with an appropriate disinfectant. Place all the equipment and supplies you will need inside the cabinet to minimize entering and exiting. This includes placing a receptacle for waste and used pipettes **inside** the BSC. Segregate items that will remain clean from the ones that will get contaminated. Allow the HEPA filtered air to wash over them for a minute or two. Wipe all the supplies with an appropriate disinfectant.

WORKING IN THE CABINET

- These units are designed for a single operator. Never work two or more people at a time. This will cause enough air disturbance to breach the containment capabilities of the BSC, even in the six-foot cabinets.
- Never operate a cabinet while a warning light or alarm is on.
- The operator should be seated with armpits level with the bottom of the sash.
- Make sure everything necessary for the procedure is already inside and sterile. Slowly introduce gloved hands into the BSC and let air wash over them for a few seconds before beginning. Perform all work using a limited number of slow movements, as quick movements disrupt the air barrier.
- Keep all materials at least four inches inside the sash opening. Never place items on the front or rear perforated grills. This creates air turbulence that increases the risk of contamination to the user or the research.
- Activities that create eddy currents (opening and closing doors and windows, personnel walking near the cabinet) should be minimized as these types of activities can disrupt the air barrier.
- Avoid movements in and out of the cabinet during the procedure.
- Do not use an open flame in a BSC as it creates turbulence that affects the unit's containment ability.

COMPLETING WORK IN THE CABINET

- All equipment that has come in contact with the research agent should be decontaminated. The cabinet should be allowed to run for at least three minutes with no activity so that the airborne contaminants will be purged from the work area. Then remove the equipment.
- After all items have been removed, wipe the interior surfaces with a disinfectant.

COMMON ERRORS TO AVOID

- Keep papers, paper towels, Kim Wipes, work surface diapers, vials, or any other objects from being pulled in the back, front, or side slots or grills. These items can damage your cabinet's internal components.
- Do not store equipment or supplies in the cabinet.
- Do not use the top of the cabinet for storage. The HEPA filter could be damaged and the airflow disrupted.
- Never disengage the alarm. It indicates improper airflow and reduced performance that may endanger the researcher or the experiment.

A.10.3 Personal Protective Equipment (PPE)

- Wear gowns, lab coats, aprons or similar protective clothing.
- Wear fluid-resistant clothing if there is a potential for splashing or spraying of blood.
- Wear gloves for all blood and tissue sample collection.
- Wear disposable (single use) latex or polyvinyl chloride (PVC) gloves.
- Replace gloves as soon as possible when visibly soiled, torn or punctured. Latex, PVC, and hypoallergenic disposable gloves are available from various laboratory supply companies.
- Wash your hands or any other contaminated skin with soap and water immediately or as soon as possible after removal of gloves and after visible contact with blood or other potentially infectious materials.
- Use facial barrier protection whenever splashes, spray, droplets, or aerosols may be generated (NOTE: Opening containers creates aerosols). Additional face protection may include the following: hood sashes, shields, masks and safety glasses, or chin-length face shields. Also, perform work in a biosafety cabinet when working with aerosols.
- Remove all PPE immediately upon leaving the work area and as soon as possible if overtly contaminated. Contaminated PPE will be DISPOSED of as biohazardous waste or decontaminated.

A.10.4 Good Laboratory Practices

- Remove all sharps from the pockets of soiled lab coats and other protective clothing prior to exchange for clean garments.
- Affix “biohazard” labels to containers of waste, refrigerators and freezers containing blood or other potentially infectious material. Labels for contaminated equipment must also state which portion of the equipment remains contaminated. Individual containers of blood or other potentially infectious materials that are placed in a labeled secondary container during storage, transport, shipment, or disposal, need not be labeled. Caution signs should be labeled with a “biohazard” warning sticker and posted at the entrances of work areas where risk of exposure exists.
- DO NOT pick up broken glassware that may be contaminated directly with your hands.
- Mouth pipetting is prohibited.
- Minimize splashing or spraying.
- Needles and other sharps will NOT be sheared, bent, broken, recapped, or resheathed by hand. Used needles will NOT be removed from disposable syringes.
- Eating, drinking, smoking, applying cosmetics or lip balm, and handling contact lenses is prohibited in work areas.

- Do not store food and drink in refrigerators, freezers or cabinets where blood or other potentially infectious materials are stored.
- Wash hands after contact with body fluids.

A.11 Specimen Handling

The primary container for the transport or shipping of specimens must be closable, labeled, and leak-proof. If outside contamination of the primary container is likely, then a second labeled, leak-proof container must be used. The container must be labeled with the Principal Investigator's name, the person who is transporting, the primary research room, description of contents, and a contact phone number.

A.12 Biological Spills

Biological spills outside biological safety cabinets will generate aerosols that can be dispersed in the air throughout the laboratory. These spills are very serious if they involve microorganisms that require Biosafety Level (BL) 3 containment, since most of these agents have the potential for transmitting disease by infectious aerosols. To reduce the risk of inhalation exposure in such an incident, occupants should hold their breath and leave the laboratory immediately. The lab should not be reentered to decontaminate and clean up the spill for at least 30-minutes. During this time the aerosol will be removed from the lab by the exhaust air ventilation system. Appropriate protective equipment is particularly important in decontaminating spills involving microorganisms that require either BL2 or BL3 containment. This equipment includes lab coat with long sleeves, back-fastening gown or jumpsuit, disposable gloves, disposable shoe covers, safety goggles, and full face shield. Use of this equipment will prevent contact with contaminated surfaces and protect eyes and mucous membranes from exposure to splattered materials.

A.12.1 Procedures for Biological Spill On Body

- Remove contaminated clothing and vigorously wash exposed area with soap and water for 3-minutes.
- Contact Michigan Tech's OSHS for advice on medical attention
- Report the incident to the Principle Investigator.
- See other sections of the CHP for guidelines on handling spills.

A.12.2 Procedures for Spills Involving Microorganisms Requiring BL1 Containment

- Wear disposable gloves.
- Soak paper towels in disinfectant and place over the spill area.
- Place paper towels in a sealed container and put a “biohazard” marking on the container.
- Clean spill area with fresh towels soaked in a disinfectant.
- Report the spill to the Principal Investigator.

A.12.3 Saturate with an appropriate Disinfectant* and let stand 15 – 20 Minutes:

- Bleach:water (1:10 dilution),
- Lysol®,
- Virex™, or
- an EPA registered tuberculocidal disinfectant (www.epa.gov/oppad001/list_b_tuberculocide.pdf).
- Alert people in the immediate area of the spill.
- Put on protective equipment.
- Cover the spill with paper towels or other absorbent materials.
- Carefully pour a freshly prepared 1:10 dilution of household bleach and water solution around the edges of the spill and then into the spill. Avoid splashing.
- Allow a 20-minute contact period.
- Use paper towels to wipe up the spill, working from the edges into the center.
- Clean the spill area with fresh towels soaked in disinfectant.
- Place towels in a sealed container and put a “biohazard” marking on the container.
- Report the spill to the Principal Investigator.

A.12.4 Procedures for Spills involving Microorganisms Requiring BL3 Containment

- Attend to injured or contaminated persons and remove them from exposure. They should remove contaminated clothing and wash affected areas with soap and water.
- Alert people in the laboratory to evacuate.
- Close doors to the affected area.
- Call OSHS, 906-487-2118, to report the spill. If after hours, call the Public Safety and Police Services (PSPS) at 906-487-2216 or 9-1-1 to report the spill.
- Have a person knowledgeable of the incident and lab assist emergency personnel.
- Report the spill to the Principal Investigator, the Department Chair and OSHS.

A.13 Laboratory Animals

This section was written by Gary L. Hofing, D.V.M., Ph.D., Clinical Instructor in Lab Animal Medicine, UM Medical School. It is included in this CHP because it provides a good discussion of safety issues pertaining to lab animals, a category of “biological” hazards.

Introduction – The process of developing a set of requirements and guidelines for the safe handling of laboratory animals must begin by identifying areas of potential hazard. Several general categories of hazard, e.g., physical, infectious, and allergic, can readily be identified as potential problems encountered when handling animals. The most easily recognized hazard of working with animals is the physical hazard. Many higher vertebrates have defensive and, in some cases, offensive behaviors and adaptations that make them capable of rendering painful and even incapacitating injuries. Procedures and safety equipment must be geared to the capability of the various species. Not necessarily so obvious to most people is the potential for spread of diseased organisms from animals to man. These so-called zoonotic diseases include agents of all the major categories of infectious organisms, i.e., viruses, bacteria, parasites, and fungi. Spread can occur, for example, through bite wounds, by direct contact with agents on the animal or in its excretions, by aerosol, or on fomites. The degree of hazard from a given animal varies with the species, source of the animal, and the use of the animal. Measures to minimize infectious hazards involve all stages of animal research from procurement through final disposition. Protective apparel varies with the species involved. However, a minimum requirement is a laboratory coat over street clothing. Infectious hazards are insidious and, therefore, safe practices should be habitual and diligently enforced. The intent of these guidelines is to safeguard human health and to ensure that handling does not put the experimental animals at undue risk. Some diseases of humans (e.g., tuberculosis, salmonellosis, influenza) represent a risk to animal health as well as a possible complication of experimental procedures. Safe handling techniques are also intended to prevent injuries to research animals. For some individuals, handling animals means immediate discomfort due to rhinitis, conjunctivitis, asthma, or atopic dermatitis. These are signs associated with allergy to animals. The specific materials (allergens) which trigger an allergic response are not easily identified, but may include fur, dander, or proteins occurring in animal urine or saliva. Persons with known allergies to animals should consult a physician regarding their condition and work environment. Methods to prevent the development of allergies are aimed at minimizing exposure to animals. These include: separation of animal space from human occupancy areas, providing proper sanitation in animal rooms, using only high quality, relatively dust-free bedding materials, using HEPA filtered vacuum cleaners to clean animal fur, and wearing gloves and laboratory clothing. Working with animals also entails working in animal rooms which have inherent physical hazards. Regular use of water makes floors slippery and increases danger from electrical shock.

Animal caging is heavy, cumbersome, and if not in good repair, may have sharp edges, etc. Precautions need to be taken to prevent falls, back injuries, cuts, and similar injuries. Finally, particular protocols may require using hazardous substances or infectious organisms in laboratory animals. Such studies present unique hazards not encountered in routine work with animals. Special precautions may be needed. Review by the responsible investigator and the Animal Care and Use Committee is required. Safety requirements and action plans need to be decided before study is initiated.

First Aid and Researcher Health Assessment -- Bite and scratch wounds should be treated as contaminated wounds. Persons sustaining such wounds should obtain First Aid immediately. The wound should be cleansed with mild soap under running tap water. It should be permitted to bleed freely during cleansing. Employees should notify their supervisor and report to the Portage medical facility for medical evaluation and follow-up. Further instructions will be provided by health care professionals. Health care professionals should contact David Dixon at 906-487-2131 to investigate any instance of animal bite wound. Depending on circumstances, animals may be placed under observation for rabies. A “RABIES SUSPECT” tag will be placed on the animal's cage to identify it as a potentially hazardous animal. The animal will be quarantined according to established procedures. In addition to the pre-employment and routine health assessments, individuals handling non-human primates should be evaluated once a year for tuberculosis.

Sick, Injured, or Dead Animals -- By law and University policy, sick or injured animals must be provided adequate veterinary care. Any person observing an animal that appears sick or injured should immediately report the incident to OSHS. Animals found dead from unknown causes must be reported to OSHS personnel. Assessment of cause of death is both a regulatory requirement and a requirement for human safety and the health of animal colonies.

Animal Waste Disposal – OSHS personnel provide receptacles for animal carcasses and eventual pick-up by OSHS. Members of the scientific staff are responsible for both assuring that animals are dead prior to disposal and for placing carcasses in leakproof plastic bags before depositing in the provided receptacle. Carcasses generated on weekends must be placed in cold rooms designated for that purpose. Cold rooms used for animal food storage must not be used for carcasses. Tissues and other animal waste may be disposed by incineration.

A.14 Institutional Biosafety Committee (IBC)

The Institutional Biosafety Committee oversees **recombinant DNA research** at Michigan Tech. Michigan Tech adheres to the NIH Guidelines for Research Involving Recombinant DNA Molecules with regard to all uses of recombinant DNA at the University. Michigan Tech requires that all use of recombinant DNA at the University be registered with the IBC even if such use is exempt from the requirements of the NIH Guidelines.

The Principal Investigator at Michigan Tech is responsible for registering rDNA work and for ensuring the use of proper microbiological practices and laboratory techniques at the approved biosafety level. Additional Principal Investigator responsibilities are detailed in Section IV-B-7 of the NIH Guidelines. Principal Investigators are asked to update their IBC registrations periodically and when new projects arise involving rDNA, so as to ensure the registrations on record are consistent with the investigator's current rDNA work. Visit the IBC web page at www.admin.mtu.edu/admin/committe/memberi.htm for more information.

Appendix B: Radiation Safety

B.1 Requirements

In order to be in compliance with this chapter of your CHP the following items must be completed. Maintain the following records in accordance with State and Federal regulations or Tech's protocols:

- radioactive material inventories,
- contamination survey results,
- personnel radiological safety training and annual re-training, and
- radioactive waste manifests.

B.2 General Considerations

Radioactive material compounds, radiation-producing devices, radioactive sealed or plated sources, and devices that contain a radioactive source require special authorization, training, and adherence to Michigan Tech's policies and procedures. Personnel working with such materials or devices must address all aspects of the hazard management specified for chemicals in this CHP. In addition, there are mandatory regulatory requirements specified by the State and Federal agencies that apply to the procurement, use, and disposal of radioactive materials and radiation-producing devices. The failure to comply with these requirements can result in serious consequences including temporary suspension of radioactive material or radiation-producing device use and financial fines. As the full impact of these regulatory requirements is beyond the scope of this CHP, it may be necessary to contact OSHS for guidance or assistance in developing policies and procedures necessary for regulatory compliance. Contact the Michigan Tech Radiation Safety Officer (RSO) at 906-487-2118 for specific radiological assistance with respect to proper radiation safety program protocols. Michigan Tech has one NRC License: 21-00278-02, "The use of small quantities of by-product material for lab research." The State of Michigan's regulations have been published as "Regulations Governing the Use of Radioactive Isotopes, X-Radiation, and all Other Forms of Ionizing Radiation." Copies of both the State and Federal regulation are on file in the Office of Occupational Safety and Health Services. In all cases, operations shall be undertaken only within the limits of the applicable government regulations

Anyone handling radioactive materials or working with an x-ray machine or other radiation-producing device should first contact the OSHS RSO for advice or assistance regarding all necessary State and Federal regulations. See www.mtu.edu/oshs/safety-programs/required/radiation-safety/ for further information regarding university policies, RSC structure and on how to become a university recognized Documented Responsible User (DRU).

B.3 Regulatory Compliance

The following discussion regarding radiological safety and regulatory compliance was drafted by University of Michigan Radiation Safety Officer (RSO) Mark L. Driscoll, M.S., in a general memorandum to radioactive material users. It has been edited to conform to Michigan Tech policies. Additional radiological safety/regulatory compliance and low-level radioactive waste (LLRW) disposal information can be obtained from Michigan Tech's Radiation Safety Website at www.mtu.edu/oshs/safety-programs/required/radiation-safety/.

Introduction – The Nuclear Regulatory Commission (NRC) conducts comprehensive regulatory inspections at the University; therefore, it is essential that all individuals using radioactive materials follow established radiological safety protocols. Please ensure the protocols described below are properly addressed and followed at all times in your laboratories or facilities:

Documented Responsible User Authorization – All personnel intending to become a Documented Responsible User (DRU) and work with radioactive material **must** first be approved by Michigan Tech's RSO. Contact the RSO at 906-487-2118 for an Application for Authorization to Use Radioactive Material. In addition, any significant changes in authorized radioactive material protocols must be approved by the RSC. The RSO may grant temporary approval pending final approval by the RSC.

Storage of Radioactive Material – Radioactive material must **only** be used in laboratories or facilities that have been approved by the RSC. In addition, containers or radioactive material or potentially contaminated objects must be labeled with radioactive material warning tape bearing the radiation symbol and the words "CAUTION RADIOACTIVE MATERIAL." At the university of Michigan, Medical and research institutions have been issued Notices of Violations (NOV) recently by the NRC for failing to:

1) secure radioactive material from unauthorized removal or use (10 CFR 20.1801 (re: US NRC Storage and Control of Licensed Material, www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1801.html) and 20.1802, Control of material not in storage, www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1802.html),

2) post rooms in which radioactive material is used or stored (10 CFR 20.1902, www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1902.html), and

3) label radioactive material containers or contaminated objects with appropriate warning tape (10 CFR 20.1904, www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1904.html).

NOTE: Door labels and refrigerator/freezer labels are available from OSHS RSO. The NRC **requires** each licensee to use, to the extent practicable, procedures and engineering controls based upon sound radiation protection principles to maintain occupational doses and doses to the members of the public "as low as is reasonably achievable" (ALARA) [10 CFR 20.1101(b), www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1101.html].

ALARA Program – Research personnel **must** be familiar with the "as low as is reasonably achievable" (ALARA) dose concept. NRC inspectors have been known to question research and clinical personnel regarding their understanding of this philosophy. At Michigan Tech, implementation of the ALARA program is the responsibility of the Administration, RSO, OSHS RSC, DRUs, and all users of radioactive material. It is the responsibility of all radioactive material users to maintain both internal and external doses and radioactive contamination ALARA.

Documentation of Radioactive Contamination Surveys – Research and clinical personnel **must** conduct and document contamination surveys in the manner and frequency specified in license #21-00278-02. Radioactive materials must be used, stored, and disposed of according to 10CFR/20 (Standards for protection against radiation, www.nrc.gov/reading-rm/doc-collections/cfr/part020/) rules. Each DRU has a copy of these rules and is expected to follow all of them. Note that it is essential that some form of documentation is **required** in your radiation safety records binder even if unsealed radioactive material had not been used in a particular authorized room over the established survey frequency. While the actual contamination survey is not required when no work has been performed during the survey frequency period, you **must** document in your contamination survey records that "NO RAD WORK WAS CONDUCTED" during this time period. The NRC will expect to see some form of documentation whether contamination surveys were performed or not. Another option available to DRUs to alleviate the burden of having to perform and document contamination surveys is to request (in writing) that a certain laboratory or facility be removed from your radionuclide authorization application and be officially decommissioned by the OSHS RSO personnel. However, be aware that once a lab is decommissioned you must submit a request (in writing) to OSHS RSO requesting reactivation of the laboratory or facility **before** work with radioactive material can be initiated. Failure to obtain the appropriate authorization from OSHS RSO prior to working with radioactive material in a laboratory **will** result in a Notice of Deficiency (NOD) from OSHS RSO, or worse, an NOV and possible financial fine from the NRC.

Common NRC Violations – The following incidents are frequently cited during NRC inspections at universities:

- Failure to conduct and document routine contamination surveys.
- Failure to secure radioactive material from unauthorized use, removal, or vandalism. This includes radioactive material packages delivered to departmental “package” rooms by dock personnel awaiting pickup by users.
- Failure to monitor your hands, shoes, floors, and work areas for contamination after handling radioactive material or departing a laboratory.
- Failure to conduct and document **annual** radiation safety retraining.
- Failure to wear appropriate protective clothing (labcoats / disposable gloves) or use appropriate shielding when working with radioactive material.
- Failure to wear required whole body and finger ring dosimeters when required by OSHS RSS.
- Failure to notify RSS (in writing) prior to establishing, vacating, or relocating a radioactive material laboratory.
- Failure to label radioactive material containers and contaminated laboratory equipment and supplies.
- Failure to report radioactive spills or contamination incidents to OSHS RSS.
- Failure to monitor and document radioactive material package surveys.
- Failure to provide complete and accurate information in your records or to regulatory inspectors.
- Failure to have a thyroid count by OSHS RSS personnel when required by OSHS RSS.

Responsibilities of “DRUs” – At the University of Michigan, recent NOVs issued to medical and research institutions by the NRC are focusing on the responsibilities of the “DRU”; especially, with respect to the supervision and oversight of supervised individuals. The intent of this discussion is to remind DRUs of their responsibilities. Adequate supervision by the DRU ensures that supervised individuals do not use radioactive material in a manner that is contrary to Michigan Tech radiological safety protocols, the requirements of the University’s radioactive material license, NRC regulations, or which may otherwise be potentially hazardous to public health and safety. “Supervised individuals” include: research personnel, laboratory technicians, laboratory assistants, clinical technologists, secretaries, visitors, supervised physicians, etc.

NRC Regulatory Requirements – A DRU is required to supervise and provide instruction to supervised individuals and periodically review the supervised individual’s use of radioactive material and the records maintained to reflect this use. The licensee (Michigan Tech) and the

DRU that supervises individuals are both responsible for the acts and omissions of the supervised individual.

Adequate Supervision by the DRU – When individuals receive authorization from Michigan Tech RSO to work with radionuclides, they become directly responsible for:

- compliance with all regulations governing the use of radioactive materials in their possession and
- the safe use of radionuclides by other research personnel, technicians, or supervised physicians who work with the materials under their radionuclide authorization and supervision. DRUs must limit the possession and use of radionuclides to the activities and the purposes specified on their radionuclide authorization and are obligated to: Ensure that individuals working with radionuclides under their authorization are properly supervised and have received Michigan Tech training and indoctrination to enable safe working habits, compliance with the regulations, and prevention of unnecessary personnel exposures or facility contamination. In addition, workers should be instructed in the health and safety concerns associated with exposure to radiation or radioactive materials, and female workers should be given specific instructions about prenatal exposure risks to the developing embryo/fetus and their right to privately "declare" their pregnancy to the OSHS RSO dosimetry coordinator (906-487-2118). RSO will issue pregnancy declaration forms upon request. In addition, DRUs must:
- Limit the use of authorized radionuclides to individuals over whom they have supervision and to the authorized locations of use or storage.
- Instruct individuals under their supervision in the proper handling, monitoring, storage, and disposal of radioactive materials.
- Conduct and maintain records of required routine radioactive contamination surveys.
- Ensure their staff receive annual radiological safety regulatory compliance refresher training and maintain records of such training.
- Maintain current documentation of the receipt, possession, and disposition of radionuclides in their possession.
- Notify OSHS RSO (906-487-2118) of additions to their staff, changes in radionuclide protocols, and desired changes in rooms or areas in which radioactive materials are to be used, stored, or analyzed.
- Maintain a current inventory of the quantity (activity) of each radionuclide possessed and be prepared to have this inventory reviewed by the OSHS RSO and NRC inspectors upon request.

- Ensure that a properly operating and calibrated radiation survey meter, liquid scintillation counter, or gamma counter are available to monitor for radioactive contamination or radiation exposure rates.
- Ensure that radioactive material is secured from unauthorized use, removal, or vandalism. Security measures may include locking laboratory/facility doors or securing radioactive material within a locked cabinet, refrigerator, or freezer when research or clinical personnel are not in attendance.
- Ensure that contamination surveys are performed routinely by lab personnel working with unsealed forms (liquids or powders) of radioactive material in accordance with their Radionuclide Authorization. Documentation of contamination surveys must be maintained and available for OSHS RSO laboratory reviews or NRC inspections at all times.
- Ensure that supervised individuals are trained and educated in good radiological safety practices and in maintaining radiation exposures and/or contamination “as low as is reasonably achievable” (ALARA).
- Ensure that all personnel handling unsealed radioactive materials or contaminated objects wear a buttoned-up lab coat, disposable gloves, and/or approved safety apparel. Eye protection should also be worn.
- Review each planned new use of radioactive materials to ensure radiation doses and potential radioactive contamination are maintained ALARA.
- Ensure that designated radionuclide work and storage areas are clearly identified and all equipment or containers used for radionuclide work are labeled properly with radioactive material warning tape.
- Notify the OSHS RSO of any radiological emergencies or radioactive material spills that could result in the spread of radioactive contamination to unrestricted areas (offices, hallways, elevators, etc.), other facility personnel, or members of the public.

The importance of maintaining required regulatory records, e.g., radionuclide inventories, personnel training, contamination survey results, waste disposal, etc., by radioactive material users cannot be overemphasized.

B.4 Safety Training

Michigan Tech’s NRC license requires that “DRUs” and staff learn about the safe use of radioactive materials by viewing a lecture series on video tape before working with radioactive materials (www.mtu.edu/oshs/safety-programs/required/radiation-safety/). This is available from the OSHS office and includes the following:

Lecture 1: Fundamentals of Nuclear Radiation.

Origin, nature, properties, hazards, interaction with material, effects on living things, shielding, flux, dose, measurements, and dosimetry techniques.

Lecture 2: Nuclear Laboratory Techniques.

Receiving radioactive material, radioactive badges, maintenance of log book, swipe tests, safety precautions when working with radioactive materials, monitoring and disposal of radioactive material, emergency procedures.

Lecture 3: Rules and Regulations.

NRC rules and regulations, individual rights. A videotape, Radiation Protection Standards from Radiological Training Services that addresses these issues will be shown.

All three lectures have been videotaped so that students and staff can view them whenever they want. After attending the lectures, the DRU will provide students and staff with clarifications and for information of more specific procedures to be followed in their laboratory. Students and staff will then sign the statement below confirming that they have received the training and understand the hazards and procedures of working with radioactive materials.

An annual refresher training session will also be attended by the users described above.

B.5 Radioactive Material Spills or Contamination Incidents

Spreading of radioactive material beyond the immediate spill area can easily occur by the movement of personnel involved in the spill or cleanup effort. Prevent contamination from spreading by confining movement of personnel until they have been monitored and found to be free of contamination. A minor radioactive spill is one that the laboratory staff is capable of handling safely without the assistance of safety and emergency personnel. All other radioactive spills are considered to be major.

B.5.1 Procedures for radioactive contamination on body

- Remove contaminated clothing at once and thoroughly rinse exposed area with water. Refer to Section 13.1.1 for procedures on Chemical Spill on Body and Hazardous Materials Splashed in Eye.
- Obtain immediate medical attention **only** when injury is involved or there is significant cross contamination.
- Report the incident to OSHS RSO at 906-487-2118, and to the Principal Investigator.
- See other sections of the CHP for guidelines on handling spills.

B.5.2 Procedures for minor radioactive spills or contaminated incidents

- Alert people in the immediate area of the spill.
- Notify OSHS RSO at 906-487-2118. After-hours, call PSPS at 9-1-1 or 906-487-2116 to report a radioactive spill or contamination incident. Inform the police that they should just secure the area and not try themselves to clean up the mess.
- Wear protective equipment, including safety goggles, disposable gloves, shoe covers, and long-sleeve lab coat.
- Place absorbent paper towels over liquid spill. Place towels dampened with water over spills involving solid radioactive materials (dust, fragments, etc.)
- Using forceps, place towels in a plastic bag. Dispose of contaminated materials in a designated radioactive waste container.
- Monitor area, hands, and shoes for contamination with an appropriate survey meter or method. Repeat the cleanup effort until the radioactive contamination is no longer detected (indistinguishable from background radiation).
- Report the spill to the PI and/or DRU and Department Chair.

B.5.3 Procedures for major radioactive spills

- Attend to injured or contaminated persons and remove them from the contaminated area. They should remove contaminated clothing and flush affected areas with copious amounts of water.
- Alert personnel in the laboratory to evacuate and monitor themselves for contamination.
- Have potentially contaminated personnel stay in one area until they have been monitored and shown to be free of contamination.
- Notify OSHS RSO at 906-487-2118 as soon as possible after the occurrence. After hours, call PSPS at 9-1-1 or 906-487-2216 to report a radioactive spill.

- Close doors, label as contaminated area, and prevent entrance into the affected area.
- Have a person knowledgeable of the incident and the laboratory assist emergency response personnel.
- Report the spill to the PI and/or DRU, and Department Chair.

B.6 Registration of X-Ray Machines and Radiation-Producing Devices

All x-ray machines and other radiation-producing devices are **REQUIRED** to be registered with the Michigan Department of Energy Labor and Economic Growth (MDELEG), **BEFORE** initial use, see picture below. In addition, it is the responsibility of each Michigan Tech **department** or **individual user** of radiation-producing equipment to inform OSHS's RSO when x-ray machines or other radiation-producing devices are:

- Newly placed into service in your department.
- Placed into storage and/or not intended to be used for several months.
- Relocated or moved to a different room or building.
- Transferred or sold to another department or individual.
- Transferred or sold to an off-campus individual or institution.

NOTE: Users or departments **MUST** notify OSHS RSO of the name and address of the individual and/or institution to which equipment is transferred.

- On loan to an individual or department on the campus.
- On loan to an individual or institution on or off the campus.
- Dismantled and used or sold for parts.
- Dismantled and junked or discarded.
- Transferred to physical plant Property Disposition.

It should be emphasized that OSHS RSO has the authority to prohibit the use of x-ray equipment and other radiation-producing devices or can issue **cease** and **desist** orders for the continued use of such equipment if an individual or department is found to be in non-compliance with MDELEG regulations or OSHS RSO protocols. OSHS RSO personnel conduct annual inspections, inventories, and registration of x-ray equipment and other radiation-producing devices at the University. In addition, all such equipment is subject to unannounced inspections by MDELEG radiological safety inspectors.

Annual inventories and inspections include verification of the following:

- MDELEG yellow registration tag number.

- Proper postings: Notice to Employees / MDELEG Registration Certificate / Operating Procedures (analytical and research equipment only).
- Manufacturer and model numbers.
- Building and room number(s) where unit is used or stored.
- Maximum kVp and mA output of each unit.
- Intended use (radiographic, analytical, intraoral, research, etc).
- Status of unit: new/in-storage/sold/transferred/loaned/junked/etc.
- Secured enclosure around x-ray equipment.
- Safety interlock system integrity and required use.
- Proper shielding (1/16-inch equivalent lead): primary-beam walls and table.
- Proper use of radiation monitoring dosimeters and survey equipment.
- Proper use of protective aprons (0.5 mm equivalent lead), leaded glasses, and thyroid collars (if applicable).

Picture of a Single Crystal X-ray Diffractometer in the Chemistry Department depicting the required registration postings on the top left.

Appendix C: Security Issues

C.1 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. At a minimum, the following security measures should be employed in all campus laboratories:

- The laboratory door should remain locked when not occupied.
- Always feel free to question anyone that enters the lab that you do not know and ask to see identification if necessary.
- If you see anything suspicious or someone displays suspicious behavior, immediately report it to the Michigan Tech Police Department by dialing 911 (emergency) or 906-487-2216 (non-emergency).
- Any sensitive information or particularly hazardous chemicals should not be stored out in the open where anyone can readily have access to them. These types of materials should be stored in a secure location and lab personnel should always be present when these materials are in use.

C.2 Civil Disturbance

Civil disturbances include riots, demonstrations, threatening individuals, or assemblies that have become significantly disruptive. IN CASE OF CIVIL DISTURBANCE:

- Call PSPS at 9-1-1.
- Contact your Facilities Management Office, if one is available.
- Avoid provoking or obstructing demonstrators.
- Secure your area (lock doors, safes, files, vital records, and expensive equipment).
- Avoid area of disturbance.
- Continue with normal routines as much as possible.
- If the disturbance is outside, stay away from doors or windows. STAY INSIDE!!!

C.3 Suspicious Package / Object

If you receive or discover a suspicious package or foreign device, **DO NOT TOUCH IT, TAMPER WITH IT, OR MOVE IT!!! IMMEDIATELY DIAL 9-1-1 TO REPORT IT TO PSPS.** LETTER AND PARCEL BOMB RECOGNITION CHECKLIST BE CAUTIOUS OF:

- Foreign mail, airmail, and special deliveries
- Restrictive markings such as “confidential” or “personal”

- Excessive postage
- Handwritten or poorly typed address
- Incorrect titles
- Misspellings of common words
- Oily stains or discolorations on package
- Excessive weight
- Rigid, lopsided, or uneven envelopes
- Protruding wires or tinfoil
- Excessive tape or string
- Visual distractions
- No return address

IF YOU ARE SUSPICIOUS OF A MAILING AND ARE UNABLE TO VERIFY THE CONTENTS WITH THE ADDRESSEE OR SENDER:

- Do not touch or move the article.
- Do not open the article.
- Isolate the mailing and evacuate the immediate area.
- Do not put in water or a confined space such as a desk drawer or a filing cabinet.
- If possible, open windows in the immediate area to assist in venting potential explosive gases.
- If you have any reason to believe a letter or parcel is suspicious, do not take a chance or worry about possible embarrassment if the item turns out to be innocent. Contact PSPS at 9-1-1 for assistance.

C.4 Procedures for Theft

The University is not responsible for loss, damage, or theft of personal property. To prevent theft, make sure that doors are shut and locked behind you whenever you leave, regardless of the time of day. Valuable personal property should be kept on your person or in locked drawers or cabinets. Minimize the amount of valuable personal property kept in University buildings. Always carry your Michigan Tech ID card with you when you are in University buildings as a means of positive identification. Immediately report all lost or stolen keys and all problems with locks or keys to the Department Chair. If you notice any suspicious activity, call PSPS, at 906-487-2216.

- If you see a theft in progress, do not attempt to stop it.

- Call PSPS, at 9-1-1, immediately. Report the following information: your name and location, what was taken, from where, how long you think it has been missing, and identification of the thief (if known).
- Do not disturb the area of the theft until PSPS and other authorities are finished with their investigation in the area.
- Report the theft to the Principal Investigator and Facility Director.

C.5 Transporting Hazardous Chemicals

Transporting chemicals is a potentially hazardous process that must be done properly to avoid accidents and potential injuries. The following subsections discuss how to properly ship chemical off campus using a shipping company, how to transport chemicals on campus using a Michigan Tech-owned vehicle, and how to safely move chemicals by foot across campus.

C.5.1 Shipping Hazardous Chemicals off Campus

Shipping chemicals, research samples, or other similar materials off campus is potentially regulated by the Department of Transportation (DOT) and/or other regulatory agencies. Chemicals regulated for shipping require very specific types of packaging, labeling, and documentation and must be prepared by trained personnel. OSHS makes the determination on whether a chemical is classified as hazardous for transportation purposes. Unless the researcher is DOT trained, they are not authorized to make this determination. Shipments that are not prepared by trained personnel can result in delays, loss of research samples, and potential regulatory fines. OSHS can provide assistance by either providing shipment services, or if necessary, training personnel on the proper shipping procedures. More information about shipping chemicals may be obtained by contacting OSHS at 906-487-2118. As previously stated, OSHS prepares all regulated chemicals for shipment according to DOT requirements. However, laboratory personnel prepare the inner container (e.g., vial, jar) and provide it to OSHS for shipment. When selecting an inner container to be given to OSHS for an off-campus hazardous materials shipment, the following guidelines must be followed:

- The chemical must be compatible with the container. For example, corrosive chemicals must not be placed in metal containers; hydrofluoric acid in any concentration must not be placed in glass containers.
- Chemical permeability should be considered when selecting a plastic container, especially for organic solvents. The container must be able to effectively contain the chemical during transportation under normal conditions.

- The container must have an appropriate lid that is able to close and seal, meaning the container will not leak during transportation under normal conditions. Any containers that do not properly seal (e.g., beaker, flask, test tube) will not be shipped off campus by OSHS.

C.5.2 Transporting Chemicals on Campus via Michigan Tech Vehicle

Michigan Technological University is a state agency and therefore is exempt from Department of Transportation (DOT) hazardous materials regulations. However, the “intent” of the DOT regulations is still required when transporting chemicals on campus using a motor vehicle. This essentially means that all chemical containers must be properly packaged, labeled, and segregated according to hazard class. Do not attempt to move large volumes (e.g., greater than 5 gallons in total volume) of chemicals across campus. If a large volume of chemicals needs to be moved across campus, such as an entire lab move, contact OSHS 906-487-2118 for further assistance. The following procedures must be followed in order to properly and legally transport chemicals across campus:

- Only Michigan Tech-owned vehicles are permitted to be used to transport chemicals. For liability and insurance purposes, no personal vehicles should ever be used to transport hazardous chemicals.
- The hazardous materials cannot be stored/transported in the same compartment that the passengers are in; must be placed either in the trunk of a car or bed of truck depending on the specific hazards and quantity, contact OSHS for further instruction.
- Ensure that each container has an appropriate, tight fitting lid. The lid should have the ability to contain the contents of the container even if it becomes inverted during transport. Examples of inappropriate lids include cracked caps, loosely fitting rubber stoppers, or Parafilm®.
- Chemicals should be segregated according to the primary hazard class. For example, do not place an oxidizer such as ammonium nitrate in the same container as an organic solvent such as acetone.
- All containers should be packaged upright.
- Chemical containers should be placed in some type of outer packing such as a box, bin or bucket. Containers should remain securely packaged during loading, transport, and unloading. Glass to glass contact should be avoided. Bubble wrap, newspaper, and vermiculite are good examples of packaging material that will prevent glass to glass contact.
- The outer containers should remain tightly secured during transport. Measures should be taken to avoid movement of the outer containers. For example, the containers

should be secured using a strap or an empty box can be used to fill the gap between the last box and the sidewall of the vehicle.

- The outer container must be labeled in a manner that identifies the contents (e.g. corrosives, flammables).
- Transport with two or more people if possible.
- Be prepared for unseen accidents. At least one person should be knowledgeable of the materials being transported. An inventory with an estimated volume or weight per hazard should be recorded and available during transport (e.g., 5 gallons of flammable liquid and 10 pounds of toxic solids).
- Prepare a spill kit prior to transport. Material such as appropriate PPE, absorbent material, and an empty bucket is sufficient for most small spills.
- Carry a cell phone and know who to call in the event of an emergency. The Fire Department will respond to on-campus emergencies. Dial 911 from a Michigan Tech phone or 906-487-2216 from a cell phone to contact Michigan Tech Police dispatch.

C.5.3 Transporting Chemicals on Campus via Foot

Transporting small volumes of chemicals across campus via foot (e.g., from two neighboring campus buildings) is acceptable as long as it is done properly. Do not attempt to move large volumes (e.g., greater than 5 gallons in total volume) of chemicals across campus via foot. If a large volume of chemicals needs to be moved, such as an entire lab move, contact OSHS 906-487-2118 for further assistance. The following procedures must be followed when moving chemicals on campus by way of foot:

- PPE must be worn when handling potentially contaminated surfaces. During the time which the chemicals are moved on campus via foot, PPE may not be necessary or even appropriate (e.g., employees should not wear chemical-resistant gloves in public areas). However, appropriate PPE and spill containment equipment should be brought along in the event of a spill or incident.

- Michigan Tech Stores' stock room personnel shall not dispense or sell chemicals in breakable containers of any size unless the customer has an approved transport container in which to place the chemical for transporting before leaving the Stock Room. Chemical requisitioners may purchase or borrow a transport container from Michigan Tech Stores. Approved transport container means a commercially available bottle carrier made of rubber, metal, or plastic with carrying handle(s) which is large enough to hold the contents of the container if broken in transit. Carrier lids or covers are recommended, but not required. Rubber or plastic should be used for acids/alkalis; and metal, rubber, or plastic for organic solvents. An example of a bottle carrier is illustrated in Figure 18.1.

Figure 18.1 – Chemical Bottle Carrier

- Laboratory carts used to transport chemicals from one area to another shall be stable and in good condition. Transport only a quantity which can be handled easily. Plan the route ahead of time so as to avoid all steps or stairs. Use large plastic trays to contain spills when using carts.
- Freight elevators, not passenger elevators, should be used to transport hazardous chemicals whenever possible. The individual transporting the hazardous chemicals should operate the elevator alone if possible. Avoid getting on an elevator when a person is transporting hazardous chemicals.

Appendix D: Classes of Hazardous Chemicals

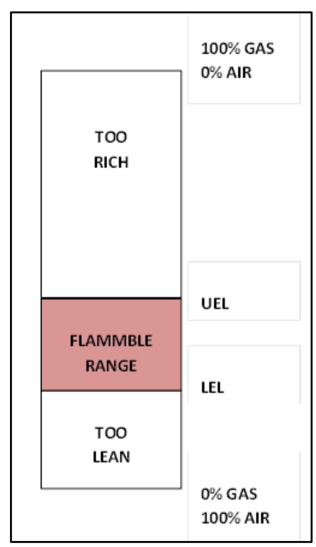
Chemicals can be divided into several different hazard classes. The hazard class provides information to help determine how a chemical can be safely stored and handled. Each chemical container, whether supplied by a chemical manufacturer or produced in the laboratory, must have a label that clearly identifies the chemical constituents. In addition to a specific chemical label, more comprehensive hazard information can be found by referencing the SDS for that chemical. The OSHA Laboratory Standard defines a hazardous chemical as any element, chemical compound, or mixture of elements and/or compounds which is a physical or health hazard. This definition of a hazardous chemical and the GHS primary classes of chemicals are briefly discussed below.

D.1 Physical Hazards

A chemical is a physical hazard if there is scientifically valid evidence that it is flammable, combustible, compressed gas, explosive, organic peroxide, oxidizer, pyrophoric, self-heating, self-reactive, or water-reactive. Each physical hazard is briefly defined below.

D.1.1 Flammable Liquids

Flammable hazards are materials which under standard conditions can generate sufficient vapor to cause a fire in the presence of an ignition source. Flammable liquids (e.g., hexane, ethyl acetate, xylene) are more hazardous at elevated temperatures due to more rapid vaporization. The following definitions are important to understand when evaluating the hazards of flammable liquids:



- **Auto ignition temperature** is the minimum temperature at which self-sustained combustion will occur in the absence of an ignition source.
- **Boiling point** is the temperature at which the vapor pressure of a liquid equals the atmospheric pressure and the liquid changes into a vapor.
- **Explosives:** A liquid or solid which is in itself capable by chemical reaction of producing gas at such a temperature and pressure and at such a speed as to cause damage to the surroundings.

- **Flammable Liquids:** Materials which under standard conditions can generate sufficient vapor to cause a fire in the presence of an ignition source and have a flash point no greater than 93 °C (200 °F).
- **Flash point** is the minimum temperature at which the application of an ignition source causes the vapors of a liquid to ignite under specified test conditions.
- **Lower explosive limit (LEL)** is the lowest concentration (percentage) of a gas or a vapor in air capable of producing a flash of fire in presence of an ignition source (arc, flame, heat).
- **Organic Peroxide:** A liquid or solid which contains the bivalent -0-0- structure and may be considered a derivative of hydrogen peroxide, where one or both of the hydrogen atoms have been replaced by organic radicals.
- **Oxidizer:** A liquid or solid, while in itself is not necessarily combustible, may generally by yielding oxygen, cause or contribute to the combustion of other material.
- **Pyrophoric Substance (also called Spontaneously Combustible):** A liquid or solid that even in small quantities and without an external ignition source can ignite after coming in contact with the air.
- **Self-Heating Substance:** A liquid or solid, other than a pyrophoric substance, which, by reaction with air and without energy supply, is liable to self-heat.
- **Self-Reactive Substance:** A liquid or solid that is liable to undergo strong exothermic thermal decomposition even without participation of oxygen (air).
- **Upper explosive limit (UEL)** is the highest concentration (percentage) of a gas or a vapor in air capable of producing a flash of fire in presence of an ignition source (arc, flame, heat).
- **Water-Reactive Substance:** A liquid or solid that reacts violently with water to produce a flammable or toxic gas, or other hazardous conditions.

Some organic solvents (e.g., diethyl ether) have the potential to form potentially shock-sensitive organic peroxides. See below for additional information regarding peroxide forming chemicals.
Section 6.1.2 of the CHP details flammable liquids storage requirements.

D.1.2 Flammable Solids

A flammable solid is a solid which is readily combustible, or may cause or contribute to a fire through friction. Readily combustible solids are powdered, granular, or pasty substances which are dangerous if they can be easily ignited by brief contact with an ignition source. Flammable solids are more hazardous when widely dispersed in a confined space (e.g., finely divided metal powders).

D.1.3 Gases under Pressure

Gases under pressure are gases which are contained in a receptacle at a pressure not less than 280 kPA at 20 °C or as a refrigerated liquid. Gases under pressure include the following:

- **Compressed gas** is a gas which when packaged under pressure is entirely gaseous at -50 °C; including all gases with a critical temperature ≤ -50 °C.
- **Liquefied gas** is a gas which when packaged under pressure is partially liquid at temperatures above -50 °C.
- **Refrigerated liquefied gas** is a gas which when packaged is made partially liquid because of its low temperature.
- **Dissolved gas** is a gas which when packaged under pressure is dissolved in a liquid phase solvent.

All compressed gases are hazardous due to the fact they are stored in compressed cylinders, which can explode and act as a projectile if ruptured. Compressed gases also carry the hazards of the chemicals they contain such as asphyxiation (carbon dioxide), toxicity (nitric oxide), flammable (propane), and corrosive (hydrogen chloride).

Section 6.1.3 of the CHP details compressed gases storage requirements.

D.1.4 Pyrophoric, Self-Heating, and Self-Reactive Materials

Pyrophoric material (also called "spontaneously combustible") is a liquid or solid that even in small quantities and without an external ignition source can ignite after coming in contact with the air.

Self-heating material is a solid or liquid, other than a pyrophoric substance, which, by reaction with air and without energy supply, is liable to self-heat. This endpoint differs from a pyrophoric substance in that it will ignite only when in large amounts (kilograms) and after long periods of time (hours or days).

Self-reactive material is a thermally unstable liquid or solid liable to undergo a strongly exothermic thermal decomposition even without participation of oxygen (air).

Section 6.1.4 of the CHP details the storage requirements for reactive chemicals.

D.1.5 Water-Reactive Materials

A water-reactive material is a liquid or solid that reacts violently with water to produce a flammable or toxic gas, or other hazardous conditions. Alkali metals (e.g., sodium, potassium) and metal hydrides (e.g., calcium hydride) are common water-reactive materials found in laboratories.

Section 6.1.4 of the CHP details the storage requirements for reactive chemicals.

D.1.6 Oxidizers

An oxidizing solid/liquid is a solid/liquid which, while in itself is not necessarily combustible, may generally by yielding oxygen, cause or contribute to the combustion of other material. Hydrogen peroxide, nitric acid, and nitrate solutions are examples of oxidizing liquids commonly found in a laboratory. Sodium nitrate, Sodium perchlorate, and Potassium permanganate are examples of oxidizing solids commonly found in a laboratory.

Section 6.1.7 of the CHP details oxidizer storage requirements.

D.1.7 Organic Peroxides

An organic peroxide is an organic liquid or solid which contains the bivalent -0-0- structure and may be considered a derivative of hydrogen peroxide, where one or both of the hydrogen atoms have been replaced by organic radicals. The term also includes organic peroxide formulations (mixtures). Such substances and mixtures may:

- Be liable to explosive decomposition;
- Burn rapidly;
- Be sensitive to impact or friction; or
- React dangerously with other substances

- Section 6.1.7 of the CHP details organic peroxide storage requirements.

D.1.7.1 Peroxide Forming Chemicals

Autoxidation in common laboratory solvents can lead to unstable and potentially explosive peroxide formation. The reaction can be initiated by exposure to air, heat, light, or contaminants. Most of these solvents are available with inhibitors to slow the peroxide formation. Examples of inhibitors include BHT (2,6-di-tert-butyl-4-methyl phenol) and Hydroquinone. There are three categories of peroxide formers:

Group A chemicals are those which form explosive levels of peroxides after prolonged storage, especially after exposure to air without concentration. Test these for peroxide formation before using and discard 3 months after opening.

Table C.1 – Group A Chemicals	
Butadiene	Isopropyl ether
Chloroprene	Tetrafluoroethylene
Divinylacetylene	Vinylidine chloride

Group B chemicals form peroxides that are hazardous only on concentration by distillation or evaporation. Test these before distillation and discard after 12 months.

Table C.2 – Group B Chemicals		
Acetal	Dicyclopentadiene	Methyl isobutyl ketone
Acetaldehyde	Diethyl ether	4-Methyl-2-pentanol
Benzyl alcohol	Diethylene glycol dimethyl ether	2-Pentanol
2-Butanol	Dioxane	4-Penten-1-ol
Cumene	Ethylene glycol dimethyl ether	1-Phenylethanol
Cyclohexanol	4-Heptanol	2-Phenylethanol
2-cyclohexen-1-ol	2-Hexanol	2-Propanol
Cyclohexene	Methylacetylene	Tetrahydrofuran
Decahydronaphthalene	3-Methyl-1-butanol	Tetrahydronaphthalene
Diacetylene	Methylcyclopentane	Vinyl ether

Group C chemicals consist of monomers which form peroxides that can initiate explosive polymerization. Inhibited monomers should be tested before use and discarded after 12 months. Uninhibited monomers should be discarded 24 hours after opening.

Table C.3 – Group C Chemicals	
Acrylic acid	Styrene
Acrylonitrile	Tetrafluoroethylene
Butadiene	Vinyl acetate
Chloroprene	Vinyl acetylene
Chlorotrifluoroethylene	Vinyl chloride
Methyl methacrylate	Vinyl pyridine

General Guidelines

- Solvents containing inhibitors should be used whenever possible.
- All peroxide forming solvents should be tested prior to distillation.
- Peroxide forming solvents should be purchased in limited quantities.
- Peroxide forming solvents should be marked with the purchase date and the date opened.
- Peroxide forming solvents should be sealed tightly and stored away from light and heat.
- Periodic testing should be done on opened containers and the results marked on the containers.

Testing

- Obtain test strips for the range of 0-100 ppm peroxide.
- Record the test results on the bottle.
- If the test results are 100 ppm or greater, contact OSHS at 906-487-2118 for proper disposal.

D.1.8 Explosives

An explosive substance (or mixture) is a solid or liquid substance (or mixture of substances) which is in itself capable by chemical reaction of producing gas at such a temperature and pressure and at such a speed that can cause damage to the surroundings. Pyrotechnic substances are included even when they do not evolve gases. A pyrotechnic substance (or mixture) is designed to produce an effect by heat, light, sound, gas or smoke or a combination of these as the result of non-detonative, self-sustaining, exothermic chemical reactions. An explosive compound that is sometimes found in a laboratory setting is picric acid (2,4,6-trinitrophenol).
If a laboratory plans to work with explosive compounds, contact OSHS for further instructions before any work occurs.

D.2 Health Hazards

A chemical is a health hazard if there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees. Each health hazard is defined and briefly discussed below.

D.2.1 Irritants

Irritants are defined as chemicals that cause reversible inflammatory effects on living tissue by chemical action at the site of contact. A wide variety of organic and inorganic compounds, including many chemicals that are in a powder or crystalline form, are irritants. Symptoms of exposure can include reddening or discomfort of the skin and irritation to respiratory systems.

D.2.2 Sensitizers

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

D.2.3 Corrosives

Corrosive substances cause destruction of living tissue by chemical corrosion at the site of contact and can be either acidic or caustic (basic). Major classes of corrosive substances include:

- Strong acids such as sulfuric, nitric, hydrochloric and hydrofluoric acids
- Strong bases such as sodium hydroxide, potassium hydroxide, and ammonium hydroxide
- Dehydrating agents such sulfuric acid, sodium hydroxide, phosphorus pentoxide and calcium oxide
- Oxidizing agents such as hydrogen peroxide, chlorine, and bromine
- Section 6.1.6 of the CHP details corrosives storage requirements.

D.2.4 Hazardous Substances with Toxic Effects on Specific Organs

Substances with toxic effects on specific organs include:

- Hepatotoxins, which are substances that produce liver damage, such as nitrosamines and carbon tetrachloride.
- Nephrotoxins, which are substances that cause damage to the kidneys, such as certain halogenated hydrocarbons.
- Neurotoxins, which are substances that produce toxic effects on the nervous system, such as mercury, acrylamide, and carbon disulfide.
- Substances that act on the hematopoietic system (e.g., carbon monoxide and cyanides), which decrease hemoglobin function and deprive the body tissues of oxygen.
- Substances that damage lung tissue such as asbestos and silica.

D.2.5 Particularly Hazardous Substances

Substances that pose such significant threats to human health are classified as "particularly hazardous substances" (PHSs). The OSHA Laboratory Standard requires that special provisions be established to prevent the harmful exposure of researchers to PHSs, including the establishment of designated areas for their use. Particularly hazardous substances are divided into three primary types:

1. Carcinogens
2. Reproductive Toxins
3. Substances with a High Acute Toxicity

D.2.6 Carcinogens

Carcinogens are chemical or physical agents that cause cancer. Generally they are chronically toxic substances; that is, they cause damage after repeated or long-duration exposure, and their effects may only become evident after a long latency period. Chronic toxins are particularly insidious because they may have no immediately apparent harmful effects. These materials are separated into two classes:

1. **Select Carcinogens:** Select carcinogens are materials which have met certain criteria established by the National Toxicology Program or the International Agency for Research on Cancer regarding the risk of cancer via certain exposure routes. It is important to recognize that some substances involved in research laboratories are new compounds and have not been subjected to testing for carcinogenicity.
2. **Regulated Carcinogens:** Regulated carcinogens are more hazardous and have extensive additional requirements associated with them. The use of these agents may require personal exposure sampling based on usage. When working with Regulated Carcinogens, it is particularly important to review and effectively apply engineering and administrative safety controls as the regulatory requirements for laboratories that may exceed long term (8 hour) or short term (15 minutes) threshold values for these chemicals are very extensive.

D.2.7 Reproductive Toxins

Reproductive toxins include any chemical that may affect the reproductive capabilities, including chromosomal damage (mutations) and effects on fetuses (teratogens). Reproductive toxins can affect the reproductive health of both men and women if proper procedures and controls are not used. For women, exposure to reproductive toxins during pregnancy can cause adverse effects on the fetus; these effects include embryolethality (death of the fertilized egg, embryo or fetus), malformations (teratogenic effects), and postnatal functional defects. For men, exposure can lead to sterility. Examples of embryotoxins include thalidomide and certain antibiotics such as tetracycline. Women of childbearing potential should note that embryotoxins have the greatest impact during the first trimester of pregnancy. Because a woman often does not know that she is pregnant during this period of high susceptibility, special caution is advised when working with all chemicals, especially those rapidly absorbed through the skin (e.g., formamide).

D.2.8 Substances with a High Acute Toxicity

Substances that have a high degree of acute toxicity are materials that may be fatal or cause damage to target organs as the result of a single exposure or exposures of short duration. Acute toxins are quantified by a substance's lethal dose-50 (LD_{50}) or lethal concentration-50 (LC_{50}), which is the lethal dose of a compound to 50% of a laboratory tested animal population (e.g., rats, rabbits) over a specified time period. High acute toxicity includes any chemical that falls within any of the following OSHA-defined categories:

- A chemical with a median lethal dose (LD_{50}) of 50 mg or less per kg of body weight when administered orally to certain test populations.
- A chemical with an LD_{50} of 200 mg less per kg of body weight when administered by continuous contact for 24 hours to certain test populations.
- A chemical with a median lethal concentration (LC_{50}) in air of 200 parts per million (ppm) by volume or less of gas or vapor, or 2 mg per liter or less of mist, fume, or dust, when administered to certain test populations by continuous inhalation for one hour, provided such concentration and/or condition are likely to be encountered by humans when the chemical is used in any reasonably foreseeable manner.

Section 6.1.5 of the CHP details acutely toxic compounds storage requirements.

D.3 Biological Hazards

The Michigan Technological University Biosafety Officer (BO) is the person that has the responsibility for reviewing and approving all proposals, activities, and experiments involving an organism or product of an organism that presents a risk to humans, plants, animals, or the environment. The Laboratory Supervisor must submit to the BO an application to use rDNA, synthetic nucleic acids, potential pathogens, human tissue, fluids, and/or cell lines in their research. The BO review is conducted in accordance with the guidance and requirements of National Institutes of Health, the Centers for Disease Control, and Michigan Technological University policies, and the Biosafety Manual. All Laboratory Supervisors have an obligation to be closely familiar with EHS guidelines applicable to their work and to adhere to them. More detail regarding the BO process can be found on the Michigan Tech OSHS website: www.mtu.edu/oshs/safety-staff/staff/

D.4 Radioactive Material Hazards

The Michigan Technological University Radiation Safety Committee (RSC) is the campus-based committee that has the responsibility for reviewing and approving all proposals, activities, and experiments involving radioactive material and radiation producing devices. The Laboratory Supervisor must submit to the RSC through OSHS, an application to use radioactive material or radiation-producing devices. Use of radioactive materials at Michigan Technological University is authorized under a license issued by the US Nuclear Regulatory Commission or a registration with the Indiana State Department of Health and all work must comply with applicable regulations. The policies and procedures for handling radioactive materials are contained in the

Michigan Technological University Radiation Safety Manual. www.mtu.edu/oshs/safety-programs/required/radiation-safety/)

D.5 Laser Hazards

At Michigan Tech, Laser safety falls under the domain of the Radiation Safety Committee (RSC) The RSC can review and approve all proposals, activities, and experiments involving laser radiation devices. Laboratory Supervisors must submit to the RSC through OSHS, an application to use Class 3B and Class 4 lasers or laser devices. The use of lasers is subject to OSHA regulations and utilizes current ANSI standards to develop guidance. The policies and procedures for handling lasers are contained in the Michigan Tech University Radiation Safety Guidelines, www.mtu.edu/oshs/safety-programs/required/radiation-safety/. The following link also provides a useful guide. ehs.okstate.edu/links/laser.htm

D.6 Explosions

Explosions are usually accompanied by fire or vice-versa! In addition to fires, there are many chemicals which can lead to an explosion when handled improperly. Some specific dangers of explosions are listed below:

D.6.1 Peroxides in ether solvents:

One of the most common cause of explosion in the organic lab is peroxides. Many a laboratory has been destroyed by this! Simple dialkyl ethers as well as cyclic ethers such a 1,4-dioxane and tetrahydrofuran form less volatile peroxides when exposed to air and light. When these solvents are distilled, the pot residue is enriched in the peroxide and eventually a violent explosion can result (if the drying agent is spent). To avoid this risk:

(i) such solvents should not be stored for long in half empty containers.

(ii) it is best to buy smaller containers of ether rather than buy larger containers (which are less expensive) and store for prolonged periods.

(iii) it is best <u>not to</u> distill these solvents when old. But if distillation must be carried out, test for peroxide before distilling. If peroxides are detected, they must be destroyed. The process of drying these solvents with sodium metal usually destroys any peroxides but it is best to discard very old bottles (> 1 year). One can also add $FeCl_2$ to the solvent before distilling.

D.6.2 Alkali metals with halogenated solvents:

Alkali metals (Na, K, Li) and also finely divided Al and Mg react violently with halogenated organic solvents especially carbon tetrachloride. Residues of these metals should never be washed with halogenated solvents. A dangerous explosion can result.

D.6.3 Perchloric acid:

This acid reacts violently with most organic material such a rubber, cork, wood etc. Never store perchloric acid near organic material or in a wooden cabinet.

D.6.4 Chromic acid and Nitric Acid:

These should never be heated with an organic compound. If tarry residues cannot be removed by small quantities of cold chromic acid, the flask is best discarded! <u>A very dangerous explosion will result if nitric acid is added to alcohols, especially ethanol and methanol</u>.

D.6.5 Liquid Nitrogen:

Liquid nitrogen (bp – 196 °C) contains some liquid oxygen (bp – 183 °C). When liquid nitrogen evaporates, the residue is enriched in oxygen which can cause an explosion when in contact with an organic substance. It is better to use dry-ice/isopropanol baths rather than liquid nitrogen. If liquid nitrogen is used in traps for vacuum work, it will often cool oxygen from air in the trap. If an organic material is then condensed in that trap, an explosion can result during evaporation. The use of liquid nitrogen in routine organic work is best avoided.

D.6.6 Vacuum Work:

Before evacuating any glassware, check carefully for cracks. All dewars and rotovap assemblies should be covered with a safety net to prevent flying glass. Vacuum desiccators should be similarly covered.

D.6.7 Opening Sealed bottles and Ampoules:

Volatile chemicals must be cooled thoroughly before opening. Cooling should be done in steps, not rapidly. A salt-ice bath is usually sufficient for most purposes.

D.6.8 Compressed gas cylinders:

These should always be secured to a wall. The valves and screws should never be greased. Cylinders should be moved around only in trolleys to which they should be secured. An empty cylinder should be immediately labeled clearly.

D.6.9 Some Dangerous Inorganic Chemicals:

Strong Acids:

All of the following give off very harmful vapors and also react violently with bases. They should always be handled with gloves and in the hood. Adequate eye protection must also be worn.

- Hydrobromic acid and HBr gas
- Hydrochloric acid and HCl gas
- Hydrofluoric acid and HF gas— Both react with glass! Rubber or plastic gloves should be worn. Skin burns require immediate medical attention.
- Nitric acid and Perchloric Acid (See under Explosions Section)
- Sulfuric acid: caution must be exercised when diluting this acid. Always add acid to water slowly with stirring. Never the other way around.

Strong Bases:

Most inorganic bases have a very corrosive action on the corneal tissue of the eye. Hence safety glasses are particularly important when handling these compounds. Solutions of alkalis tend to bump when heated. Exercise great care when heating these. Use a stir bar to insure smooth heating.

Halogens:

The most common halogen in the lab is perhaps bromine. Glassware containing bromine residue must never be rinsed with acetone since this results in the powerful lacrymator, bromoacetone. Instead, destroy residual aqueous bromine by addition of a solution of sodium metabisulfite in water (10 % aq. solution). Since this results in production of SO_2 gas, this process must be done in the hood. Bromine in carbon tetrachloride or other organic solvents can be destroyed by adding cyclohexene and then disposing the mixture in a container for halogenated waste.

Reactive halides:

Boron tribromide, boron trichloride, aluminum chloride, phosphorous trichloride, phosphorous pentachloride and phosphorous oxychloride etc., are very reactive toward water. They should not be exposed to air for any length of time as they will release toxic gases.

D.6.10 Chemical Hazards:

Given below is a list of some dangerous chemicals that are often encountered in the lab. This is not a complete list of such chemicals! It simply includes the more common reagents. Many of these are useful compounds. While their useful properties should be taken advantage of, it is important to be aware of the risks so that adequate precautions can be taken while handling them.

The following are severe lachrymators (cause copious watering of the eyes) acetyl chloride, benzyl chloride, acrolein, diketene, allyl alcohol, dimethyl acetylenedicarboxylate, allyl chloride, benzoyl chloride, bromoacetone (easily produced by mixing bromine with acetone) oxalyl chloride

The following are a major explosion hazard especially when heated:

- sodium azide
- diazomethane
- acetylene salts
- p-toluenesulfonyl azide
- diazonium salts
- perchlorates

The following are extremely toxic by ingestion and can be fatal in even small doses:

- aromatic amines (aniline and its substituted derivatives)
- arsenic and its compounds
- hydrogen sulfide (this gas with the odor of rotten eggs cannot be detected at higher concentrations !)
- mercury chloride
- nitric oxide and nitrogen dioxide • osmium tetroxide (severe hazard to eye) • oxalic acid and its salts
- phenols and aromatic nitro compounds
- selenium and its compounds
- sodium and potassium cyanide
- thallium acetate and other thallium salts
- vanadium pentoxide

The following substances have very harmful cumulative effects which manifest after prolonged exposure over a relatively long period. If you will be working with these for long periods of time, biological monitoring of the body may be necessary.

- benzene (it has a mildly pleasant odor; if you can smell it, you are inhaling dangerous quantities)
- isocyanates (in particular toluene isocyanate)

- large quantities of methanol
- lead and its compounds
- mercury and mercury compounds

The following are known or suspected carcingoens. If you must use these, make every effort to wear gloves, handle them only in the hood and wear protective clothing. Label all vials and flasks containing these appropriately

Amines

1,1-dimethylhydrazine, methyl hydrazine, hydrazine 1- and 2-napthylamines

Nitrosocompounds

All nitroso compounds are potential carcinogens.

Alkylatingagents

aziridine, epichlorohydrin, Bis(chloromethyl)ether, methyl iodide, diazomethane, propiolactone

Aromatichydrocarbons

benzene, dibenz[a,h]anthracene, benzo[a]pyrene, 7,12-dimethylbenz[a]anthracene

Halogenatedhydrocarbons

carbon tetrachloride, hexachlorobutadiene, chloroform, vinyl chloride, 1,2-dibromoethane

PhosphorousandSulfurcompounds:

hexamethylphosphoramide, 1,3-propanesultone (3-hydroxy-1-propanesulfonic acid)
thioacetamide and thiourea.

Appendix E: Safety aspects associated with common lab procedures:

1. The following statements concern the use of a rotary evaporator
(a) The body of a rotovap should not be protected with a safety net since this can obscure the vision of the condenser and the condensates. Is this True or false?

This is false. Implosion is a serious hazard. Safety net does not obscure vision. The risk from an implosion is real and dangerous.

(b) What is the largest size flask that should be used in most rotovaps?

One liter flask.

(c) Should an Erlenmeyer flask be evacuated?

No, Flat surfaces vessels should never be evacuated unless they are specifically designed for the purpose (such as filtration flasks)

(d) Is there a greater risk in evacuating a rotovap with a vacuum pump (<0.5 mm Hg) than with a water aspirator (20 mm Hg?

No. the risk is the same. Both pressures are quite far from atmospheric pressure. It is the pressure differential that is important.

2. Why should contact lenses be never worn in the laboratory?

Soft contact lenses will absorb organic vapors like methanol, chloroform etc. If chemicals enter the eye, then the eye cannot be easily washed due to contact coverage. Only ANSI-Z87.1 approved safety glasses should be worn in the laboratory.

3. **Familiarize yourself with the location of fire extinguishers,** first-aid boxes and circuit breaker boxes (in the event that power has to be shut off) for the labs that you will be working in.

4. Suggested ways to dry the following solvents: Consult reference textbooks on this subject and feel free to ask Rudy Luck if you have questions regarding the arrangement of a distillation still.

Diethyletherandtetrahydrofuran:

These are best dried with sodium metal. Even though the use of Lithium aluminum hydride ($LiAlH_4$) has been recommended and is often used in many research groups, **$LiAlH_4$ should not be used to dryethers.** $LiAlH_4$ decomposes (often explosively) at 125 °C, a temperature that can be easily attained with a heating mantle.

Dichloromethaneandacetonitrile:

Calcium hydride

Methanolandethanol:

Magnesium metal (caution: the reaction is vigorous)

5. What is the best solvent for use in cooling baths containing dry-ice?

Isopropyl alcohol is the preferred solvent. Acetone is commonly used but is more flammable and hence its use should be avoided in cooling baths.

6. One of the most common accident in a lab results from broken glass. What precautions can be taken to avoid such injury?

Broken glassware should either be repaired immediately or disposed of in the appropriate container. They should never be left around. Never force glass tubing through a rubber cork. Always lubricate cork and glass tubing with glycerin. Wear leather or thick rubber gloves when inserting tubing through corks etc.

7. What is the best way to heat flasks and round bottomed flasks containing flammable liquids?

An oil bath provides good temperature control. Heating mantels should be avoided since they do not provide good temperature control. A temperature controller (if available) should be attached to the oil bath.

8. The building ventilation is supposed to be good. At night the hallway fans may be turned off.

This could result in a lower internal pressure in the hallways than the pressure inside the laboratories. As a consequence, odors and toxic gases can be swept back into the lab and hallways through open sinks. So never pour solutions of thiols, HCN etc. down the drain.

9. Unlabeled chemicals pose a great hazard. Current US Environmental Protection Agency regulations forbid disposal of unknown chemicals. How should unlabeled chemicals be handled?

Sometimes identification is easy (A ^{1}HNMR might reveal the nature of the compound).

Often partial labels can be found on bottles. Look for hazard symbols such as flammable, explosive, etc. Do not add water or other chemicals to unknown reagents in an attempt to destroy them until their identity is established and you are certain that they can be destroyed safely. Be aware that you should label all containers containing chemicals.

10. Appropriate clothing must be worn in a lab.

Loose clothing should never be worn in the lab. They pose a greater fire hazard. Long hair (including dreadlocks) also poses a similar risk. Shorts and sleeveless dress offer less protection than long pants and full sleeve shirts. If a corrosive chemical is being handled, it is best to wear a laboratory coat. Shoes must be worn at all times in the lab. Open toed shoes and sandals offer little protection against spills and hence are not permitted in the lab. Hosiery should not be worn since they "melt" upon contact with acids.

11. On the use of gloves.

Leather gloves are best for handling broken glass and for inserting tubing into corks but they do not offer protection from chemicals. There are many kinds of gloves available in the market. Check with your research advisor to see if a particular kind is more suited for the type of work you are doing. <u>Latex surgical gloves are of little value in the chemical laborartory and should not be worn.</u> It is important not to spread chemicals and spills with gloves: Do not handle door knobs, items in stock rooms and instruments with contaminated gloves.

12. When should a blast shield be used?

Whenever a potentially explosive reaction is being carried out (such as generation of diazomethane) or the use of a pressurized equipment is involved, a safety shield should be used to provide added protection against an implosion.

13. When should the safety shower be used?

In the event of a major spill on your face, neck, eyes, head or shoulders, use the safety shower immediately. Do not worry about being modest, i.e, strip down completely if necessary! Contaminated clothing should be immediately removed. Hence it is a good idea to have lab coats available in every lab!

14. What are the five hazard classes recommended by Environmental and Safety for separating chemicals?

Flammables, Oxidizers, Acids, Bases and Reactives

15. How should glass bottles containing solvents be carried around in the hallways?

A bottle carrier should always be used in the halls, elevators and stairwells.

16. What is the best container to collect waste solvents?

The EPA requires that waste solvents be collected in polyethylene jerri cans (www.usplastic.com/catalog/product.asp?catalog_name=USPlasticandcategory_name=10and product_id=12696andcookie_test=1 list them for $42.56). Use the acetone plastic containers for this purpose if you can't afford this. Metal cans rust easily while glass bottles are easily broken.

17. Flooding: Major damage to equipment has often resulted from flooding. How can this be avoided?

- **Do not use tubing that is too old or brittle.**
- **Don't use pure gum rubber tubing for water lines**
- **All tubing must be secured with wire or clamps.**
- **Unattended water lines must have a regulator.**
- **Check sink for debris that can clog the sink and cause water to back up.**

18. What should I do if there is a mercury spill (as is common when a thermometer breaks)? How can this be avoided?

- **A catch pan must be provided under all mercury containing equipment (such as manometers and McLeod Gauges).**
- **Use a non-mercury thermometer whenever possible.**
- **Never use a mercury thermometer in a heated oven**
- **The use of sulfur has been recommended but it is unclear whether this serves any purpose. (It is believed that this lowers the vapor pressure by reacting with Hg on**

the surface forming HgS). It is best to physically remove the mercury than spray sulfur all over!

19. What common substance can react explosively with Teflon (there are many Teflon objects in the lab such as stirrers, tubing etc.) at high temperatures?

Potassium metal

20. In the event of "small" spill, describe the steps you will take to insure a smooth and complete clean up.

- **<u>Personal Safety:</u> Wear appropriate clothing and eye protection. Wear gloves.**
- **<u>Containment of spill:</u> Turn off sources of ignition such as burners if a flammable material is involved. Do not turn light switches off or on as that can generate a spark. Close all lab doors to contain the spill.**
- **<u>Absorb the spill:</u> Absorb the spill with a spill absorbent.**
- **<u>Cleanup:</u> Scoop the mixture into a plastic bag and label appropriately. Keep in your lab until waste disposal pick-up.**

21. What special precautions must be observed when running overnight reactions or reactions that have to be left unattended for some length of time?

- **An index card containing the following information should be posted clearly outside the hood or near the reaction site.**
- **Your name and telephone contact number**
- **Contents of the flask. This is useful if someone else has to respond to an emergency situation associated with your reaction.**
- **If water is being used through a hose, make sure it is secured with hose clamps. Also insure that the sink is <u>not</u> clogged with debris.**
- **Oil baths should not be heated overnight unless a temperature controller is installed in the bath.**

21. What to do in case of a major fire?

PULL THE FIRE ALARM AND EVACUATE THE BUILDING IMMEDIATELY. DO NOT PUT YOUR LIFE IN JEOPARDY. After you escape the building, call 911 and/or 906-487-2216 for public safety (see above for further information).

22. What to do in case of a major accident that seems life threatening (such as a a severe cut or a chemical burn?

If the accident involves your lab mate or someone around you, keep them calm. Call campus security (906-487-2216) and/or 906-370-7405 for Rudy Luck through the phone in the hallway. You can obtain a form to report accidents from www.sas.it.mtu.edu/fm/oshs/index.htm. Print out the appropriate form and give a copy to the main office in addition to sending one over to the Michigan Tech's OSHS.

23. Solvent Baths for Cooling

System	ºC	System	ºC
p-Xylene/N_2	13	Carbitol acetate/CO_2	-67
p-Dioxane	12	t-Butyl amine/N_2	-68
Cyclclohexane/N_2	6	Acetone/CO_2	-72
Benzene/N_2	5	Trichloroethylene/N_2	-73
Formamide/N_2	2	Butyl acetate/N_2	-77
Aniline/N_2	-6	Acetone/CO_2	-77
Cycloheptane/N_2	-12	Isoamyl acetate/N_2	-79
Benzonitrile/N_2	-13	Acrylonitrile/N_2	-82
Ethylene glycol/CO_2	-15	Sulfur dioxide/CO_2	-82
o-Dichlorobenzene/N_2	-18	Ethyl acetate/N_2	-84
Tetrachloroethane/N_2	-22	Ethyl methyl ketone/N_2	-86
Carbon tetrachloride/N_2	-23	Acrolein/N_2	-88
Carbon tetrachloride/CO_2	-23	Nitroethane/N_2	-90
o-Dichlorobenzene/N_2	-25	Heptane/N_2	-91
Nitromethane/N_2	-29	Cyclopentane/N_2	-93
o-Xylene/N_2	-29	Hexane/N_2	-94
Bromobenzene/N_2	-30	Toluene/N_2	-95
Iodobenzene/N_2	-31	Methanol/N_2	-98
Thiophene/N_2	-38	Diethyl ether/CO_2	-100
3-Heptanone/CO_2	-38	n-Propyl iodide/N_2	-101
Acetonitrile/N_2	-41	n-Butyl iodide/N_2	-103
Pyridine/N_2	-42	Cyclohexene/N_2	-104
Acetonitrile/CO_2	-42	Isooctane/N_2	-107
Chlorobenzene/N_2	-45	Ethyl iodide/N_2	-109
Cyclohexanone/CO_2	-46	Carbon disulfide/N_2	-110
m-Xylene/N_2	-47	Butyl bromide/N_2	-112
n-Butyl amine/N_2	-50	Ethyl bromide/N_2	-119

Diethyl carbitol/CO_2	-52	Acetaldehyde/N_2	-124
n-Octane/N_2	-56	Methyl cyclohexane/N_2	-126
Chloroform/CO_2	-61	n-Pentane/N_2	-131
Chloroform/N_2	-63	1,5-Hexadiene/N_2	-141
Methyl iodide/N_2	-66	i-Pentane/N_2	-160

Appendix F: Case Studies

The following six case studies highlight the critical need for planning safe research. These cases are just a few of the lab incidents seen at various universities and at Michigan Tech. Although some of these incidents seem minor, it should be easy to see the potential for catastrophic loss and understand that planning for the safety of experiments is far better than dealing with employee injury, equipment damage, work stoppage, or environmental damage, which result from a lab incident.

(1) Fluorine Gas Inhalation Injury

A graduate student, working alone in a laser lab, was using fluorine gas in a delivery system to fill the laser. The gas bottle and delivery system were not enclosed or vented, and no sensors or alarms were in place to detect leakage. The copper line delivery system was hanging out and unsecured. As the student attempted to fill the laser with 5% fluorine, the delivery system failed at an unexpected location, allowing leakage to the laboratory. Odor of gas was apparent, but the student continued the fill attempt. Another 45 minutes passed before she gave up the unsuccessful fill attempt and summoned assistance from another student, who immediately implemented the posted emergency response plan for fluorine gas leaks. The student suffered pulmonary edema that produced serious symptoms over the course of a week. Medical specialty treatment was necessary after several emergency room visits. Root cause analysis of the circumstances of the exposure revealed small fluorine leaks to be a fairly common occurrence in the lab. Students were left to differentiate high hazard leaks from low hazard leaks based solely on odor levels. In this case, the student misjudged. Suggested corrective actions included: revision of fluorine filling procedures and a review with laboratory staff; installation of a vented gas box for the fluorine, with sensors to alarm in the event of a leak.

(2) Drying Oven Explosion And Fire

A post-doctoral researcher was processing several polymer samples, dissolved in ethanol. The process required evaporating the ethanol from open beakers to leave the polymer residue. This was usually done at room temperature in the chemical fume hood. Late in the afternoon, he was in a hurry to have the experiment completed, so he decided to accelerate the ethanol evaporation by using a drying oven. There was no written SOP for the procedure. An hour into the evaporation, and with the lab empty, the ethanol vapors found an ignition source in the thermostatic switch for the oven, creating an explosion and fire. The oven was clearly labeled as not being suitable for use with flammable solvents. With no SOP, specific instructions on drying were not available from the PI - employees were left to their own devices to carry out the experiment. Also, the post-doctoral researcher was confused about flash points. He claimed that the flash point of his ethanol solution was 70°C when in fact it was 70°F. Running the oven at 60°C equated to 140°F, well above the flash point for the solution. Corrective actions included re-education of the laboratory staff on flammability risks of solvents and the development of written SOP for their methods utilizing flammable solvents.

(3) Pyrophoric Gas Release, Fire, Alarm And Building Evacuation

A graduate student, working with a post-doctoral researcher, was attempting to change the oil in a turbo pump used for a Molecular Beam Epitaxy (MBE) tool. This research involves solid state electronics production. The hydride gas had not been adequately purged from the system prior to cracking open the pump. Hydride gas escape produced a moderate fire and sensors set the building into alarm. Students were unable to extinguish the fire for some minutes, facing potential exposure during that time. This was the second such incident in two years. The gas exhaust system had no reliable gauges to indicate failure, so the researcher had no positive indications that the purge had been unsuccessful. Pump placement, in an awkward position, was another complicating factor. Later, it was found that purge pressure gauges were inadequate to indicate system blockage. An SOP was not in place for most of the lab procedures. An emergency response plan was not in place. Equipment maintenance was non-existent. Two years of continuous use lead to exhaust system blockage. Corrective actions have been undertaken to relocate pumps to more serviceable positions. Interlocked pressure gauges have been installed for system shutdown in the event of flow failure. An SOP has been developed for each experimental procedure. A mandatory prior approval system is in place for MBE runs. Students have been retrained on all procedures. Equipment maintenance and upgrade schedules have been developed.

(4) Laser Eye Injury

A student, working alone with a Class 4 laser, wished to align the laser but chose not to use eye protection. The student removed a shield, meant to guard against accidental eye exposure and injury, and received an exposure from the laser off the edge of the optical lens. This was enough to burn the student's eye and some damage to the retina was sustained. The laser guard was not interlocked with the power, which would have prevented laser operation when the guard was removed. Corrective actions included retraining of the research lab staff on SOP for safe laser use, and interlocking laser power to the guard mechanism.

(5) Dichloromethane Spill

During one hot summer month, a graduate student in the chemistry department purchased 4 litres of dichloromethane from the department's store room in the basement and transported this to the 7th floor using a cart. As the student pushed the cart out of the elevator, the bottle tipped over, fell onto the floor and broke with the entire contents spilled. A chemistry professor happened to be coming out of his office, experienced a strong smell of dichloromethane and then observed the spill in the hallway outside the elevators. The student was then observed trying to clean up the mess. The correct procedure at this stage is to ring the fire alarm to evacuate the building and wait until trained personnel arrived to deal with the situation. Instead the decision was taken to seal off the elevators from the 7th floor and open the hallway windows to flush out the chemical, nearly all of which had evaporated. This proved difficult to accomplish quickly and the custodian worker ended up on the 7th floor right where the spill occurred and inhaled the fumes. The floor tiles sustained damage as a result of this spill. The obvious precaution here is to transport large quantity of chemicals using plastic trays that can contain spills from accidental breakages and/or prevent the containers from tipping over. In this case, pulling the fire alarm and evacuating the building should have been the first action. Physical plant (906-487-2707) could have then been notified to engage the ventilation system to purify the building air.

(6) Lithium aluminum hydride ($LiALH_4$) fire

A glass container of $LiAlH_4$ exploded on the bench top in one of the labs in the chemistry department. The material was observed to be grey in appearance suggesting that the $LiAlH_4$ had decomposed. Testing of this substance by placing some of it into water (no sign of reaction) confirmed this. The decision was then taken to scoop the material into a large evaporating dish and place this in a fume hood, where the moisture in the summer air would facilitate a slow decomposition. After a few minutes of being in the hood, the material exploded with a loud bang and caught on fire. In anticipation of this, a larger glass dish was already available and this was placed on top of the fire and the fume hood sash closed. This had the unintended consequence of supplying more air to the fire and the room filled with white smoke. The area was evacuated and the lab doors secured. After about 10 minutes, the air cleared and the fire had extinguished itself. The glass receptacles were cracked and the fire was intense enough to crack the sash in the fume hood. A report was filed to OSHS. This illustrates the potential danger of storing "old" chemicals.

$$LiAlH_4 + 4H_2O \rightarrow LiOH + Al(OH)_3 + 4H_2$$

The above equation states how small quantities of water (i.e., humidity) can lead to spontaneous combustion. It is always a good idea to utilize $LiAlH_4$ under an inert atmosphere. Destruction of $LiAlH_4$ at the end of a chemical reaction can be accomplished by the addition of ice-cold water but this also liberates large quantities of hydrogen that could burn or explode. In this case it is preferable to use 10% solutions of sodium hydroxide or ammonium chloride. The alumina which precipitated can be removed by filtration. Ice-cold solutions of 20% sodium hydroxide (5N) can also be used. The best method (also more expensive) to destroy $LiAlH_4$ without liberating hydrogen is to use ethyl acetate. This reaction is still exothermic and must be

$$4\ CH_3CO_2C_2H_5 + LiAlH_4 \longrightarrow C_2H_5OLi + (C_2H_5O)_3Al + 4\ C_2H_5OH$$

avoided if basic compounds are in the reaction as possible secondary acetylation reactions can occur with ethyl acetate. In light of these clarifications, the spilled material should have been slowly added into a container of ethyl acetate. However it is also believed that the use of a metal scapula facilitated the explosion and a plastic one is advised.