LABORATORY SAFETY
and
CHEMICAL HYGIENE PLAN

INDIANA UNIVERSITY

Produced by

University Environmental Health and Safety
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in cooperation with
University Chemical Hygiene Committees

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EMERGENCY INFORMATION

Major Emergencies

In the event of an accident in the laboratory which involves a fire, explosion, or a large release of a hazardous chemical:

- Evacuate the building by activating the nearest fire alarm.
- Call **911** to give the details of the accident including the location, personal injuries, and types of hazardous material involved.

If the accident also involves chemical contamination or serious personal injury (e.g. profuse bleeding, broken bone, unconsciousness, immobile victim, etc.) follow the steps above and:

- Move the victim from the immediate area of the fire, explosion, or spill (but only if this can be done without further injury to the victim or to you).
- Remove any contaminated clothing from the victim and flush all areas of the body contacted by chemicals with copious amounts of water for 15 minutes.
- Administer first aid as appropriate and wait for emergency medical responders to arrive.

Minor Emergencies

If the accident involves minor injuries requiring treatment, report to the medical services provider for your respective campus (See Section 5.0 of this document):

- Administer first aid as appropriate and report to the appropriate supervisor or to the administrative office in the building or department as necessary.
- Responsible departmental personnel such as faculty, staff, or building managers should coordinate transportation assistance for the injured person upon request.
- Use departmental vehicles whenever possible or voluntary use of personal vehicles if necessary.
- Drivers must have a valid driver's license and observe local speed limits and traffic ordinances.

In the event of an accident in the laboratory which involves a minor chemical release or spill (with no personal injuries):

- Follow the *Chemical Spill Response Procedures* - SOP 3.13.
- For assistance call the IUEHS representative for your respective campus (see Laboratory Safety Contacts).

Accident Reports

All laboratory accidents must be reported:

- Submit OSHA required occupational injury report and worker's compensation claims to Human Resources at http://hr.iu.edu/workers.
- Report all accidents (including non-injury and near-misses) to University Environmental Health and Safety for your respective campus.

Fires and Fire Alarms

If a fire alarm sounds, laboratory workers should:

- Extinguish open flames (Bunsen burners, alcohol lamps etc.) and close the fume hood sash.
- Exit the building immediately to a designated assembly area.
- Report any incident information to the IU Police Department (IUPD) for your respective campus and stay available for a personnel count or any questions.

If a fire occurs, laboratory workers should:

- Pull the fire alarm and evacuate.
- Any employee *may* use an extinguisher to clear a route to make an escape.
- Employees who have received annual field training* in the use of extinguishers *may* use an extinguisher to fight an incipient fire but *must* evacuate if the fire is not immediately extinguished.
- To activate a fire extinguisher use the PASS method:

  Pull the pin.

  Aim at the base of the fire.

  Squeeze the handle, and

  Sweep from side to side.

  If the fire is not extinguished after using one fire extinguisher then evacuate the building.
- Clothing can be extinguished using the Stop, Drop, and Roll method, a fire blanket, or the emergency shower.
- Water reactives and burning metals may be extinguished using a Class D fire extinguishing media (such as a bucket of dry sand or a commercial Class D fire extinguisher if available such as Met-L-X, Super-D, or Lith-X, etc.).

Note: Classification of fires and extinguishers - Class A, ordinary combustibles; Class B, flammable liquids and gasses; Class C, live electrical equipment; Class D, combustible metals and metal alloys. Most laboratories are equipped with combination Class ABC fire extinguishers. Some also have carbon dioxide Class B and Class C fire extinguishers for flammable liquids, gases, and electrical fires. A bucket of dry sand (marked “Class D Fire Extinguisher”) or commercial Class D fire extinguisher must be present in laboratories where water reactives and combustible metals and metal alloys are used or stored.

* Insurance, Loss Control and Claims (INLOCC) approved annual field training (http://inlocc.webhost.iu.edu)

Tornado Watches and Warnings (Sirens)

A tornado watch means that conditions are favorable for the possible formation of a tornado. If a tornado watch is issued laboratory workers should:

- Monitor weather conditions or monitor your weather alert radio.
- Complete existing experiments to a termination point. Do not start any new experiments. Shut down equipment if hazardous conditions may result from loss of utilities (e.g. loss of coolant, vacuum, steam for autoclaves).
- Be prepared to terminate experiments immediately if conditions deteriorate and a tornado warning is issued.
- Complete any animal research activities in progress and be prepared to terminate activities immediately if conditions deteriorate.
- Confirm that all laboratory animals are moved to appropriate housing.
- Close any open containers, secure and protect valuable research samples, radioactive isotopes, biohazardous agents, recombinant materials and hazardous chemicals to prevent breakage and release.
- Secure chemical, radioactive, and biological waste.
- Secure any other regulated materials.
- Extinguish open flames and close all fume hood sashes.
- Unplug computers and all other electrical equipment (except refrigerators and freezers).
- Breakable items or items that may become airborne in heavy winds should be moved away from outside windows.
- Cover and secure or seal vulnerable equipment with plastic.
- Protect valuable files, research notebooks, and data to a safe secure location.
- Gather personal valuables and take them with you.
- Ensure you have your University issued ID with you.
- If a tornado warning is issued you must immediately suspend all laboratory procedures and seek shelter immediately.

A tornado warning means a tornado has been sighted in our area or nearby county. If a tornado warning siren is activated laboratory workers shall:

- Seek shelter immediately.
- Go to the designated tornado shelter.
- Basements, interior hallways and rooms on lower floors are the best locations for shelter.
- Stay away from windows and exterior doors.
- If no shelter is available, lie down in a low-lying area.
- Protect yourself from flying debris.

LABORATORY SAFETY CONTACTS

University Environmental Health and Safety - www.protect.iu.edu/ehs			
Name	**Title**	**Phone**	**E-mail**
Steve Adams	Interim University Director	(812) 856-2871	stpadams@iu.edu
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Lee Stone	Interim Director – IUPUI Indianapolis	(317) 274-2829	leestone@iupui.edu
Kathryn Manteuffel	Regional Campus Director	(219) 981-4230	kmanteuf@iun.edu
IU Bloomington			
Name	**Title**	**Phone**	**E-mail**
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Hazardous Waste			
Dan Derheimer	Environmental Manager	(812) 855-3234	dderheim@iu.edu
Rex Howard	Hazardous Materials Specialist	(812) 855-7907	rehoward@indiana.edu
Susan Howard	Hazardous Materials Specialist	(812) 856-2351	suhoward@indiana.edu
Rick Peterson	EHS Specialist	(812) 856-5432	rspeters@iu.edu
IUB Physical Plant/Facilities			
Control Center		(812) 855-8728 (812) 855-9514	phypltbl@iub.edu
IUPD Bloomington		(812) 855-4111	
IU East			
Jon Hoffman	EHS Specialist	(812) 941-2989	jonahoff@indiana.edu
Physical Facilities		(765) 973-8254 (765) 973-8423	phyp@iue.edu
IUPD –East		(765) 973-8429	

IU Kokomo			
Name	**Title**	**Phone**	**E-mail**
Thaddeus Johnson	EHS Specialist	(547) 520-4575	thbjohns@iu.edu
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IUPD-Kokomo	(non-emergencies)	(765) 455-9432	jerlwill@iuk.edu
IUPD-Kokomo	(emergencies)	(765) 455-9363	
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IUPUI and IUPU Columbus			
General Information		(317) 274-2005	ehs@iupui.edu
Lab Safety and Chemical Hygiene			
K. Lee Stone	Laboratory Safety Manager	(317) 278-6150	leestone@iupui.edu
Winston Baity	Laboratory Safety Specialist	(317) 274-3778	wibaity@iupui.edu
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Biological Safety			
Andrew Houppert	Manager Biological Safety	(317) 274-2103	ahoupper@iupui.edu
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Environmental Management and Chemical Waste			
Kevin Mouser	Environmental Manager	(317) 274-4351	kmouser@iupui.edu
Radiation Safety			
Michael Martin	Radiation Safety Officer	(317) 274-0331	radsafe@iupui.edu
IUPUI Campus Facility Services			
Call Center		(317) 278-1900	
IUPD-IUPUI			
	Emergency	(317) 274-7911	
	Non-Emergency	(317) 274-2058	
IU South Bend			
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Physical Plant		(812) 941-2330	phpwkord@ius.edu
IUPD-Southeast		(812) 941-2400	

Departmental and Laboratory Contacts (Chair and/or Co-chair, Laboratory Safety Coordinator, Principal Investigator, Lab Manager and/or Lab Supervisor, and Laboratory Personnel, etc.)

Name	Building/Room No.	Phone	E-mail

1. INTRODUCTION

The *Laboratory Safety and Chemical Hygiene Plan (CHP)* is a written program for ensuring the safe use of chemicals in laboratories at Indiana University. It describes policies, procedures, and control measures that must be understood and observed by all individuals involved in the laboratory use of chemicals. Major components of the plan include:

- Employee information and training,
- Hazard identification,
- Personal exposure monitoring,
- Medical surveillance,
- Standard operating procedures,
- Personal protective equipment, and
- Containment and engineering controls.

1.1. Purpose

The purpose of this Laboratory Safety and Chemical Hygiene Plan is to provide guidance for the safe handling of all hazardous chemicals in laboratories; ensure compliance with OSHA, EPA, and other applicable regulations; and demonstrate that this Plan meets or exceeds the requirements of OSHA's Laboratory Safety Standard, 29 CFR 1910.1450, Occupational Exposure to Hazardous Chemicals in Laboratories.

1.2. Regulatory Basis

On January 31, 1990, the Occupational Safety and Health Administration (OSHA) promulgated a final rule entitled Occupational Exposures to Hazardous Chemicals in Laboratories (commonly known as "The Laboratory Standard" - see 1910.1450, Appendix A). The basis for this standard is a determination that laboratories differ from industrial operations in their use and handling of hazardous chemicals and that a different approach than that found in OSHA's substance specific health standards is warranted to protect workers. This standard does not establish new exposure limits, but sets other performance provisions designed to protect laboratory workers from potential hazards in their work environment.

The development and implementation of a chemical hygiene plan (*Laboratory Safety and Chemical Hygiene Plan)* is a central requirement of the "Laboratory Standard" (1910.1450, Appendix A). The Laboratory Standard defines a laboratory as a "workplace where relatively small quantities of hazardous chemicals are used on a non-production basis." It is clear from this definition that the Laboratory Standard applies to all laboratories that use chemicals at Indiana University.

Laboratories that do not meet the above definition or areas where chemicals are used for non-laboratory purposes are governed by other state and federal regulations including OSHA's "Toxic and Hazardous Substances" standard (29 CFR part 1910, subpart Z,) which contains the Hazard Communication (HazCom) standard and permissible exposure limits for all hazardous chemical usage. Assistance in determining which regulatory requirements apply to specific work areas is provided by Indiana University Environmental Health and Safety.

1.3. Applicability

The Laboratory Standard applies to all employees engaged in the laboratory use of hazardous chemicals. Laboratory use of hazardous chemicals is defined as the use or handling of chemicals in which all of the following conditions are met:

- Chemical manipulations are carried out on a "laboratory scale". Laboratory scale is defined as work with substances in which the containers used for reactions, transfers, and other handling of substances are designed to be easily and safely manipulated by one person. This definition excludes those workplaces whose function is to produce commercial quantities of materials.

- Multiple chemical procedures or chemicals are used.
- The procedures involved are not part of a production process, nor in any way simulate a production process.

This standard does not apply to:

- Uses of hazardous chemicals which do not meet the definition of laboratory use, and in such cases, the employer shall comply with the relevant standard in 29 CFR part 1910, subpart Z,, even if such use occurs in a laboratory.
- Laboratory uses of hazardous chemicals which provide no potential for employee exposure.

Where the standard does apply, it shall supersede, for laboratories, the requirements of all other OSHA health standards in 29 CFR part 1910, subpart Z, except as follows:

- For any OSHA health standard, only the requirement to limit employee exposure to the specific permissible exposure limit shall apply for laboratories, unless that particular standard states otherwise or unless the action level (or in the absence of an action level, the PEL) is routinely exceeded. Where the action level (or in the absence of an action level, the PEL) is routinely exceeded for an OSHA regulated substance with exposure monitoring and medical surveillance requirements, the employee exposure monitoring and medical monitoring requirements of this standard shall apply.
- Prohibition of eye and skin contact where specified by any OSHA health standard shall be observed.

Any substance specific standard can require coverage to remain under that standard rather than under the laboratory standard. In the absence of a statement of preemption in a substance specific standard, the determination of whether the laboratory standard applies must be dependent on both “laboratory use” and “laboratory scale” criteria. Where these criteria are met, the laboratory standard applies.

1.4. Organization and Content

The *Laboratory Safety and Chemical Hygiene Plan* (CHP) is intended to serve as an operational guide for the incorporation of prudent safety practices into the day-to-day use of chemicals within laboratories. It was developed and issued in a general form which shall be adapted and expanded by particular departments and research groups to meet their specific needs. The CHP was organized in a format that should enable desired information to be quickly found and readily updated. The content of the CHP was established directly from the requirements of the Laboratory Standard and includes the following information:

- Designation of the personnel responsible for the implementation of the Laboratory Safety and Chemical Hygiene Plan.
- Provisions for personnel training and sources of information.
- Hazard identification.
- Criteria that the employer will use to implement control measures to reduce individual exposures to chemicals. These measures include administrative controls, containment and engineering controls, procedural controls, and the use of personal protective equipment.
- Standard operating procedures (SOPs) relevant to the safety and health considerations that must be observed for the use of hazardous chemicals in the laboratory. Generic SOPs for handling of all hazardous chemical groups are included in the CHP. However, each laboratory group must develop and add specific SOPs that are appropriate for their particular uses of chemicals.

- Personal exposure monitoring.
- Provisions for medical consultations and examinations.
- Circumstances under which a laboratory procedure shall require prior approval before implementation.
- Provisions for additional personnel protection for work with carcinogens, reproductive toxins, and chemicals with high acute toxicity known as "particularly hazardous substances."
- A requirement that fume hoods and other protective equipment function properly and that measures will be taken to ensure this.

1.5. Definitions

ACGIH – American Conference of Governmental Industrial Hygienists.

Action level - A concentration designated in the OSHA (29 CFR) Part 1910 (or in the absence of an action level, the PEL) for a specific substance, calculated as an eight-hour time-weighted average, which initiates certain required activities such as exposure monitoring and medical surveillance.

ANSI - American National Standards Institute.

Chemical Hygiene Officer - The Chemical Hygiene Officer (CHO) is an employee who is designated by the employer, and who is qualified by training or experience, to provide technical guidance in the development and implementation of the provisions of the Chemical Hygiene Plan.

Chemical Hygiene Plan - The Chemical Hygiene Plan (CHP) is a written program developed and implemented by the employer which (1) sets forth procedures, equipment, personal protective equipment, and work practices that are capable of protecting employees from the health hazards presented by hazardous chemicals used in that particular workplace, and (2) meets the requirements of OSHA's Laboratory Safety Standard; 29 CFR 1910.1450(e).

CHO - Chemical Hygiene Officer.

CHP - Laboratory Safety and Chemical Hygiene Plan (CHP).

Chemical Hygiene Committee - Established to assist and guide the Chemical Hygiene Officer with the implementation of the Laboratory Safety and Chemical Hygiene Plan (CHP). It consists of representatives from departments with laboratory facilities and personnel that are affected by the programs and procedures applicable to laboratory chemical safety.

Designated area - An area which may be used for work with ''select carcinogens,'' reproductive toxins or substances which have a high degree of acute toxicity. A designated area may be the entire laboratory, an area of a laboratory or a device such as a laboratory hood.

IUEHS - University Environmental Health and Safety.

EPA - Environmental Protection Agency.

Hazardous chemical - Any chemical which is classified as health hazard or simple asphyxiant in accordance with the Hazard Communication Standard (29 CFR 1910.1200).

Health hazard - Any chemical that is classified as posing one of the following hazardous effects: acute toxicity (any route of exposure); skin corrosion or irritation; serious eye damage or eye irritation; respiratory or skin sensitization; germ cell mutagenicity; carcinogenicity; reproductive toxicity; specific target organ toxicity (single or repeated exposure); aspiration hazard or simple asphyxiant.

Laboratory - OSHA defines a laboratory as "a workplace where relatively small quantities of hazardous chemicals are used on a non-productive basis".

Lab Manager - A staff employee responsible for managing laboratory operations.

Lab Safety Coordinator – A safety officer designated, when requested by IUEHS, for a school, department, or other subdivision by the dean, chairman, or director to serve as liaison to IUEHS.

Lab Supervisor - A staff employee responsible for supervising laboratory personnel.

Laboratory use of hazardous chemicals - the handling or use of such chemicals in which all of the following conditions are met:

- Chemical manipulations are carried out on a "laboratory scale;"
- Multiple chemical procedures or chemicals are used;
- The procedures involved are not part of a production process, nor in any way simulate a production process; and
- "Protective laboratory practices and equipment" are available and in common use to minimize the potential for employee exposure to hazardous chemicals.

Lab Workers - The Laboratory Workers referred to in the Lab Standard are employees. OSHA defines an employee as "an individual employed in a laboratory workplace who may be exposed to hazardous chemicals in the course of his or her assignments." An example of a Laboratory Worker would be a University teaching assistant, research assistant or faculty member instructing an academic lab. OSHA does not consider students in an academic laboratory to be workers. However, instructors are expected to ensure that students in academic laboratory classes adhere to the principles of this Plan. Also included, are visiting professors and volunteers that might be working in a laboratory. Thus, Laboratory Supervisors must ensure that these groups that are in their laboratories are adequately instructed in safe laboratory procedures.

NFPA - National Fire Protection Association.

OSHA - Occupational Safety and Health Administration.

Oxidizer - A chemical, other than a blasting agent or explosive as defined in 29 CFR 1910.109(a) that initiates or promotes combustion in other materials, thereby causing fire either of itself or through the release of oxygen or other gases.

Particularly Hazardous Substances - Chemicals that are a select carcinogen, a reproductive toxin, or a chemical having a high degree of acute toxicity.

PEL - Permissible Exposure Limit. PELs are the regulatory limit or maximum concentration of a substance in the air that personnel can be exposed to without personal protective equipment or engineering controls (such as a fume hood). These chemicals may also have a “skin designation” that prohibits skin contact.

Physical hazard - Any chemical which is classified as posing one of the following hazardous effects: explosives, flammables (gases, aerosols, liquids, or solids), oxidizers (liquid, solid, or gas), self-reactive; pyrophorics (gas, liquid or solid), self-heating, organic peroxides, chemicals corrosive to metal, gases under pressure, water reactives that emit flammable gases, or combustible dusts.

PPE - Personal Protective Equipment.

Principal Investigator (PI) - The lead scientist that plans and/or conducts the laboratory research and assumes the overall supervisory responsibility for laboratory operations and project completion.

PI - The Principal Investigator.

Reproductive Toxin - Chemicals that affect the reproductive capabilities including adverse effects on sexual function and fertility in adult males and females, as well as adverse effects on the development of the offspring including but not limited to those that damage chromosomes (mutagens) or the fetus (teratogens).

Select Carcinogen - Any substance which meets one of the following criteria: (1) it is regulated by OSHA as a carcinogen; or (2) it is listed under the category "known to be carcinogens" in the Annual Report on Carcinogens published by the National Toxicology Program (NTP) (latest edition); or (3) it is listed under Group 1 ("carcinogenic to humans") by the International Agency for Research on Cancer Monographs (IARC) (latest editions); or (4) it is listed in either Group 2A or 2B by IARC or under the category "reasonably anticipated to be carcinogens" by NTP, and causes statistically significant tumor incidence in experimental animals in accordance with any of the following criteria: (a) after inhalation exposure of 6-7 hours per day, 5 days per week, for a significant portion of a lifetime to dosages of less than 10 mg/m3; (b) after repeated skin application of less than 300 (mg/kg of body weight) per week; or (c) after oral dosages of less than 50 mg/kg of body weight per day.

TLV - Threshold Limit Value.

SOP - Standard Operating Procedure.

1.6. Authority and Responsibility

Indiana University supports the use of chemicals and other potentially hazardous materials for purposes of research and teaching.

The University is committed to ensuring the safety of its students, employees, and visitors and to complying with all regulatory requirements which impact its facilities and operations relating to the environment, health and safety. University administration, faculty, staff, and students are asked to support this goal in all university activities.

Indiana University has designated the following specific responsibilities for developing and implementing the *Laboratory Safety and Chemical Hygiene Plan.*

1.6.1. University Environmental Health and Safety (IUEHS)

Indiana University Environmental Health and Safety (IUEHS) is an administrative unit under the Executive Vice President for University Academic Affairs which has responsibility for the development and implementation of all university programs concerning safety and environmental quality. IUEHS developed the *Laboratory Safety and Chemical Hygiene Plan* and has the primary role in overseeing its implementation. This role is accomplished by IUEHS staff through the provision of a range of safety services including project reviews and consultations, formal training sessions, and periodic laboratory audits (see Appendix A, Form LCS-1 IU*EHS Laboratory Safety Audit*).

Specific responsibilities include:

- Perform annual chemical hygiene and housekeeping inspections including inspections of emergency equipment.
- Provide and document training for laboratory employees' concerning requirements of the Plan and their responsibilities.
- Provide guidance for the preparation of procedures, chemical inventories, and training programs required by the CHP.
- Maintain a master file of documentation and records associated with the CHP, including training, personal exposure, medical surveillance, chemical inventories, and Safety Data Sheets (SDSs).
- Respond to requests for Safety Data Sheets (SDSs).
- Evaluate non-injury near misses and communicate lessons learned to laboratory personnel.

1.6.2. Chemical Hygiene Officer

The Chemical Hygiene Officer (CHO) is an employee who is qualified by training or experience, to provide technical guidance for the continuing implementation of the CHP. The Chemical Hygiene Officer for Indiana University is the Laboratory Safety Manager. Specific responsibilities of the CHO include:

- Work with administrators and other employees to develop and implement appropriate chemical hygiene programs and practices.
- Monitor procurement and use of chemicals in the lab, including determining that facilities and training levels are adequate for the chemicals in use.
- Maintain current knowledge concerning the requirements for storage and use of regulated substances in the laboratory.
- Review the Chemical Hygiene Plan annually and revise as necessary.
- Chair the Chemical Hygiene Committee.
- Maintain overall responsibility for the laboratory chemical safety program.
- Monitor adherence to the requirements of the Laboratory Safety and Chemical Hygiene Plan.
- Provide guidance for determining the proper level of personal protective equipment.

1.6.3. Chemical Hygiene Committee

The Chemical Hygiene Committee (CHC) is established to assist and guide the Chemical Hygiene Officer with the implementation of the Laboratory Safety and Chemical Hygiene Plan (CHP). It consists of representatives from departments with laboratory facilities and personnel that are affected by the programs and procedures applicable to laboratory chemical safety. The primary responsibilities of the CHC are to:

- Review the Laboratory Safety and Chemical Hygiene Plan at least annually to provide recommendations for improvement.
- Provide a mechanism or point of contact to distribute important information to departments with laboratory facilities.
- Support the Chemical Hygiene Officer with the authority to send letters containing recommendations regarding non-compliance to the appropriate individuals in accordance with Section 1.7.2 Corrective Action Procedure.

1.6.4. Academic Departments

1.6.4.1. Department Chair

The Chair of each academic department (or head of each academic unit) is responsible for the safety of all individuals working in the department's laboratories. The Chair fulfills this responsibility, in part, by ensuring that all departmental faculty members understand and take seriously their roles in implementing the *Laboratory Safety and Chemical Hygiene Plan.* To facilitate this process, each Chair must appoint a Laboratory Safety Coordinator (LSC) who will coordinate and monitor the implementation of the CHP within the department.

1.6.4.2. Laboratory Safety Coordinator

A Laboratory Safety Coordinator (LSC) will be requested for a school, department, or other subdivision when IUEHS determines that the standard practice of contacting the laboratory is not meeting the communication needs due to the number of laboratories, scope of research or complexity within the organization. Responsibilities of the LSC include:

- Provide information about chemical hazards to contract employees or maintenance employees working in the area.

- Serve as a conduit for information between laboratories in their area and IUEHS and the CHO.
- Review laboratory safety inspections on behalf of the department and help ensure that all required deficiencies have been corrected.
- Provide safety information to all departmental lab users when IUEHS furnishes it to LSC.
- Update IUEHS when there are changes in professional staff (chairman, director, professor, post-doc, etc.) or changes in mailing addresses of existing staff.
- Alert IUEHS of any suspected deficiencies during routine walkthroughs of laboratories.

1.6.4.3. Faculty, Principal Investigators, Lab Managers, and Lab Supervisors

Each faculty member, principal investigator, lab manager, and lab supervisor is responsible for the safety of individuals working within his or her laboratories. Faculty members must work with IUEHS, or when applicable, the department's respective Laboratory Safety Coordinator (LSC) to adapt and implement the provisions of the *Laboratory Safety and Chemical Hygiene Plan*.

This includes ensuring that each individual working within the lab is provided with appropriate training on safety and regulatory requirements; that required safety equipment and personal protective devices are provided, maintained, and used; that specific standard operating procedures incorporating safety considerations are developed and observed; that their laboratory personnel receive the appropriate procedure-specific instruction and are proficient at performing those procedures; that laboratory personnel follow the procedures, and that prompt action is taken to correct any unsafe acts or conditions which have been observed or reported.

Specific responsibilities include:

- Review laboratory safety inspection reports and ensure that all required deficiencies have been corrected.
- Attend training provided by IUEHS concerning the requirements of this Plan and their responsibilities and ensure all laboratory employees are trained.
- Ensure that the Chemical Hygiene Plan is incorporated into routine training sessions for new laboratory personnel.
- Ensure employee training at the time of initial assignment to the area, whenever a new hazard is introduced to the area or when the employee is reassigned to an area using new or different materials and/or processes.
- Provide appropriate personal protective equipment and require its proper use and maintenance.
- Ensure an inventory is completed for all reportable chemicals used in their work areas following the instructions provided by IUEHS.
- Review and understand SDSs on materials used by employees under their direct supervision and inform employees as new SDSs become available.
- Ensure SDSs are available in the work area and are readily accessible to employees.
- Ensure that employee requests for SDSs and other materials are promptly handled, and/or requesting any necessary information or help from IUEHS.
- Ensure that all containers of hazardous materials are labeled with the chemical name or trade name.
- Ensure that safe work conditions are maintained.

1.6.4.4. *Laboratory Workers*

Each laboratory worker is responsible for implementing the requirements of the *Laboratory Safety and Chemical Hygiene Plan*. This includes but is not limited to:

- Participating in required training;
- Wearing appropriate lab apparel and using personal protection equipment (such as lab coat, safety glasses, gloves);
- Utilizing the appropriate safety equipment properly (such as the fume hood);
- Following the established standard operating procedures; and
- Informing the PI, Lab Supervisor, or Lab Manager of any accident or unsafe conditions.

1.7. Chemical Laboratory Inspections and Corrective Action Procedures

Compliance with federal, state, and local regulations is the responsibility of the laboratory Principal Investigator (PI), Lab Manager, or Lab Supervisor. Many agencies require regulatory compliance depending on the activity being performed. Chemicals are primarily regulated by OSHA, the EPA, and the Department of Homeland Security at the state or federal level. During an actual regulatory inspection, the University and the department can be cited and fined for violations.

Because of the potential safety problems and liability that exists when laboratory safety deficiencies are identified, this corrective action process has been prepared to enforce compliance.

The PI, Lab Manager, or Lab Supervisor is responsible for ensuring that all safety deficiencies documented in a laboratory inspection are corrected. A corrective action process will be implemented if correction of the deficiencies has not begun within 2 weeks of delivery of an inspection report. It is anticipated that the vast majority of laboratories will complete the process during the first stage of inspection before corrective action will need to be taken.

Imminent danger or egregious violations are cause to terminate laboratory operations immediately. University Environmental Health and Safety (IUEHS) provides free compliance assistance upon request.

1.7.1. Annual Laboratory Inspection

A Laboratory Safety Inspection shall be completed annually by IUEHS Laboratory Safety Personnel. The department or school will be notified two weeks in advance of the upcoming inspection. Appointments for the inspection can be made with IUEHS as necessary.

Following the initial laboratory inspection, the PI, Lab Manager, or Lab Supervisor will be given 2 weeks from the receipt of the inspection date to correct violations. At the completion of the initial inspections for each Department (or building) copies of the initial inspection report will be sent to the Laboratory Safety Coordinator, and/or Safety Committee Chair (if a committee has been appointed for the Department) by IUEHS Laboratory Safety Personnel.

A written verification of complete or partial corrections is required by the end of that time period and can be sent by one of the following methods:

- E-mail IUEHS representative for your respective campus. (see Laboratory Safety Contacts)
- Hard copy sent via campus mail to IUEHS for your respective campus (see Laboratory Safety Contacts).

A follow-up inspection will be conducted at least 2 weeks after the initial inspection to ensure that sufficient progress has been made unless written verification is deemed sufficient. Follow-up inspections at the regional campuses are the responsibility of the IUEHS representatives for the respective campus

If an infrastructure or facility-related issue is documented as a laboratory deficiency, submission of a request for repair will qualify as an attempt for correction. Action items must be noted in the written verification.

1.7.2. Corrective Action Procedure

1.7.2.1. Level 1

Failure to take sufficient corrective action by the follow-up inspection or the severity of remaining violations will determine if the process proceeds to Level 1. If very little or no progress has been made a Level 1 response will be necessary and a full re-inspection of the laboratory will be conducted. IUEHS Laboratory Safety Personnel will send copies of the Level 1 re-inspection report to the PI, Lab Manager, or Lab Supervisor, Laboratory Safety Coordinator, and/or Departmental Safety Committee Chair (if one exists).

The IUEHS Laboratory Safety Personnel will discuss the Level 1 re-inspection report with the PI, Lab Manager, or Lab Supervisor to agree upon corrective actions. The PI, Lab Manager, or Lab Supervisor will be given an additional ten (10) business days to correct all violations. Written verification of corrected deficiencies must be submitted to IUEHS within that time period. A follow-up inspection will be conducted to verify that all corrections have been made unless written verification is deemed sufficient.

1.7.2.2. Level 2

If written verification has not been submitted within the additional ten (10) business day time period, a re-inspection and follow up inspection will be conducted by IUEHS personnel if necessary. The IUEHS Laboratory Safety Manager will send a letter and copies of inspections and any PI, Lab Manager, or Lab Supervisor responses to the PI, Lab Manager, or Lab Supervisor, the Laboratory Safety Coordinator, the Department Safety Committee Chair (if one exists), and the Department Chair or Director. The letter will give the PI, Lab Manager, or Lab Supervisor an additional five (5) business days to correct remaining violations and submit written verification.

Mandatory retraining of lab personnel will be considered if the violations reveal a lack of understanding or deliberate avoidance of lab safety guidelines.

1.7.2.3. Level 3

If written verification of completed corrective actions has not been submitted to IUEHS by the end of the process through Level 2 (a total of 25 business days), the Chemical Hygiene Committee will send a letter of non-compliance to the PI Lab Manager, or Lab Supervisor, the Laboratory Safety Coordinator, the Department Safety Committee Chair (if one exists), the Department Chair or Director, and the administrative head of the college, school, or unit. A re-inspection and follow up inspection will be conducted as necessary.

Failure of the PI, Lab Manager, or Lab Supervisor to submit verification of corrections will impact their ability to obtain approvals for permits and grant certifications requiring validation of compliance with applicable state and federal regulations, including Federal Certification of Environmental Compliance.

Extensions to provide corrective action may be requested in writing at any stage of this process from IUEHS Laboratory Safety Personnel (see Laboratory Safety Contacts).

1.7.2.4. Level 4

If the steps taken in the previous action levels have not resulted in the submission of a written verification of completed corrective actions to IUEHS within the established timeline then the laboratory will be deemed noncompliant. The chief academic officer of the campus where the laboratory is located and the University Director of Environmental Health and Safety will be notified of the noncompliant laboratory and punitive action will be requested which may include prohibiting employee access to the laboratory until corrective action has been taken. If the action taken by the chief academic officer does not result in compliance by the noncompliant laboratory then the Executive Vice President for University Academic Affairs will be requested to take punitive action to ensure compliance.

2. CONTROL MEASURES

The OSHA Lab Standard (29 CFR 1910.1450) requires that laboratory personnel implement appropriate control measures to ensure that chemical exposures are maintained below regulatory limits and as low as reasonably achievable. In general, control measures can be categorized as administrative controls, engineering controls, procedural controls (i.e., standard operating procedures), or personal protection.

2.1. Administrative Controls

Administrative controls consist of various hazard control requirements that are established at an administrative level (e.g., by the principal investigator, laboratory manager, laboratory supervisor, department chair, laboratory safety coordinator, department safety committee, or University Environmental Health and Safety) to promote safety in the laboratory.

Administrative controls describe the way the work is done and include other measures to reduce employee exposure to hazards. Administrative controls do not remove hazards, but limit or prevent exposure to the hazards.

Examples of administrative controls include written plans and standard operating procedures, signs, labels, training, supervision, timing of work, personnel substitutions, using a lab partner, and more. PIs, Lab Managers, and Lab Supervisors must:

- Ensure that all laboratory personnel have been provided with adequate safety and compliance training to enable them to conduct their duties safely (see Section 4.0 Information and Training Requirements).
- Ensure that all laboratory personnel have been provided with adequate procedural (experiment-specific) training and they are proficient to enable them to conduct their duties safely.
- Require prior approval of experimental procedures and implement additional control measures for certain particularly hazardous operations or activities.
- Restrict access to areas in which particularly hazardous chemicals are used.
- Post appropriate signs to identify specific hazards within an area.
- Require that various standard practices for chemical safety and good housekeeping be observed at all times in the laboratory.

2.1.1. Prior Approval of Hazardous Operations

The OSHA Lab Standard requires that activities involving certain particularly hazardous chemicals be reviewed and approved in advance by an appropriate individual or group. Depending upon the specific department, this approving entity is primarily the PI, Lab Manager, or Lab Supervisor, but could also be the Department Safety Committee, the Laboratory Safety Coordinator, or the Department Chair. At the time of approval, any additional required control measures for the project shall be specified in writing (see SOP 3.7). Examples of the types of operations that must receive prior approval are those involving the use of select carcinogens, reproductive toxins, acutely toxic chemicals, energetic materials (explosives), highly reactive or shock sensitive chemicals, or highly corrosive or oxidizing chemicals. In addition, any operation that produces potentially hazardous results must receive prior approval.

2.1.1.1. Laboratory Entrance Signs

The entrance to each laboratory in which chemicals are used or stored shall be posted with the names and phone numbers of the Principal Investigator, Lab Manager, or Lab Supervisor and any other designated personnel who can be contacted in the event of an emergency.

The signage system is designed to fulfill regulatory signage requirements and alert lab users and visitors to specific hazards located in individual laboratories. The lab signs may not list every hazard associated with a lab and do not replace basic laboratory safety training or practice.

The OSHA Laboratory Standard requires that carcinogens, reproductive toxins and chemicals with a high degree of acute toxicity (known as “particularly hazardous substances”) be handled in a “designated area.” Although a designated area may be a small portion or a single fume hood within a laboratory, the laboratory signs provide a means of designating the entire laboratory as an area where particularly hazardous substances may be used.

Accurate door postings facilitate emergency response actions by providing immediate information to firefighters, paramedics, and others. Incorrect postings may place others in danger and/or delay implementation of control measures to minimize certain emergency situations (e.g., fire, explosion, etc.), thereby increasing the damage to the room and/or other portions of the building.

The Hazard Assessment and Laboratory Signage (HALS) Program described below has been developed to provide researchers with a tool to prepare and order a permanent laboratory sign for this purpose.

2.1.1.2. Hazard Assessment and Laboratory Signage (HALS) Program

HALS is a web-based program designed to assist laboratory supervisors in identifying the hazards present in their laboratories and communicating this information to anyone who enters their labs. The laboratory PI, Lab Manager, Lab Supervisor or their representative can log onto the HALS Program to complete the sign at the following link:.

https://www.iu.edu/~ehs/sites/dashboard/?module=4

The laboratory PI, Lab Manager, Lab Supervisor, or their representative will then complete an electronic profile of the laboratory, and the information is incorporated into a door sign. The sign lists the name of the Principal Investigator, Lab Manager, Lab Supervisor and the name of any alternate contacts that are responsible for the room, along with corresponding contact numbers.

The PI, Lab Manager, Lab Supervisor, or their representative must select the most important hazards in their lab area from a list of hazards. They then rate the risk level as “low”, “moderate”, or “high” for each hazard. Use the drop down menus for guidance selecting the hazard types and ratings for each category.

For biological hazards present in the laboratory, please choose from Biosafety Level 1, 2 or 3 (BSL1, BSL2 or BSL3). Please note that you must have approval from Biological Safety before a sign can be posted indicating biological materials in use.

If radioactive materials are in use in the laboratory then please indicate “Present” on the pull down menu. Please note that you must have approval from the Radiation Safety Office before a sign can be posted indicating radioactive materials in use.

Eye protection classifications are based on the need for eye protection to enter the laboratory. Use the drop down menu to select the required level of eye protection (Class 1, 2 or 3).

The sign provides a method to limit access to specific personnel and also provides an area for you to type any additional warnings you would like posted.

All laboratory signs must state ***“No Food or Drinks”.***

2.2. Procedural Controls

Procedural controls (or work practice controls) are an administrative control typically in the form of rules, requirements, and standard operating procedures (SOPs) that define the *manner* in which certain types of chemicals are to be handled, or the manner in which specific operations involving chemicals are to be conducted, in order to minimize hazards. Section 3.0 of this Plan contains a number of rules, requirements and SOPs, which are generally applicable to all laboratories.

It is the responsibility of the PI and personnel in each laboratory to develop written SOPs for specific experimental procedures performed in their laboratory. These laboratory-specific procedures must be well documented and accessible to authorized personnel (incorporated into the laboratory manual or CHP). Training must be provided to new personnel by those that are proficient in the procedures. New personnel must be supervised and proficient performing the procedures before they are authorized to proceed.

2.3. Engineering Controls

Engineering controls consist of various measures for reducing a hazard at its source or for separating personnel from the hazard (see Section 6.0, Laboratory Safety Equipment). In the laboratory, examples of engineering controls include the substitution of less hazardous chemicals in an operation, isolating a particular chemical operation, enclosing a potentially explosive reaction, or utilizing local exhaust such as a fume hood for an operation that produces airborne chemicals (see Section 6.1, Chemical Fume Hoods). Because engineering controls function to reduce or eliminate a hazard at its source *before* it is created, they must be fully considered and utilized whenever possible as the *first* step in chemical hazard control within the laboratory.

2.4. Personal Protective Equipment

For many laboratory operations the risk of chemical exposure cannot be totally eliminated through the use of engineering and procedural control measures. For this reason, it is necessary to supplement such measures with the use of personal protective equipment (PPE) and apparel. Because PPE functions as a barrier between the laboratory worker and the chemical hazard, rather than by actually reducing or eliminating the hazard, its use must always be in addition to (and never as a substitute for) appropriate engineering and procedural controls. It is the responsibility of the principal investigator, lab manager, or lab supervisor of the laboratory to ensure that appropriate personal protective equipment is provided to and used by all laboratory personnel. Such equipment must be adequate to ensure personnel are protected from chemical exposure to the eyes, skin, and respiratory tract.

Selection of personal protective equipment is described in SOP 3.16. Personal protective equipment is selected based on the hazard. The Laboratory Chemical Personal Protective Equipment Guidance Form is found in Appendix A can be used for this purpose in the laboratory and will help assign the proper PPE based on the hazard.

Careful consideration to street clothes must be given when working with potential fire hazards such as flammables, reactives, or pyrophorics. Synthetic fabric street clothes are not appropriate for these applications and all cotton or fire-resistant lab coats must be utilized.

2.4.1. Eye Protection

Appropriate PPE for the eyes is *required* whenever there is a reasonable probability that the eyes could be exposed to chemicals. Vented safety goggles are the preferred eye protection to be worn when chemicals are handled in the laboratory. These must be worn *over* prescription glasses.

All protective equipment for the eyes must bear the stamp Z87, which indicates that it meets the performance guidelines established by the American National Standards Institute in ANSI Z87.1 "Practice for Occupational and Educational Eye and Face Protection."

2.4.2. Face Protection

A face shield is *required* whenever there is a potential for severe chemical exposure from splashes, fumes, or explosions. Because a face shield alone does not adequately protect the eyes, it must be worn over safety goggles. In general, any operation that requires a face shield must be conducted inside a hood with the sash down as an additional barrier.

2.4.3. Hand Protection

Because the hands are typically the part of the body in closest contact with chemicals in the laboratory, they are particularly vulnerable to chemical exposures. For this reason it is essential that laboratory personnel select appropriate protective gloves and wear them whenever handling chemicals. Because different glove materials resist different chemicals, no one glove is suited for all chemical exposures. Glove selection guides are available from most glove manufacturers and must be consulted before choosing a glove. For assistance contact University Environmental Health and Safety for your respective campus (see Laboratory Safety Contacts).

2.4.4. Foot Protection

Safety shoes or other specialized foot protection are generally not required for most laboratory operations. However, shoes must cover the entire foot. Open toed shoes and sandals are inappropriate footwear in laboratories. Fabric and athletic shoes offer little or no protection from chemical spills. Leather shoes or equivalent (chemically resistant shoes) with slip-resistant soles are required. Shoes may have to be discarded if contaminated with a hazardous material.

Chemical resistant overshoes, boots, or disposable shoe coverings ("booties"), may be used to avoid possible exposure to corrosive chemicals or large quantities of solvents or water that might penetrate normal footwear (e.g., during spill cleanup).

Although generally not required in most laboratories, composite-toed safety shoes may be necessary when there is a risk of heavy objects falling or rolling onto the feet, such as in bottle-washing operations, animal care facilities, or if large quantities of liquids are stored and moved in drums.

2.4.5. Body Protection

By virtue of its large surface area, the skin is at considerable risk of exposure to chemicals in the laboratory. To lessen this risk, it is essential that laboratory personnel wear clothing, which, to the extent possible, covers all skin surfaces (i.e. shorts are inappropriate attire for the laboratory). In addition, a fully-buttoned lab coat or chemical resistant apron must be worn during chemical manipulations. Clothing and lab coats must be regarded not as means of preventing exposure, but as means of lessening or delaying exposure. The effectiveness of clothing as a protective barrier for the skin depends upon its prompt removal in the event that it becomes contaminated. Do not wear synthetic fabric street clothes or polyester lab coats when working with flammables, reactives, or pyrophorics. Use all cotton or fire-resistant materials.

2.4.6. **Respiratory Protection**

The implementation of appropriate engineering and procedural controls should always be the preferred strategy for ensuring that any airborne levels of chemicals within the laboratory are well below regulatory limits. However, in rare circumstances where such control measures are not sufficient, laboratory personnel may need to utilize respirators for a particular operation. In such instances, personnel must participate fully in the University's Respiratory Protection Program, which requires a medical evaluation, respirator fit-testing (to ensure that the respirator properly fits the persons face and that there are no leaks which may lead to chemical exposure), and training prior to respirator use. Contact University Environmental Health and Safety for your respective campus for more information (see Laboratory Safety Contacts).

3. STANDARD OPERATING PROCEDURES

3.1. General Laboratory Safety Procedures

DO

- Know the potential hazards of the materials used in the laboratory. Review the Safety Data Sheet (SDS) and container label prior to using a chemical.
- Know the location of safety equipment such as telephones, emergency call numbers, emergency showers, eyewashes, fire extinguishers, fire alarms, first aid kits, and spill kits which can be found on all campuses (IUPUI does not provide laboratory spill kits).
- Review your laboratory's emergency procedures with your Principal Investigator, Lab Supervisor, or Lab Manager to ensure that necessary supplies and equipment are available for responding to laboratory accidents.
- Practice good housekeeping to minimize unsafe work conditions such as obstructed exits and safety equipment, cluttered benches and hoods, and accumulated chemical waste.
- Wear the appropriate personal protective apparel for the chemicals you are working with. This includes eye protection, lab coat, gloves, and appropriate foot protection (no sandals or open toed shoes). Gloves must be made of a material known to be resistant to permeation by the chemical in use.
- Shoes must cover the entire foot. Open toed shoes and sandals are inappropriate footwear in laboratories. Fabric and athletic shoes offer little or no protection from chemical spills. Leather shoes with slip-resistant soles are recommended.
- Street clothing is to be chosen so as to minimize exposed skin below the neck. Long pants and shirts with sleeves are examples of appropriate clothing. Avoid rolled up sleeves. Shorts (including cargo shorts), capris and miniskirts are inappropriate clothing in laboratories. Tank tops, sleeveless shirts and midriff-length shirts are not appropriate if not covered by a full length laboratory coat and must not be worn if wearing an apron alone. Synthetic fabrics must be avoided in high-hazard areas where flammable liquids and reactive chemicals are utilized.
- Contact lenses are not recommended but are permitted. Appropriate safety eyewear is still required for those that use contact lenses. Inform the lab supervisor of the use of contact lenses.
- Wash skin promptly if contacted by any chemical, regardless of corrosivity or toxicity.
- Label all new chemical containers with the "date received" and "date opened."
- Label and store chemicals properly. All chemical containers must be labeled to identify the container contents (no abbreviations or formulas) and should identify hazard information. Chemicals must be stored by hazard groups and chemical compatibilities.
- Use break-resistant bottle carriers when transporting chemicals in glass containers that are greater than 500 milliliters. Use lab carts for multiple containers. Do not use unstable carts.
- Use fume hoods when processes or experiments may result in the release of toxic or flammable vapors, fumes, or dusts.
- Restrain and confine long hair and loose clothing. Pony tails and scarves used to control hair must not present a loose tail that could catch fire or get caught in moving parts of machinery.

DON'T

- Eat, drink, chew gum, or apply cosmetics in rooms or laboratories where chemicals are used or stored.
- Store food in laboratory refrigerators, ice chests, cold rooms, or ovens.
- Drink water from laboratory water sources.
- Use laboratory glassware to prepare or consume food.
- Smell chemicals, taste chemicals, or pipette by mouth.
- Work alone in the laboratory without prior approval from the Principal Investigator, Lab Manager, or Lab Supervisor. Avoid chemical work or hazardous activities at night or during off-hours. Have a partner for assistance (use the "buddy-system") at night or during off-hours.
- Leave potentially hazardous experiments or operations unattended without prior approval from the Principal Investigator, Lab Manager, or Lab Supervisor. In such instances, the lights in the laboratory should be left on and emergency phone numbers posted at the laboratory entrance.

3.2. Procedures for Proper Labeling, Storage, and Management of Chemicals

Proper chemical labeling and storage is essential for a safe laboratory work environment. Inappropriate storage of incompatible or unknown chemicals can lead to spontaneous fire and explosions with the associated release of toxic gases. To minimize these hazards, chemicals in the laboratory must be segregated properly. The storage procedures listed below are not intended to be all-inclusive but should serve instead to supplement more specific procedures and recommendations obtained from container labels, Safety Data Sheets (SDSs), and other chemical reference material. For more information about chemical storage contact the University Environmental Health and Safety for your respective campus. (see Laboratory Safety Contacts).

3.2.1. Labeling

- Manufacturer chemical labels must never be removed or defaced until the chemical is completely used.
- All secondary chemical and waste containers must be clearly labeled with the full chemical name(s) (no abbreviations or formulas).
- Small containers that are difficult to label such as 1-10 ml vials and test tubes can be numbered, lettered, or coded as long as an associated log is available that identifies the chemical constituents. Groups of small containers can be labeled as a group and stored together.
- Unattended beakers, flasks, and other laboratory equipment containing chemicals used during an experiment must be labeled with the full chemical name(s).
- All chemicals should be labeled with the "date received" and "date opened."
- All laboratory chemical waste containers must be labeled with the name of the chemicals contained.
- All full waste containers must be disposed of promptly. Waste containers must NOT be filled to more than 90% of their capacity~~)~~.
- Chemical storage areas such as cabinets, shelves and refrigerators may be labeled to help the laboratory personnel identify the hazardous nature of the chemicals stored within the area (e.g., flammables, corrosives, oxidizers, water reactives, toxics, carcinogens, and reproductive toxins).

3.2.2. Safety Data Sheets

Safety Data Sheets (SDS) for all laboratory chemicals are required to be maintained in the laboratory or on-line. Safety Data Sheets are available from manufacturer's web sites and through the MSDSOnline® service at the IUEHS website, https://msdsmanagement.msdsonline.com/6df89148-4e9b-4af6-9ba8-da0d494c926a/ebinder/?nas=Truew

- The SDS for the exact chemical or mixture provided by the manufacturer of the product must be available. The chemical identity and manufacturer found on the label must match the chemical identity and manufacturer found on the SDS.
- All personnel must know how to access the SDS whether they are maintained on paper or electronically.
- All personnel must know how to read and understand an SDS.

Additional guidance on how to read, understand, maintain and (if necessary) prepare a Safety Data Sheet is available from IUEHS for your respective campus.

3.2.3. Storage

<u>HAZARD GROUPS</u>

- ∗ Flammable/Combustible Liquids
- ∗ Flammable Solids
- ∗ Inorganic Acids
- ∗ Organic Acids
- ∗ Oxidizing Acids (Nitric, etc.)
- ∗ Caustics (Bases)
- ∗ Oxidizers
- ∗ Water Reactives
- ∗ Air Reactives
- ∗ Unstable (shock-sensitive, explosive)
- ∗ Carcinogens & Reproductive Toxins
- ∗ Toxins, Poisons
- ∗ Non-Toxics
- ∗ Gases:
  - Toxic Gases
  - Flammable Gases
  - Oxidizing Gases
  - Corrosive Gases
  - Inert Gases

- A defined storage place should be provided for each chemical and the chemical should be returned to that location after each use.
- Chemical containers must be in good condition before they are stored. Containers must be managed to prevent leaks.
- Maximum quantities of chemicals that can be in storage and use in laboratories are found in the Uniform Building Code[1], the Uniform Fire Code[2], the International Building Code[3] and International Fire Code[4]. The tables of maximum allowable quantities are found in Appendix B. These codes place specific quantity limits on storage of chemicals in all hazard classes and some are very low, such as those for highly toxic gases and organic peroxides.
- Chemicals (including waste) must be separated and stored according to their hazard group and specific chemical incompatibilities. Chemicals within the same hazard group can be incompatible, therefore, it is important to review the chemical label and Safety Data Sheet (SDS) to determine the specific storage requirements and possible incompatibilities. Appendix B contains a partial list of incompatible chemicals.
- Special attention should be given to the storage of chemicals that can be classified into two or more hazard groups. For example, acetic acid and acetic anhydride are both corrosive and flammable. In addition, nitric and perchloric acids are both corrosive and strong oxidizers. Separate organic acids from oxidizing acids using secondary tubs or trays in the corrosives cabinet. Refer to the Safety Data Sheet (SDS) for proper storage procedures.
- Chemicals should be separated by distance. Physical barriers such as storage cabinets and secondary containers should be used to prohibit contact of incompatible chemicals in the event that they are accidentally released or spilled.
- Secondary containers are highly recommended for the storage of liquid chemicals. Secondary containers must be made of a material that is compatible with the chemical(s) it will hold and must be large enough to contain the contents of the largest container.
- Liquids should not be stored above dry chemicals unless they are stored in secondary containers.
- Storage of chemicals within hoods and on bench tops should be avoided.
- Stored chemicals should not be exposed to heat or direct sunlight.

- Storage shelves and cabinets should be secure to prevent tipping. Shelving should contain a front-edge lip or doors to prevent containers from falling.
- Flammable and corrosive storage cabinets should be used when possible.
- Flammable liquids in quantities exceeding a total of 10 gallons in each laboratory must be stored in an approved flammable storage cabinet.
- Only explosion-proof or laboratory-safe refrigerators may be used to store flammable liquids.
- Liquid chemicals should be stored below eye level to avoid accidental spills.
- Chemicals must not be stored in areas where they can be accidentally broken and spilled such as on the floor or on the edge of a bench top.
- Chemicals must not be stored in areas where they obstruct aisles, exits, and emergency equipment.

3.2.4. Chemical Inventory Management

All reportable chemicals must be inventoried. A list of reportable chemicals can be found in the appendices of the Chemical Hygiene Plan located at IUEHS.

In addition to reportable chemicals, all chemicals should be inventoried. Inventories provide a method for tracking chemicals for ordering and re-ordering, waste disposal, complying with the maximum allowable quantity limits in accordance with the International Building and Fire Codes (found in Appendix B), hazard communication, community right-to-know requirements, and tracking dangerous or time-sensitive chemicals for safety and security reasons.

Inventories should contain all pertinent information including the following data:

- Chemical name (synonym or trade name found on the Safety Data Sheet), if mixture list composition and percent of components.
- Chemical Abstract Service (CAS) number.
- Manufacturer.
- Product number.
- Physical state.
- Hazard class.
- Container size.
- Units of measure.
- Quantity or number of containers.
- Principal Investigator, Lab Manager, Lab Supervisor, or Chemical Hygiene Officer.
- Owner or researcher.
- Location (e.g., building, room number, cabinet).
- Receiving date.
- Opened container date.
- Expiration date.

Other information such as cost can be recorded as necessary for accounting purposes. Expiration dates are of particular importance for time-sensitive chemicals that can become dangerous with age. Several noteworthy time-sensitive laboratory chemicals include:

- Chemicals that form peroxides.
- Picric acid and other multi-nitro aromatics.
- Chloroform.
- Anhydrous hydrogen fluoride and hydrogen bromide.
- Liquid hydrogen cyanide.
- Formic acid.

- Alkali metals (such as potassium, sodium, and lithium).

See Standard Operating Procedure (SOP 3.17), Peroxide-Forming Chemicals and Other Time-Sensitive Materials, Procedures for Safe Handling and Management.

Use the following guidelines to manage laboratory chemicals including time-sensitive materials:

3.2.4.1. Acquisition control

- Do not hoard chemicals
- Do not over-purchase quantities
- Use just-in-time purchasing whenever possible
- Dispose of unused portions

3.2.4.2. Research the literature and Safety Data Sheet (SDS) information

- Define storage conditions
- Consider refrigeration requirements or other storage options
- Consider chemical incompatibilities

3.2.4.3. Define “unsafe” conditions such as:

- Temperature or humidity extremes
- Peroxide concentrations greater than 100 ppm
- Dry picric acid
- Expiration dates

3.2.4.4. Track Laboratory Chemicals

- Maintain a chemical inventory and check expiration dates regularly
- Define inspection interval for each chemical
- Log the date of inspection and re-inspect without fail

3.2.4.5. Manage Expired or “Unsafe” Chemicals

- Never place chemicals where they will become lost or forgotten.
- Do NOT touch lost time-sensitive chemicals. Call IUEHS for your respective campus immediately (see Laboratory Safety Contacts).

References:

1. Uniform Building Code, 1997, Section 307, Requirements for Group H Occupancies.
2. Uniform Fire Code, 1997, Article 80, Hazardous Materials.
3. International Building Code, 2000, Section 307, High-Hazard Group H
4. International Fire Code, 2000, Chapter 27, Hazardous Materials-General Provisions
5. Journal of Chemical Health and Safety, Management of Time-Sensitive Chemicals, p. 14-17, Vol. 11, No. 5, September/October 2004.

3.3. Chemical Fume Hoods – Procedures for Proper and Safe Use

Chemical fume hoods are one of the most important items of safety equipment present within the laboratory. Chemical fume hoods serve to control the accumulation of toxic, flammable, and offensive vapors by preventing their escape into the laboratory atmosphere. In addition, fume hoods provide physical isolation and containment of chemicals and their reactions and thus serve as a protective barrier (with the sash closed) between laboratory personnel and the chemical or chemical process within the hood.

- A chemical fume hood must be used for any chemical procedures that have the potential of creating:
    1. Airborne chemical concentrations that might approach Permissible Exposure Limits (PELs) for an Occupational Safety and Health Administration (OSHA) regulated substance. These substances include carcinogens, mutagens, teratogens, and other toxics. PELs are found in 1910.1450, Appendix A. The OSHA Select Carcinogens and examples of reproductive toxins are found in Appendix B of this document.
    2. Flammable/combustible vapors approaching one tenth the lower explosive limit (LEL). The LEL is the minimum concentration (percent by volume) of the fuel (vapor) in air at which a flame is propagated when an ignition source is present.
    3. Explosion or fire hazards.
    4. Odors that are annoying to personnel within the laboratory or adjacent laboratory/office units.
- Vertical fume hood sashes can be used in three positions: 1) closed, 2) the operating height (or half open), and 3) the set-up position (or fully open).
- Hoods must be closed when unattended.
- The sash opening must be positioned no higher than the operating height (or half open) when the hood is being used with chemicals present or when chemical manipulations are performed. Place the sash in front of the face to protect the persons breathing zone near the nose and mouth from chemical contaminants released within the fume hood. When working with hazardous chemicals, the hood sash should always be positioned so that it acts as a protective barrier between laboratory personnel and the chemicals.
- The set-up position (fully open) is only used to place equipment in the hood when no chemicals are present. Do not fully open the sash when chemicals are present.
- Sliding horizontal sash panels are used with one panel placed in front of the face and arms reaching around the sides to perform manipulations. Do not slide the panels laterally exposing the face to the interior of the hood with chemicals present.
- Hood baffles or slots should be positioned properly if available. The top baffle/slot should be opened when chemicals with a vapor density of less than 1 (lighter than air) are used. The bottom baffle/slot (if available) should be opened when chemicals with vapor densities greater than 1 (heavier than air) are used.
- Chemicals and equipment (apparatus, instruments, etc.) should be placed at least 6 inches (15 cm) from the front edge of the hood.
- Equipment should be placed in the center of the working surface in the hood. Do not place materials at the front of the working surface because it will block the slot under the air foil sill at the front. Do not place materials at the back of the working surface because it will block airflow to the lower slot under the baffle in the back. Separate and elevate equipment by using blocks or lab jacks to ensure that air can flow easily around and under the equipment.

- Chemical fume hoods must be kept clean and free from unnecessary items and debris at all times. Solid material (paper, tissue, aluminum foil, etc.) must be kept from obstructing the rear baffles and from entering the exhaust ducts of the hood.
- Minimize the amount of bottles, beakers and equipment used and stored inside the hood because these items interfere with the airflow across the work surface of the hood.
- Chemicals should not be stored in a hood because they will likely become involved if there is an accidental spill, fire or explosion in the hood, thus creating a more serious problem. Fume hoods are not flammable cabinets and do not offer fire protection for materials stored inside.
- Sliding horizontal sash windows must not be removed from the hood sash.
- Laboratory personnel must not extend their head inside the hood when operations are in progress.
- The hood must not be used for waste disposal (evaporation).
- Hoods must be monitored by the user to ensure that air is moving into the hood. A small piece of thread, yarn, or small piece of Kimwipe® can be taped to the hood sash as a visual indicator that the hood is pulling air. Any hoods that are not working properly must be taken out of service and reported to Facility Services/Physical Plant (FS/PP) and University Environmental Health and Safety for your respective campus (see Laboratory Safety Contacts). IUEHS is responsible for evaluating chemical fume hoods annually.
- Perchloric acid digestions and other procedures using perchloric acid at elevated temperatures must not be performed in standard chemical fume hoods. Specially designed perchloric acid fume hoods must be utilized for this purpose. Call IUEHS for your respective campus for more information.

3.4. **Corrosive Chemicals –** Procedures for Safe Handling and Storage

Corrosives (liquids, solids, and gases) are chemicals that cause visible destruction or irreversible alterations to living tissue by chemical action at the site of contact. Corrosive effects can occur not only to the skin and eyes, but also to the respiratory tract through inhalation and to the gastrointestinal tract through ingestion. Corrosive liquids have a high potential to cause external injury to the body, while corrosive gases are readily absorbed into the body through skin contact and inhalation. Corrosive solids and their dusts can damage tissue by dissolving rapidly in moisture on the skin or within the respiratory tract when inhaled. In order to minimize these potential hazards, precautionary procedures must be observed when handling corrosives.

3.4.1. Handling

- Appropriate personal protective equipment (e.g., gloves, fire-resistant or all cotton lab coat, and safety goggles) must be worn when working with corrosive chemicals. A face shield, rubber apron, and rubber booties may also be appropriate depending on the work performed.
- Appropriate protective gloves that are resistant to permeation or penetration from corrosive chemicals must be selected and tested for the absence of pin holes prior to use.
- Eyewashes and safety showers must be readily available in areas where corrosive chemicals are used and stored. In the event of skin or eye contact with a corrosive chemical, the affected area should be immediately flushed with water for 15 minutes. Contaminated clothing should be removed and medical attention sought.
- Corrosive chemicals should be handled in a fume hood to ensure that any possible hazardous or noxious fumes generated are adequately vented.
- When mixing concentrated acids with water, add the acid slowly to the water. Allow the acid to run down the side of a container and mix slowly to avoid violent reactions and splattering. Never add water to acid.
- Appropriate spill clean-up material should be available in areas where corrosive chemicals are used and stored.
- Protective carriers shall be used when transporting corrosive chemicals.

3.4.2. Storage

- Containers and equipment used for storage and processing of corrosive material must be corrosion resistant.
- Corrosive chemicals must be stored below eye level, preferably near the floor to minimize the danger of their falling from cabinets or shelves.
- Acids and caustics (i.e. bases) must be stored separately from each other. Secondary containers or trays must be used to separate acids and bases or other incompatible corrosives within a corrosive cabinet.
- Oxidizing acids must be separated from organic acids and flammable/combustible materials (oxidizing acids are particularly reactive with organics and flammable/combustible materials).
- Acids must be segregated from active metals (e.g., sodium, potassium, and magnesium) and from chemicals that can generate toxic gases (e.g., sodium cyanide and iron sulfide).
- Corrosive gas cylinders must be returned for disposal every two years.

3.5. **Flammable and Combustible Liquids –** Procedures for Safe Handling and Storage

Chemicals which exist at ambient temperatures in a liquid form with sufficient vapor pressure to ignite in the presence of an ignition source are called flammable or combustible liquids (note that the flammable/combustible liquid itself does not burn; it is the vapor from the liquid that burns). According to the National Fire Protection Association (NFPA) classification system, “flammables” generate sufficient vapor at temperatures below 100 °F (37.8° C), whereas “combustibles” generate sufficient vapor at temperatures at or above 100 °F. Invisible vapor trails from these liquids can reach remote ignition sources causing flashback fires. In addition, these liquids become increasingly hazardous at elevated temperatures due to more rapid vaporization. For these reasons, precautionary measures must be observed when handling and storing flammables and combustibles.

3.5.1. Classification

NFPA Classification		**Flash Point[1]**	**Boiling Point**
Flammable Liquid			
	Class IA	<73° F (22.8 ° C)	<100° F (37.8° C)
	Class IB	<73° F	≥100° F
	Class IC	≥73° F and <100 ° F	NA
Combustible Liquid			
	Class II	≥100° F and <140° F (60°C)	NA
	Class IIIA	≥140° F and <200° F (93°C)	NA

[1] The minimum temperature at which liquid gives off enough vapor in sufficient concentration to form an ignitable mixture in air near the surface of a liquid.

3.5.2. Handling

- Appropriate personal protective equipment (e.g., gloves, fire-resistant or all cotton lab coat, and safety goggles) must be worn when working with flammable/combustible liquids.
- Flammable/combustible liquids must never be heated using open flames. Preferred heat sources include steam baths, water baths, oil baths, hot air baths, and heating mantels.
- Ignition sources must be eliminated in areas where flammable vapors may be present.
- Flammable/combustible liquids should only be dispensed under a fume hood. Ventilation is one of the most effective ways to prevent the formation and concentration of flammable vapors.
- When pouring from conductive containers with a capacity of 1 gallon (3.8 liters) or greater, make sure both containers involved are electrically interconnected by bonding to each other and to a ground. The friction of flowing liquid may be sufficient to generate static electricity, which in turn may discharge, causing a spark and ignition
- Flammable/combustible liquids in containers with a volume greater than 1 gallon (3.8 liters) should be transferred to smaller containers that can be easily manipulated by one person.
- Appropriate fire extinguishers must be available in areas where flammables are used.

3.5.3. Storage

- Flammable/combustible liquid in quantities exceeding a total of 10 gallons (38 liters) within a laboratory must be stored in approved flammable storage cabinets or safety cans.
- Flammable/combustible liquid stored outside of flammable storage cabinets in the laboratory should be kept to the minimum necessary for the work being done.
- Containers with a volume greater than 5 gallons (19 liters) shall not be stored in the laboratory without prior approval of IUEHS for the respective campus.
- Flammable/combustible liquid stored in glass containers shall not exceed 1 gallon (3.8 liters).
- Flammable storage cabinets and safety cans must not be altered or modified.
- Safety cans with damaged screens (spark arrestors) or faulty springs (that do not close tightly) do not meet the required specifications of a safety can and must be taken out of service immediately and repaired or replaced.
- Flammable liquids must only be stored in explosion-proof or laboratory-safe refrigeration equipment.
- Flammable/combustible liquid containers, filled or empty, must not be stored in hallways or obstructing exits.
- Bulk waste flammable/combustible liquids should be stored in safety cans.
- Flammables and combustibles must not be stored near oxidizers, corrosives, combustible material, or near heat sources. Make sure all chemicals stored near flammables and combustibles are compatible.

3.6. Oxidizing Agents – Procedures for Safe Handling and Storage

Oxidizing agents are chemicals that bring about an oxidation reaction. The oxidizing agent may 1) provide oxygen to the substance being oxidized (in which case the agent has to be oxygen or contain oxygen) or 2) receive electrons being transferred from the substance undergoing oxidation (chlorine is a good oxidizing agent for electron-transfer purposes, even though it does not contain oxygen). The intensity of the oxidation reaction depends on the oxidizing-reducing potential of the material involved. Fire or explosion is possible when strong oxidizing agents come into contact with easily oxidizable compounds, such as metals, metal hydrides or organics. Because oxidizing agents possess varying degrees of instability, they can be explosively unpredictable.

3.6.1. Examples of Oxidizing Agents

Gases	Fluorine, Chlorine, Ozone, Nitrous Oxide, Oxygen
Liquids	Hydrogen Peroxide, Nitric Acid, Perchloric Acid, Bromine, Sulfuric Acid
Solids	Nitrites, Nitrates, Perchlorates, Peroxides, Chromates, Dichromates, Picrates, Permanganates, Hypochlorites, Bromates, Iodates, Chlorites, Chlorates, Persulfates

3.6.2. Handling

- Appropriate personal protective equipment (e.g., safety goggles, gloves, fire resistant or all cotton lab coat) must be worn when working with oxidizers.
- If a reaction is potentially explosive or if the reaction is unknown, use a fume hood (with the sash down as a protective barrier), safety shield, or other methods for isolating the material or the process.
- Oxidizers can react violently when in contact with incompatible materials. For this reason, know the reactivity of the material involved in an experimental process. Assure that no extraneous material is in the area where it can become involved in a reaction.
- The quantity of oxidizer used should be the minimum necessary for the procedure. Do not leave excessive amounts of an oxidizer in the vicinity of the process.
- Perchloric acid digestions and other procedures using perchloric acid at elevated temperatures must not be performed in a standard chemical fume hood. A specially designed Perchloric Acid Fume Hood must be utilized for this purpose. Contact IUEHS for your respective campus (see Laboratory Safety Contacts) for more information.

3.6.3. Storage

- Oxidizers should be stored in a cool, dry place.
- Oxidizers must be segregated from organic material, flammables, combustibles and strong reducing agents such as zinc, alkaline metals, and formic acid.
- Oxidizing acids such as perchloric acid and nitric acid must be stored separately in compatible secondary containers away from other acids.

For the purpose of storage, the Uniform and International Building Code and the National Fire Protection Association classify oxidizers based on the increase in the burning rate of the combustible material with which it comes into contact. See Appendix B of this document for the definitions and a list of examples. Contact IUEHS for your respective campus (see Laboratory Safety Contacts) for more information.

3.7. **Reactive Chemicals** – Procedures for Safe Handling and Storage

Reactives are substances that have the potential to vigorously polymerize, decompose, condense, or become self-reactive due to shock, pressure, temperature, light, or contact with another material. All reactive hazards involve the release of energy in a quantity or at a rate too great to be dissipated by the immediate environment of the reaction system so that destructive effects occur. Reactive chemicals include: 1) **explosives**, 2) **organic peroxides**, 3) **water-reactives** and 4) **pyrophorics**. Effective control is essential to minimize the occurrence of reactive chemical hazards.

3.7.1. Explosives

A chemical that causes sudden, almost instantaneous release of pressure, gas, and heat when subjected to sudden adverse conditions. Heat, light, mechanical shock, detonation, and certain catalysts can initiate explosive reactions. Compounds containing the functional groups azide, acetylide, diazo, nitroso, haloamine, peroxide, or ozonide are sensitive to shock and heat and can explode violently.

- Appropriate personal protective equipment (e.g., face shield, safety goggles, leather outer gloves, chemical resistant gloves, fire-resistant or all cotton lab coat) must be worn when working with explosives.
- Before working with explosives, understand their chemical properties, know the products of side reactions, know the incompatibility of certain chemicals, and monitor environmental catalysts such as temperature changes.
- Containers should be dated upon receipt and when opened. Expired explosives should be disposed of through IUEHS for your respective campus promptly.
- Explosives should be kept to the minimum necessary for the procedure.
- If there is a chance of explosion, use protective barriers (e.g., fume hood sash and safety shield) or other methods for isolating the material or process.
- Explosives should be stored in a cool, dry, and protected area. Segregate from other material that could create a serious risk to life or property should an accident occur.

3.7.2. Organic Peroxides

These chemicals contain an -O-O- structure bonded to organic groups. These compounds can be considered as structural derivatives of hydrogen peroxide, H-O-O-H, in which one or both of the hydrogen atoms have been replaced by an organic group. Generally, organic peroxides are low-powered explosives that are sensitive to shock, sparks, and heat due to the weak -O-O- bond which can be cleaved easily. Some organic compounds such as ethers, tetrahydrofuran, and p-dioxane can react with oxygen from the air forming unstable peroxides. Peroxide formation can occur under normal storage conditions, when compounds become concentrated by evaporation, or when mixed with other compounds. These accumulated peroxides can violently explode when exposed to shock, friction, or heat.

- Appropriate personal protective equipment (e.g., safety goggles, gloves, fire-resistant or all cotton lab coat) must be worn when working with organic peroxides or peroxide-forming compounds.
- Containers must be labeled with the receiving and opening dates. Discard unopened material within the timeframes outlined in the IU Waste Management Guide for the respective campus.
- Containers should be airtight, and stored in a cool, dry place away from direct sunlight and segregated from incompatible chemicals.
- Do not refrigerate Peroxide-formers, liquid peroxides, or solutions below the

temperature at which the peroxide freezes or precipitates. Peroxides in these forms are extra sensitive to shock (never store diethyl ether in a refrigerator or freezer).

- Unused peroxides should never be returned to the stock container.
- Do not use Metal spatulas with peroxide-formers. Use ceramic or plastic spatulas. Contamination by metal can cause explosive decomposition.
- Avoid friction, grinding, and all forms of impact, especially with solid organic peroxides. Never use glass containers with screw cap lids or glass stoppers. Instead, use plastic bottles and sealers.
- Containers with obvious crystal formation around the lid or viscous liquid at the bottom of the container must NOT be opened or moved. Call IUEHS for your respective campus (see Laboratory Safety Contacts) for guidance and disposal.
- Organic peroxides produce vapors during decomposition. This can result in pressure build-up. The rapid increase in pressure may cause explosive rupture of containers, vessels or other equipment.
- Ignition sources must be avoided.
- Organic Peroxides have a Self-Accelerating Decomposition Temperature (SADT). Never store organic peroxides where they may be exposed to temperatures above the SADT. At or above this temperature an irreversible runaway reaction will take place. The recommended storage temperature is printed on the product label and Safety Data Sheet.

For more information on organic peroxide-forming compounds please refer to SOP 3.17, Peroxide-Forming Chemicals and Other Time-Sensitive Materials, Procedures for Safe Handling and Management and Appendix B of this document, for a list of chemicals that can form peroxides upon aging.

3.7.3. Water-Reactives

A chemical that reacts with water or moisture in the air (humidity) releasing heat or flammable, toxic gas. Examples include alkali metals, alkaline earth metals, carbides, hydrides, inorganic chlorides, nitrides, peroxides, and phosphides.

- Appropriate personal protective equipment (e.g., safety goggles, gloves, fire-resistant or all cotton lab coat) must be worn when working with water-reactives.
- Water-reactives should be stored under mineral oil in a cool, dry place and isolated from other chemicals.
- Water-reactives must not be stored near water, alcohols, and other compounds containing acidic OH.

In case of fire, keep water away. Appropriate fire extinguishers should be available in areas where water-reactives are used (use a Type “D” fire extinguisher to extinguish active metal fires).

3.7.4. Pyrophorics

A chemical that ignites spontaneously in air below 130^{o} F (54^{o} C). Often the flame is invisible. Examples of pyrophoric materials include silane, silicon tetrachloride, white and yellow phosphorus, sodium, tetraethyl lead, potassium, nickel carbonyl, and cesium.

- Appropriate personal protective equipment (e.g., safety goggles, gloves, fire-resistant or all cotton lab coat) must be worn when working with pyrophorics.
- Pyrophorics must be used and stored in inert environments.
- Appropriate fire extinguishers must be available in areas where pyrophorics are used.

3.7.5. **Synthesis**

Synthesis of any reactive or energetic (explosive) compound is subject to the following requirements:

- The principal investigators written prior approval of the procedure is required. (use Chemical Reaction Hazard Assessment Form, Appendix A, Form LCS-7).
- The procedure must be documented in writing with specific step by step instructions.
- The principal investigator is required to provide documented procedure-specific training and documented daily supervision of the research.
- A written hazard analysis of the procedure is required prior to start up and whenever a change to the procedure is made. Worst case scenarios must be considered (Appendix A, Form LCS-7).
- Appropriate hazard controls, as determined by the hazard analysis, must be in place prior to the experiment.
- The synthesized quantity is limited to 100 milligrams. Synthesis of more than 100 mg of reactive or energetic compounds is prohibited.

3.8. **Particularly Hazardous Substances** - Procedures for Safe Handling and Storage

The Occupational Safety and Health Administration (OSHA) Laboratory Standard requires that special handling procedures be employed for certain chemicals identified as "particularly hazardous substances." Particularly hazardous substances include chemicals that are "select carcinogens, reproductive toxins, and chemicals that have a high degree of acute toxicity." In addition, many chemicals used (including novel chemicals that are synthesized) in research laboratories have not been tested explicitly for carcinogenic or toxic properties and must therefore be handled as "particularly hazardous substances" since their hazards are unknown.

3.8.1. Carcinogen

A carcinogen is a substance that either causes cancer in humans or, because it causes cancer in animals, is considered capable of causing cancer in humans. OSHA defines those substances that are known to pose the greatest carcinogenic hazards as "select carcinogens" (see Appendix B). These materials include substances that:

- OSHA regulates as a carcinogen; or
- The National Toxicology Program (NTP) lists as "known to be a carcinogen" or "reasonably anticipated to be a carcinogen" in their Annual Report on Carcinogens; or
- The International Agency for Research on Cancer (IARC) lists under Group 1 ("carcinogenic to humans"), Group 2A ("probably carcinogenic to humans"), or Group 2B ("possibly carcinogenic to humans").

3.8.2. Reproductive Toxin

A reproductive toxin is a substance that causes chromosomal damage or genetic alterations (mutagens) or substances that cause lethal or physical malformations or defects in a developing fetus or embryo (teratogens).

Additional information and guidance can be found in SOP 3.21, Reproductive Toxins, Mutagens, Teratogens, and Embryotoxins – Procedures for Safe Handling and Storage.

3.8.3. Chemicals with a High Degree of Acute Toxicity

Acute toxicity is the ability of a chemical to cause a harmful effect rapidly after a single short term exposure. Acutely toxic chemicals can cause local toxic effects, systemic effects, or both. OSHA's "chemicals with a high degree of acute toxicity" includes both "highly toxic" and "toxic" chemicals that "may be fatal or cause damage to target organs as a result of a single exposure or exposures of short duration" (i.e., acutely toxic effects) as defined in 29 CFR 1910.1200, Appendix A (Mandatory). Combining the definitions from 29 CFR 1910.1200, Appendix A, yields the following table:

Route of Entry	Highly Toxic	Toxic
Oral LD_{50} (albino rats)	≤ 50 mg/kg	>50-500 mg/kg
Skin Contact LD_{50} (albino rabbits, 24 hour)	≤ 200 mg/kg	>200-1000 mg/kg
Inhalation LC_{50} (albino rats, one hour) as vapor	≤ 200 ppm	>200-2000 ppm
Inhalation LC_{50} (albino rats, one hour) as dust, mist, or fumes	or ≤ 2 mg/liter	or >2-20 mg/liter

Note: The lethal dose (LD50) is the dose (in mg/kg of body weight) and the lethal concentration (LC50) is the concentration in air (in ppm) at which 50% of the test subjects expire.

In general, “chemicals with a high degree of acute toxicity” include 1) “highly toxic” chemicals that have an Oral LD50 of ≤50 mg/kg (rats), Skin Contact LD50 of ≤200 mg/kg (rabbits), Inhalation LC50 of ≤200 ppm (rats for 1 hour) and 2) “toxic” chemicals with acutely toxic effects or those that have an Inhalation LC50 of ≤2000 ppm (rats for 1 hour).

Comparing the former OSHA definition to the Globally Harmonized System (GHS) of chemical classification and labeling, the GHS acute toxicity ratings of 1 and 2 account for the old OSHA “highly toxic” categories and the “toxic” inhalation category. Therefore, the GHS acute toxicity ratings of 1 and 2 can be used as to determine the laboratory chemicals that are considered “chemicals with a high degree of acute toxicity” and as such, “particularly hazardous substances.”

Route of Entry	**GHS Acute Toxicity Ratings**			
	1	2	3	4
Oral LD_{50}	0-≤5 mg/kg	>5-<50	50-<300	300-<2000
Skin Contact LD_{50}	0-≤50 mg/kg	>50-≤200	>200-≤1000	>1000-≤2000
Inhalation (gas) LC_{50}	0-≤100 ppm	>100-≤500	>500-≤2500	>2500-≤5000
Inhalation (vapors) LC_{50}	0-≤0.5 mg/l	>0.5-≤2.0	>2.0-≤10.0	>10.0-≤20.0
Inhalation (dust & mist) LC_{50}	0-≤0.05 mg/l	>0.05-≤0.5	>0.5-≤1.0	>1.0-≤5.0

Using the National Fire Protection Association’s (NFPA) 704 health hazard classifications, the NFPA health hazard ratings of 3 and 4 accounts for all the OSHA “highly toxic” categories and the “toxic” inhalation category. Therefore, the NFPA health hazard ratings of 3 and 4 can be used as practical guide to determine the laboratory chemicals that are considered “chemicals with a high degree of acute toxicity” and as such, “particularly hazardous substances.”

Route of Entry	**NFPA 704 Health Hazard Classifications**				
	4	3	2	1	0
Oral LD_{50}	0-5 mg/kg	>5-50	>50-500	>500-2000	>2000
Skin Contact LD_{50}	0-40 mg/kg	>40-200	>200-1000	>1000-2000	>2000
Inhalation LC_{50}	0-1000 ppm	>1000-3000	>3000-5000	>5000-10,000	>10,000

3.8.4. Handling

- Designated areas (e.g., fume hoods, glove boxes, lab benches, outside rooms) for material use must be established and the areas identified by signs or postings.
- Containment devices such as fume hoods (if necessary) and personal protective equipment (e.g., gloves, lab coat, and eye protection) must be used when handling these hazardous substances.
- Procedures for the safe use of the material and waste removal must be established prior to use.
- Decontamination procedures must be developed in advance and strictly followed.
- Only laboratory personnel trained to work with these substances can perform the work, and always within the designated area. Prior approval is required by the Principal Investigator, Lab Manager or Lab Supervisor (see Section 2.1.1 Prior Approval of Hazardous Operations).
- Only the minimum quantity of the material should be used.

3.8.5. Storage

- These materials must be stored in areas designated for “particularly hazardous substances."

- Storage areas should be clearly marked with the appropriate hazard warning signs.
- All containers of these materials (even if the material is in very small quantities such as 0.1%) must be clearly labeled with the chemical name or mixture components and should be labeled with the appropriate hazard warning information.
- Chemical storage areas should be secure to avoid spills or broken containers.
- Storage areas or laboratory rooms must be locked when laboratory personnel are away or not present.

3.9. **Compressed Gases** – Procedures for Safe Handling and Storage

In general, a compressed gas is any material contained under pressure that is dissolved or liquefied by compression or refrigeration. Compressed gas cylinders must be handled as high-energy sources and therefore as potential explosives and projectiles. Prudent safety practices must be followed when handling compressed gases because they expose workers to both chemical and physical hazards.

This section provides general standard operating procedures for use of compressed gases in laboratories. For further information refer to the IU Compressed Gas Cylinder Safety Program.

3.9.1. Handling

- Safety glasses with side shields (or safety goggles) and other appropriate personal protective equipment must be worn when working with compressed gases.
- Cylinders must be marked with a label that clearly identifies the contents.
- All cylinders must be checked for damage prior to use. Do not repair damaged cylinders or valves. Damaged or defective cylinders, valves, etc., must be taken out of use immediately and returned to the manufacturer/distributor for repair.
- All gas cylinders (full or empty) must be rigidly secured above the mid line of the cylinder. Only two cylinders per restraint are allowed in the laboratory and only soldered link chains or belts with buckles are acceptable. Cylinder stands are also acceptable but not preferred.
- Handcarts shall be used when moving gas cylinders. Cylinders must be chained to the carts.
- All cylinders must be fitted with safety valve covers before they are moved.
- Only three-wheeled or four-wheeled carts should be used to move cylinders.
- A pressure-regulating device shall be used at all times to control the flow of gas from the cylinder.
- The main cylinder valve shall be the only means by which gas flow is to be shut off. The correct position for the main valve is all the way on or all the way off.
- Cylinder valves must never be lubricated, modified, forced, or tampered. Regulator fittings must not be sealed with Teflon tape, grease or pipe sealant. Never grease any oxygen fittings (use PTFE Telfon tape only).
- After connecting a cylinder, check for leaks at connections. Periodically check for leaks while the cylinder is in use.
- Regulators and valves must be tightened firmly with the proper size wrench. Do not use adjustable wrenches or pliers because they may damage the nuts.
- Cylinders must not be placed near heat or where they can become part of an electrical circuit.
- Cylinders must not be exposed to temperatures above 50^{o} C (122^{o} F). Some rupture devices on cylinders will release at about 65^{o} C (149^{o} F). Some small cylinders, such as lecture bottles, are not fitted with rupture devices and may explode if exposed to high temperatures.
- Rapid release of a compressed gas must be avoided because it will cause an unsecured gas hose to whip dangerously and also may build up enough static charge to ignite a flammable gas.
- Appropriate regulators must be used on each gas cylinder. Threads and the configuration of valve outlets are different for each family of gases to avoid improper use. Use the Compressed Gas Association (CGA) numbered fittings appropriate for the gas in use. Consult manufacturer's catalogs for the appropriate

equipment. Adaptors and homemade modifications are prohibited.

- Cylinders must never be bled completely empty. Leave a slight pressure to keep contaminants out.
- Gases shall not be transferred from one compressed gas cylinder to another.

3.9.2. Storage

- When not in use, cylinders must be stored with their main valve closed and the valve safety cap in place.
- Cylinders with less than 1.3 gallons water volume may be stored on their side. All cylinders must be secured. Dissolved gases such as acetylene (which is dissolved in acetone) must be stored upright (see Special Precautions). The pressure relief device on cylinders of gases that are liquid under pressure (such as some flammable gases) must be in contact with the gas phase.
- Cylinders awaiting use and empty cylinders must be stored according to their hazard classes.
- Cylinders must not be located where objects may strike or fall on them.
- Cylinders must not be stored in damp areas or near salt, corrosive chemicals, chemical vapors, heat, or direct sunlight. Cylinders stored outside must be protected from the weather.
- Corrosive gas cylinders must be returned for disposal every two years.

3.9.3. Special Precautions

3.9.3.1. Flammable Gases

- No more than two cylinders can be manifolded together; however several instruments or outlets are permitted for a single cylinder.
- Valves on flammable gas cylinders must be shut off when the laboratory is unattended and no experimental process is in progress.
- Flammable gas cylinders must be grounded. (Do not ground to an electrical outlet.)
- Flames involving a highly flammable gas must not be extinguished until the source of the gas has been safely shut off; otherwise it can reignite causing an explosion.

3.9.3.2. Acetylene Gas Cylinders

- Acetylene cylinders must always be stored upright. They contain acetone, which can discharge instead of or along with acetylene. Do not use an acetylene cylinder that has been stored or handled in a non-upright position until it has remained in an upright position for at least 30 minutes.
- The outlet line of an acetylene cylinder must be protected by a flame arrestor.
- Compatible tubing must be used to transport gaseous acetylene. Sometubing like copper forms explosive acetylides.

3.9.3.3. Lecture Bottles

- All lecture bottles must be marked with a label that clearly identifies the contents.
- Lecture bottles must be stored according to their hazard classes.
- Lecture bottles which contain toxic gases must be stored in a ventilated cabinet.

- Lecture bottles must be secured in storage and when in use, secured to a fixed frame or structure.
- Lecture bottles must not be stored near corrosives, heat, direct sunlight, or in damp areas.
- To avoid costly disposal fees, lecture bottles should only be purchased from suppliers that will accept returned bottles (full or empty). Contact the supplier before purchasing lecture bottles to ensure that they have a return policy.
- Lecture bottles should be dated upon initial use. It is advised that bottles be sent back to the supplier after one year to avoid accumulation of old bottles.

3.10. **Cryogenic Liquids** – Procedures for Safe Handling and Storage

Cryogenic liquids are liquefied gases having boiling points of less than -73.3ºC (-100ºF). The primary hazards of cryogenic liquids include both physical hazards such as fire, explosion, and pressure buildup and health hazards such as severe frostbite and asphyxiation. Potential fire or explosion hazards exist because cryogenic liquids are capable, under the right conditions, of condensing oxygen from the atmosphere. This oxygen-rich environment in combination with flammable/combustible materials and an ignition source are particularly hazardous. Pressure is also a hazard because of the large volume expansion ratio from liquid to gas that a cryogen exhibits as it warms and the liquid evaporates. This expansion ratio also makes cryogenic liquids more prone to splash and therefore skin and eye contact is more likely to occur. Contact with living tissue can cause frostbite or thermal burns, and prolonged contact can cause blood clots that have very serious consequences. All laboratory personnel must follow prudent safety practices when handling and storing cryogenic liquids.

3.10.1. **Properties of Common Cryogenic Liquids**

Gas	**Boiling Point ºF (ºC)**	**Liquid to Gas Volume Expansion Ratio**
Helium	-452 (-268.9)	1-757
Hydrogen	-423 (-252.7)	1-851
Nitrogen	-321 (-195.8)	1-696
Fluorine	-307 (-187.0)	1-888
Argon	-303 (-185.7)	1-847
Oxygen	-297 (-183.0)	1-860
Methane	-256 (-161.4)	1-578

Note: Absolute zero = - 459.67 ºF (- 273.15 ºC)

3.10.2. **Handling**

- Appropriate personal protective equipment must be worn when handling cryogenic liquids. This includes special cryogen gloves, safety goggles, full face shield, impervious apron or coat, long pants, and full coverage shoes. Gloves must be impervious and sufficiently large to be readily removed should a cryogen be spilled. Watches, rings, and other jewelry should NOT be worn.
- Unprotected body parts must not come in contact with vessels or pipes that contain cryogenic liquids because extremely cold material may bond firmly to the skin and tear flesh if separation is attempted.
- Objects that are in contact with cryogenic liquid must be handled with tongs or proper gloves.
- All precautions should be taken to keep liquid oxygen from organic materials; spills on oxidizable surfaces can be hazardous.
- All equipment should be kept clean, especially when working with liquid or gaseous oxygen.
- Work areas must be well ventilated.
- Transfers or pouring of cryogenic liquid must be done very slowly to minimize boiling and splashing.
- Cryogenic liquids and dry ice used as refrigerant baths must be open to the atmosphere. They must never be in a closed system where they may develop uncontrolled or dangerously high pressure.
- Liquid hydrogen must not be transferred in an air atmosphere because oxygen from the air can condense in the liquid hydrogen presenting a possible explosion risk.

3.10.3. Storage

- Cryogenic liquids must be handled and stored in containers that are designed for the pressure and temperature to which they may be subjected. The most common container for cryogenic liquids is a double-walled, evacuated container known as a Dewar flask.
- Containers and systems containing cryogenic liquids must have pressure-relief mechanisms.
- Coolers and Styrofoam boxes may be used for storage of small amounts of solid carbon dioxide (dry ice) only. Do not use coolers and Styrofoam boxes as the primary container for the transportation and storage of liquid cryogens.
- Cylinders and other pressure vessels such as Dewar flasks used for the storage of cryogenic liquids must not be filled more than 80% of capacity to protect against possible thermal expansion of the contents and bursting of the vessel by hydrostatic pressure. If the possibility exists that the temperature of the cylinder may increase to above 30^{o} C (86^{o} F), a lower percentage (e.g., 60 percent capacity) should be the limit.
- Dewar flasks should be shielded with tape or wire mesh to minimize flying glass and fragments should an implosion occur.
- Dewar flasks must be labeled with the full cryogenic liquid name and should be labeled with hazard warning information.
- Work and storage areas must be well ventilated.
- Evaporation of the liquid cryogens will displace oxygen in the room and may present an asphyxiation hazard. Air contains about 21% oxygen and breathing air with less than 19.5% is considered a dangerous oxygen deficient atmosphere. Concentrations of 18% can cause dizziness and result in unconsciousness and death.
- Note: The cloud that appears when liquid nitrogen is exposed to air is condensed moisture in the atmosphere. Gaseous nitrogen is invisible.
- Do not store cryogenic Dewar’s in walk-in refrigerators. Typical walk-in refrigerators only receive fresh air when the door is opened. Evaporating liquid cryogens could displace enough air to create an oxygen deficient atmosphere.

3.11. Electrical Safety Procedures

Serious injury or death by electrocution is possible when appropriate attention is not given to the engineering and maintenance of electrical equipment and personal work practices around such equipment. In addition, equipment malfunctions can lead to electrical fires. By taking reasonable precautions, electrical hazards in the laboratory can be dramatically minimized.

- Laboratory personnel should know the location of electrical shut-off switches and/or circuit breakers in or near the laboratory so that power can be quickly terminated in the event of a fire or accident.
- Electrical panels and switches must never be obstructed and should be clearly labeled to indicate what equipment or power source they control.
- All electrical equipment should be periodically inspected to ensure that cords and plugs are in good condition. Frayed wires and wires with eroded or cracked insulation must be repaired immediately, especially on electrical equipment located in wet areas such as cold rooms or near cooling baths. Insulation on wires can easily be eroded by corrosive chemicals and organic solvents.
- All electrical outlets should have a grounding connection requiring a three-pronged plug.
- All electrical equipment should have three-pronged, grounded connectors. The only exception to this rule are instruments entirely encased in plastic (such as electric pipetters and some types of microscopes) and Glas-Col heating mantels. If equipment does not have a three-pronged plug, replace the plug and cord to ground the equipment.
- Face plates must not be removed from electrical outlets.
- Electrical wires must not be used as supports.
- Extension cords should be avoided. If used, they should have three-pronged, grounded connectors, positioned or secured as not to create a tripping hazard, and ONLY for temporary use.
- All shocks must be reported to the principal investigator or supervisor. All faulty electrical equipment must be immediately removed from service until repaired.
- Electrical outlets, wiring, and equipment within a laboratory or building must only be repaired by Facility Services/Physical Plant (FS/PP) for your respective campus or other professional electricians.
- Electrical appliances must only be repaired by authorized electricians or the manufacturer. Unauthorized modifications of electrical appliances is prohibited.
- Proper grounding and bonding of flammable liquid containers should be practiced to avoid the build-up of excess static electricity. Sparks generated from static electricity are good ignition sources.
- Experimental electrical equipment in laboratories must be shielded, insulated, or have appropriate fail-safe devices when energized or in use. Personnel must be proficient in use of the equipment and safety precautions. Personnel should be trained in first aid and CPR in case of electrical shock.

3.12. **Glassware and Sharps** – Procedures for Safe Handling and Disposal

3.12.1. Definitions

Sharps - The term "sharps" refers to "any item having corners, edges, or projections capable of cutting or piercing the skin."

Puncture Proof – Commercial sharps containers intended for the disposal of broken glass, syringe needles, scalpels, etc.

Puncture Resistant – Re-used containers that, when carefully used, will resist puncture by the disposed item.

Examples of "sharps" include:

- Needles
- Syringes
- Lancets
- Scalpel blades
- Exacto knives
- Broken glass
- Razor blades
- Glass Pasteur pipettes
- Microtome blades
- Any other sharp lab waste

3.12.2. Handling

- Glassware and sharps should be handled and stored carefully to avoid damage.
- Reusable syringes that are not biologically contaminated must be capped and put away after use. Cap syringes using the one-handed method of picking up the cap with the needle then carefully securing the cap onto the syringe. Retractable syringes are preferred. A disposable syringe should be used for biological materials and should be placed in a sharps container without recapping.
- Chipped, broken, or star-cracked glassware should be discarded or repaired. Damaged glassware should never be used unless it has been repaired.
- Because of the potential for catastrophic breakage resulting in sharp projectiles, only thick-walled, pressure-resistant glassware may be utilized under positive pressure or a vacuum.
- Use appropriate hand protection when inserting glass tubing into a rubber stopper or when placing rubber tubing on glass hose connections. Use of plastic or metal connectors should be considered.
- Use appropriate hand protection when picking up broken glass or other sharp objects. Small pieces should be swept up using a brush and dustpan.
- See SOP 3.14 Glass Apparatus and Plasticware Assembly for detailed instructions.

3.12.3. Disposal

Sharps waste is categorized by the type of contamination present. Specific disposal methods are dictated by category, but all categories require packaging in puncture-resistant cardboard or plastic containers in order to minimize the risk of injuries.

3.12.3.1. Uncontaminated Sharps

- Uncontaminated metal or glass sharps should be collected in puncture-proof containers, labeled, sealed, and disposed according to your campus procedures found in the IU Waste Management Program.

Note: Disposable items such as pipette tips and wood swabs that are not sharps but may perforate the liners of the waste receptacles present a hazard to custodians. These may be placed in any puncture resistant container such as a non-breakable plastic jar, bottle, thick plastic bag or other type of container and placed in the waste receptacle. Custodial services will remove this waste.

3.12.3.2. Chemically Contaminated Sharps

- Chemically contaminated metal or glass sharps that are grossly contaminated with hazardous chemicals, should be collected in puncture-proof containers, labeled, sealed, and disposed according to your campus procedures found in the IU Waste Management Program.

Note: Spill residue with broken glass, spill absorbents, etc., must be collected as "Hazardous Chemical Waste" and not placed into the broken glass receptacles (see SOP 3.13 Chemical Spill Response Procedures).

Caution: To avoid dumpster fires, boxes may only be used if the chemical contamination is compatible with the organic cellulose of the box material. Materials contaminated with oxidants should be placed in glass, metallic, or chemically resistant plastic containers.

3.12.3.3. Radioactive Sharps

Refer to the Radiation Safety Manual for disposal of materials with radioactive contamination.

3.12.3.4. Biohazardous items

Refer to the IU Biosafety Manual for disposal of materials with biohazardous contamination.

3.13. Chemical Spill Response Procedures

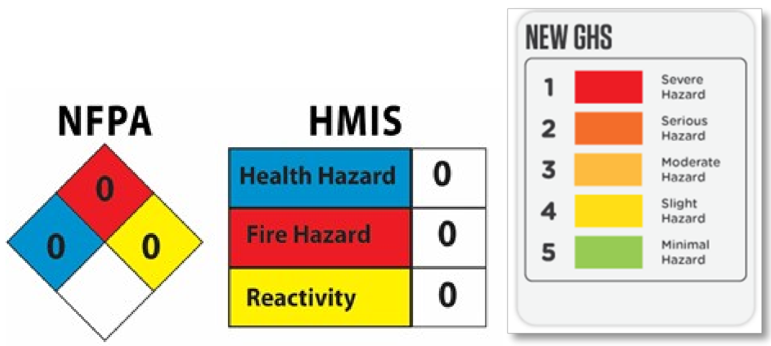
Despite the best efforts of researchers to practice safe science in the laboratory, accidents resulting in the release of chemicals will occur. For this reason, it is essential that laboratory personnel understand the spill response procedure for their campus which may include appropriate procedures and materials to adequately contain and cleanup a spill.

All chemical spills must be reported to your campus IUEHS representative (see Laboratory Safety Contacts). University Environmental Health and Safety will respond to evaluate the release and determine the best course-of-action for the containment and cleanup of the spill.

Do not attempt to clean up spills involving chemicals that are flammable, toxic, corrosive or reactive as indicated on the label or Safety Data Sheet (SDS); or that cause eye or respiratory tract irritation; or chemicals that emit strong, or noxious odors or fumes.

Exceptions for in-house spill response include minor chemical spills, which meet **all** of the following criteria and mercury thermometer spills that are contained in your workspace and for which you have a mercury spill kit:

- Personnel directly involved in the spill that have immediate access to an SDS for the chemical, and the NFPA and/or HMIS ratings are a 0 or 1 for health and fire, and 0 for reactivity, and/or the GHS rating on the label or SDS is a 5 or 4 for health, fire and reactivity and;



- The amount spilled is 500 milliliters or less for liquids or 500 grams or less for solids and;
- The material does not emit strong odors, vapors, fumes or dust that are noxious or irritating to the eyes or respiratory system and;
- The material is not a known to be a carcinogen or strong mutagen, or dangerous for the environment. This information will also be in the SDS along with the HMIS or NFPA ratings and;
- The spill is contained on an impervious surface, and cannot migrate into the environment through drains, soil, ground water or surface water.

3.13.1. Procedures for Spills that Meet the Exception Criteria

The following procedures should be used as a guide to help laboratory personnel design an effective spill control plan for their laboratory (see Section 6.10 *Spill Control Kit* for information on spill kit contents).

If you have contacted IUEHS, the spill meets the above criteria, and the chemical does not pose an immediate risk to health or require respiratory protection:

- Notify other laboratory personnel of the accident.
- Isolate the area. Close laboratory doors and evacuate the immediate area if necessary.

- Remove all ignition sources and establish exhaust ventilation. Vent vapors to outside of building only (open windows and turn on fume hood).
- Choose appropriate personal protective equipment (e.g., goggles, face shield, impervious gloves, lab coat, apron or coveralls, and boots).
- Confine and contain the spill. Cover with appropriate absorbent material. Sweep solid material into a dust pan and place in a sealed plastic container. Decontaminate the area with soap and water after cleanup and place residue in a plastic bag or another sealed plastic container.
- Label the container.
- Contact IUEHS for your respective campus for disposal.

3.13.2. Procedures for Spills that DO NOT Meet the Exception Criteria

Laboratory personnel must not attempt to clean up a hazardous chemical spill of the type and quantity that poses an immediate risk to health, the environment, or those that require respiratory protection. The most senior staff member present at the time of the spill is responsible for ensuring the following procedures are followed and that the spill is reported to IUEHS and emergency responders as necessary.

Follow the chemical spill response (ESCAPE) procedure as follows:

1. **E**xit the area — Immediately after a hazardous chemical is spilled you must exit the area. If the spill occurred in a laboratory and access to the fume hood is not blocked by the spill and/or hazardous vapors are not present in the area then raise the sash on the fume hood and increase the airflow.
2. **S**hut the doors and secure the area — Shut the doors to the area where the spill is located and secure the area if possible. Most laboratories are under negative pressure which will pull air from the hallway into the lab, keeping potentially hazardous vapors from spreading into other areas.
3. **C**all 911 from a campus phone or IUPD for your respective campus from a non-campus phone from a safe location and give the following information:
    a. Building name
    b. Room number or location
    c. Type of incident
    d. Name of chemical spilled or description of odor if unsure of the chemical, and
    e. Estimate of the volume of chemical spilled
4. **A**ssess the situation — Determine if the spill is Immediately Dangerous to Life or Health (IDLH). IDLH incidents are those that pose a significant and immediate threat to building occupants due to extreme toxicity, imminent explosion, or other life threatening conditions. These types of incidents are rare. If the spill does not pose a threat to the building occupants then remain outside the entrance to the laboratory until the spill response team arrives. If you determine that the situation is Immediately Dangerous to Life or Health, then proceed to the next step.
5. **P**ull the fire alarm — If the spill poses an immediate danger to the building occupants pull the fire alarm. Activating the fire alarm will evacuate the building occupants and in some locations will also notify the Fire Department. As a precaution dial 911 and give appropriate information to the dispatcher.
6. **E**xit the building — Once the fire alarm has been activated exit the building. Remain at a safe distance from the main entrance of the building. Give your information to the emergency response teams that will be arriving.

3.13.3. Procedures for Chemical Contamination to the Eyes or Body

In the event of chemical contamination to the eyes or body:

1. Remove any contaminated clothing immediately and flush all areas of bodily contact with copious amounts of water. This should take place while someone else makes the appropriate phone calls from a safe location.
2. Ensure that medical assistance is obtained for those injured or exposed (safety shower, medical attention, etc.). Continue to rinse body contact areas with copious amounts of water for at least 15 minutes unless directed otherwise by appropriate emergency medical personnel (Physician, Nurse, Paramedic or Emergency Medical Technician).
3. Visit the designated medical services provider for your campus or the emergency room for medical care and evaluation (see Section 5.0). If possible, take applicable Safety Data Sheets (SDS) with you.

3.14. Glass Apparatus and Plasticware Assembly

Borosilicate glassware is recommended for all laboratory glassware except for special experiments that use ultra violet (UV) or other light sources. The only soft glass provided in the laboratory should be reagent bottles, measuring equipment, stirring rods, and tubing.

Any glass equipment to be evacuated, such as suction flasks, must be specially designed with heavy walls. Dewar flasks and large vacuum vessels should be taped or otherwise screened or contained in a metal jacket to prevent flying glass in the case of an implosion. Household Thermos bottles have thin walls and are not acceptable substitutes for laboratory Dewar flasks.

3.14.1. Preparation of Glass Tubing and Stoppers

To cut glass tubing:

If the tubing does not readily pull apart, the nick probably is too shallow or rounded. Make a fresh sharp file scratch in the same place and repeat the operation.

All glass tubing and rods, including stirring rods, should be fire polished before use. Unpolished cut glass has a razor-like edge, which not only can lacerate the skin, but will also cut into a stopper or rubber hose, making it difficult to insert the glass properly. After polishing or bending glass, allow ample time for it to cool before grasping it.

To drill a stopper:

- Use only a sharp borer one size smaller than that which will just slip over the glass tube.
- Lubricate rubber stoppers with water or glycerol.
- Bore the hole by slicing through the stopper, twisting with moderate forward pressure, grasping the stopper only with the fingers, and keeping the hand away from the back of the stopper.
- Keep the index finger of the drilling hand against the barrel of the borer and close to the stopper to stop the borer when it breaks through.
- It is preferable to drill only part way through and then finish by drilling from the opposite side. Discard a stopper if a hole is irregular or does not fit the inserted tube snugly, if it is cracked, or if it leaks.
- Corks should have been previously softened by rolling and kneading. Rubber or cork stoppers should fit into a joint so that one-third to one-half of the stopper is inserted.

When available, glassware with ground joints is preferable. Glass stoppers and joints should be clean, dry and lightly lubricated.

3.14.2. Insertion of Glass Tubes or Rods into Stoppers or Flexible Tubing

To insert glass tubes into stoppers or flexible tubing:

- Make sure the diameter of the tube or rod is compatible with the diameter of the hose or stopper.
- If not already fire polished, fire polish the end of the glass to be inserted; let it cool.
- Lubricate the glass. Water may be sufficient but glycerol is a better lubricant.
- Wear heavy gloves or wrap layers of cloth around the glass and protect the other hand by holding the hose or stopper with a layered cloth pad.
- Hold the glass rod or tube near the end to be inserted, not more than 5 cm (2 in) from the end.
- Insert the glass with a slight twisting motion, avoiding too much pressure and

torque.

- If necessary, use a cork borer as a sleeve for insertion of glass tubes.
- Substitute a piece of metal tubing for glass tubing if possible.
- Remove stuck tubes by slitting the hose or stopper with a sharp knife.

3.14.3. Apparatus Assembly

The following recommendations will help make apparatus assembly easier, safer, and avoid equipment failure during use:

- Keep your workspace free of clutter.
- Set up clean, dry apparatus, firmly clamped and well back from the edge of the lab bench or hood with due regard to the proximity of reagent bottles to burners and to other workers and their equipment. Choose sizes that can properly accommodate the operation to be performed, allowing 20% free space at the minimum.
- Use only equipment that is free from flaws such as cracks, chips, frayed wire, and obvious defects. Glassware can be examined in polarized light for stains. Even the smallest chip or crack renders glassware unusable; chipped or cracked ware should be repaired or discarded.
- A properly placed pan under a reaction vessel or container will act as a secondary containment to confine spilled liquids in the event of glass breakage.
- Addition and separatory funnels should be properly supported and oriented so that the stopcock will not be loosened by gravity. A retainer ring should be used on the stopcock plug. Glass stopcocks should be freshly lubricated. Teflon stopcocks should not need lubrication.
- Condensers must be properly supported with securely positioned clamps. The attached water hoses must be secured to the glass fittings with wire or appropriate hose clamps.
- Stirrer motors and vessels should be secured to maintain proper alignment. Magnetic stirring is preferable.
- Apparatus attached to a ring stand should be positioned so that the center of gravity of the system is over the base and not to one side. There should be adequate provision for removing burners or baths quickly. Standards bearing heavy loads should be firmly attached to the bench top. Equipment racks should be securely anchored at the top and bottom.

3.14.4. Operational Precautions

The following precautions should be considered prior to assembly and during operation of the apparatus.

- When working with flammable gases or liquids, do not allow burners or other ignition sources in the vicinity. Use appropriate traps, condensers, or scrubbers to minimize release of vapors to the environment. If a hot plate is used, ensure that the temperatures of all exposed surfaces are less than the autoignition temperature of the chemicals likely to be released and that the temperature control device and the stirring or ventilating motors do not spark.
- Only non-sparking motors or pneumatic motors should be used in chemical laboratories.
- Whenever possible, use controlled electrical heaters or steam in place of gas burners.
- Inspect power cords for chemical or physical damage by unplugging the equipment then bending the cord to look for cracks in the insulation. Be sure to check carefully

and close to the point where the power cord enters the housing.

- Apparatus, equipment, or chemical bottles must not be placed on the floor.
- Never heat a closed container. Provide a vent as part of the apparatus for chemicals that are to be heated. Prior to heating a liquid, place boiling stones in unstirred vessels (except test tubes). If a burner is to be used, distribute the heat with a ceramic-centered wire gauze. Use a thermometer with its bulb in the boiling liquid if there is the possibility of a dangerous exothermic decomposition as in some distillations. This will provide a warning and may allow time to remove the heat and apply external cooling. The setup should allow for fast removal of heat.
- Whenever hazardous gases or fumes are likely to be evolved, an appropriate gas trap should be used and the operation confined to a fume hood.
- Fume hoods are recommended for all operations in which toxic or flammable vapors are evolved as in many distillations. Most vapors have a density greater than that of air and will settle on a bench top or floor where they may diffuse to a distant burner or ignition source. These vapors will roll out over astonishingly long distances and, if flammable, an ignition can cause a flash back to the source of the vapors. Once diluted with significant amounts of air, vapors move in air essentially as air itself.
- Use a hood when working with a system under reduced pressure (which may implode). Close the sash to provide a shield. If a hood is not available, use a standing shield. Shields that can be knocked over must be stabilized with weights or fasteners. Standing shields are preferably secured near the top. Proper eye and face protection must be worn even when using the shields or hood.

3.15. **Solvent Stills** – Procedures for Set-up, Use, and Neutralization

Although the procedures for purifying laboratory chemicals are inherently safe, care must be exercised if hazards are to be avoided. Solvent distillation equipment in which flammable liquids are purified by distillation with reactive metals or metal hydrides, such as sodium, potassium, calcium hydride and lithium aluminum hydride, are possibly the greatest danger in any organic chemistry laboratory. The potential fire and explosion hazards associated with the combination of air- and/or water-reactive metals with large amounts of organic solvents are great and the effects on personnel and equipment can be catastrophic. The chances of personnel escaping such an incident unharmed are very low. Consider using alternative solvent purification systems and methods before proceeding (see column purification method below for a procedure that avoids all heat and distillation).

3.15.1. Set-Up and Operation

1. Use proper personal protective equipment (e.g., gloves, safety glasses, and fire-resistant or all cotton lab coat) while operating a distillation unit.
2. Any solvent stills containing reactive metals should be located in a fume hood.
3. After set up and before start up get prior approval and a final equipment check from the principal investigator.
4. The total volume of solvent used in these stills shall be kept to a minimum (BUT they should never be allowed to go “dry”). Their useful working volume is ¼ to ⅔ of filled capacity.
5. Stills should be operated under an inert gas atmosphere of nitrogen or argon.
6. Several types of drying agents can be used:
   a) Sodium, potassium or sodium-potassium alloys must never be used for solvents containing C-Cl or O-H bonds.
   b) Because of their pyrophoric nature (possible spontaneous ignition upon contact with air) the use of sodium/potassium alloys (NaK), which are liquids at ambient temperature should be avoided. Solvent flasks containing lithium aluminum hydride must never be heated. As a drying agent, lithium aluminum hydride is therefore only suitable for non-reducible solvents that can be obtained pure by flask-to-flask vacuum-transfer at ambient temperature.
   c) The use of potassium alone is recommended for THF only – in these solvents the metal will melt providing a fresh & reactive surface. Be aware that it is much more reactive than sodium, especially when quenching a solvent still (see below).
   d) The use of sodium alone is recommended for diethyl ether and all other hydrocarbons such as toluene, benzene, pentane, hexane, heptane, etc.
   e) Calcium hydride is recommended for methylene chloride and other halogenated solvents.
   f) Magnesium/Iodine is recommended for methanol and ethanol.
   g) For all high boiling solvents the use of 4 Å molecular sieves (activated by heating under full dynamic vacuum overnight) is recommended.
7. Solvent stills should never be left running (i.e., being heated to reflux) while unattended – especially not overnight.
8. Stills must be deactivated and restarted with all fresh solvent and drying agents on a regular basis to avoid buildup of metal hydroxides and benzophenone “cakes” that would impair stirring necessary during deactivation. Record the date of maintenance activities at the still for reference.
9. To deactivate a solvent still containing reactive metals follow the procedure below for deactivation and neutralization.

Reference: Armarego, W.L.F., Perrin, D.D., Purification of Laboratory Chemicals, Fourth Edition, 1998.

3.15.2. Deactivation and Neutralization

Please read and follow these procedures carefully. This procedure can be dangerous and requires plenty of time to complete. Do not rush the process. Only properly trained persons are to perform this procedure.

1. Deactivation and neutralization must be performed immediately when there is no longer a need for the distillation process. Do not abandon distillation units for others to decommission. If an abandoned unit is discovered, do not touch it and contact IUEHS for your respective campus immediately (see pgs. ix-xi).
2. Notify other laboratory occupants and your supervisor of your intent to perform this procedure. Do not perform this procedure "after-hours".
3. Wear a lab coat, safety glasses, face shield, and appropriate gloves. Familiarize yourself with the location of the nearest emergency shower, fire blanket, and exit. Have a dry-chemical fire extinguisher available.
4. Inspect the still flask. The still flask should not be more than 1/5 full and the mixture must be stirring freely using a magnetic stir bar. If it is not, carefully attempt to break up any solid deposits in the flask using a large spatula. If this does not work, seek assistance from your supervisor.
5. In a fume hood cleared of all other reactions and equipment, set up a reaction apparatus as illustrated in the attached scheme. Securely clamp the still flask and all other parts of the apparatus to a sturdy lab-stand or support rod.
6. Make sure that there is an ample supply of nitrogen or argon that will last at least 24 hours with a slow rate of bubbling and establish that both nitrogen/argon and cooling water are flowing at a reasonable rate with the hose connections to the condenser secured by copper wire or similar.
7. If the solvent still contains **sodium or potassium**:
    a) With stirring, slowly add an equal volume of toluene or preferably xylene to the flask (see attached figure) while maintaining a slight counter-flow of nitrogen or argon through the apparatus. The counter-flow should be maintained during any additions to the flask throughout the entire procedure. Stir for 5-10 min. observing the reaction.
    b) With stirring, add 1 ml of n-butanol or t-butanol and observe the reaction. In the presence of active metal hydrogen gas evolution will occur. Further 1 ml portions of the alcohol are added at such a rate that the heat evolved by neutralization does not cause the reaction mixture to come to reflux. This will take several hours, or even longer. The reactivity of the mixture can be monitored by briefly interrupting the nitrogen flow and monitoring the bubbler. As long as there is gas evolution from the apparatus, reactive metal is present.
    c) When no further reactivity is observed, procedure b) is repeated with ethanol. Again this may take several hours, or overnight, until all hydrogen evolution ceases.
    d) Add 50-100 ml methanol in 5 ml portions and monitor the reaction. Stir at least 1 h or until no further gas evolution is observed.
    e) Repeat procedure b) with water until no further gas evolution is observed.
    f) Dispose of the contents of the flask as organic chemical waste from your laboratory.
8. If the solvent still contains **lithium aluminum hydride**:
    a) With stirring, slowly add 1 ml portions of 95 % ethanol to the flask containing the hydride in solution (see attached figure) while maintaining a slight counter-flow of nitrogen or argon through the apparatus. The counter-flow should be maintained during any additions to the flask throughout the entire procedure. Stir for 5-10 min. observing the reaction. When no more gas evolution is

observed slowly add a saturated solution of ammonium chloride.

b) Separate the organic and aqueous layers formed.

c) Dispose of the two components in the appropriate manner, i.e., the organic layer into the organic waste collection container, the aqueous layer into the aqueous waste collection container in your laboratory.

9. If the solvent still contains **calcium hydride in dichloromethane (CH_2Cl_2)**:

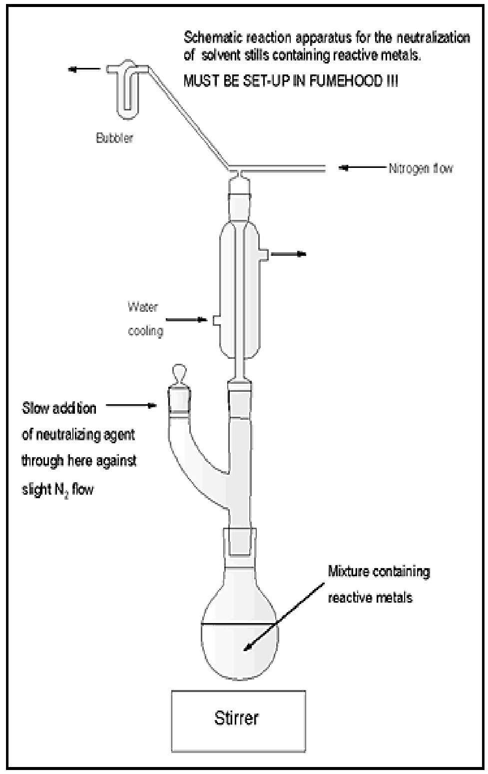
   a) With stirring, slowly add 1-2 ml portions of methanol to the flask (see figure) while maintaining a slight counter-flow of nitrogen or argon through the apparatus.

   b) The counter-flow should be maintained during any additions to the flask throughout the entire procedure. Stir for 5-10 min. after each addition observing the reaction.

   c) When no more gas evolution is observed slowly add excess water.

   d) Separate the organic and aqueous layers formed.

   e) Dispose of the two components in the appropriate manner, i.e., the organic layer into the halogenated organic waste collection container, the aqueous layer into the aqueous waste collection container in your laboratory.



3.15.3. **Column Purification Systems**

<u>Commercially available column purification systems are a viable alternative</u> for some distillation procedures. While the column method does not have the fire or explosion initiators that distillation units have, they do, however, have their own set of safety considerations that must be accounted for.

1. The quantities of solvents in the system tend to be larger so the units must be used in an appropriate location equipped with flammable liquid cabinets, fire doors, sprinklers, and the quantity limits imposed by the building codes must not be exceeded.
2. The columns are pressurized from 5-50 psi therefore; they must be secure and equipped with the appropriate valves and plumbing.
3. Peroxides may accumulate on the columns and must be changed in accordance with the manufacturer’s recommendation.
4. Some solvents, including tetrahydrofuran and methylene chloride, are incompatible with the copper catalyst therefore; the column method may not be suitable for some applications.

References: Cournoyer, Michael E., and Dare, Jeffery H., The Use of Alternative Solvent Purification Techniques, *Chemical Heallth and Safety*, July/August, 2003.

3.16. **Personal Protective Equipment** – Procedures for Selection and Use

Personal protective equipment (PPE) is selected based on the potential hazard presented by the work. Scrutinize each laboratory procedure individually for potential hazards based on the chemicals to be used and the procedure to be performed. The hazard assessment is then used to determine the appropriate personal protective equipment.

Each laboratory group is responsible for assessing the potential hazards presented by their work. The IU Personal Protective Equipment Policy and the Laboratory Chemical Personal Protective Equipment ~~guideline~~ Guidance Form found in Appendix A can be used for this purpose. The potential hazards presented by typical laboratory procedures and the corresponding personal protective equipment are found on the form. The list does not include all laboratory procedures. Additional tasks and personal protective equipment should be added as necessary on the form.

A list of chemicals that require skin protection can be found in Appendix B. These chemicals have been identified by the Occupational Safety and Health Administration (OSHA) and/or the American Conference of Governmental Industrial Hygienists (ACGIH) as chemicals that present a significant risk of skin absorption and subsequent toxicity. Many chemicals not on the list also require the use of gloves and other personal protective equipment. Never underestimate the risk of exposure. Always practice good chemical hygiene and use personal protective equipment.

3.16.1. Hand Protection

No glove is resistant to all chemicals. Consult the glove manufacturer's selection guides for chemical compatibility prior to use. Glove selection guides can also be found at the manufacturer's web sites. For further information contact IUEHS for your respective campus.

3.16.1.1. Selection

When selecting and using gloves always:

- Consider chemical resistance, thickness, length, and dexterity requirements.
- Inspect all gloves before use for signs of swelling, cracking, discoloration, pinholes, etc.
- Consider double gloving (wearing one glove over another) as a precaution.
- Change gloves frequently or as often as needed if they become contaminated.
- Do not wear gloves into the hallways or other common areas.
- Do not touch doorknobs, phones, etc., when wearing gloves. (Remove them before touching anything to prevent leaving chemical residue on the item.)
- Remove gloves by pinching the material in the palm and turning them inside out as the glove is removed over the finger tips (thus keeping contamination on the inside of the removed glove.)
- Rinse thicker reusable gloves after every use.

3.16.1.2. Chemical Resistance

Chemical resistance is based on several characteristics of the glove material. When selecting the appropriate glove, the following properties must be considered:

- Degradation,
- Breakthrough time, and
- Permeation rate.

Degradation is the change in one or more of the physical properties of a glove caused by contact with a chemical. Degradation typically appears as hardening, stiffening, swelling, shrinking or cracking of the glove. Degradation ratings indicate how well a glove will hold up when exposed to a chemical. When looking at a chemical compatibility chart, degradation is usually reported as E (excellent), G (good), F (fair), P (poor), NR (not recommended) or NT (not tested).

Breakthrough time is the elapsed time between the initial contact of the test chemical on the surface of the glove and the analytical detection of the chemical on the inside of the glove.

Permeation rate is the rate at which the test chemical passes through the glove material once breakthrough has occurred and equilibrium is reached. Permeation involves absorption of the chemical on the surface of the glove, diffusion through the glove, and desorption of the chemical on the inside of the glove. Resistance to permeation rate is usually reported as E (excellent), G (good), F (fair), P (poor), NR (not recommended), or NT (not tested). If chemical breakthrough does not occur, then permeation rate is not measured and is reported ND (none detected).

Manufacturers stress that permeation and degradation tests are done under laboratory test conditions, which can vary significantly from actual conditions in the work environment. Users may decide to conduct their own tests, particularly when working with highly toxic materials or chemicals for which no data can be found. This must always be done carefully in a fume hood with PPE and without touching the chemicals or contaminated materials with the hands (e.g., use forceps).

For mixtures, it is recommended that the glove material be selected based on the shortest breakthrough time.

The following table shows the typical glove materials and their general uses.

Glove Material	General Uses
Butyl	Offers the highest resistance to permeation by most gases and water vapor. Especially suitable for use with esters and ketones.
Neoprene	Provides moderate abrasion resistance but good tensile strength and heat resistance. Compatible with many acids, caustics and oils.
Nitrile	Excellent general duty glove. Provides protection from a wide variety of solvents, oils, petroleum products and some corrosives. Excellent resistance to cuts, snags, punctures and abrasions.
PVC	Provides excellent abrasion resistance and protection from most fats, acids, and petroleum hydrocarbons.
PVA	Highly impermeable to gases. Excellent protection from aromatic and chlorinated solvents. Cannot be used in water or water-based solutions.
Viton	Exceptional resistance to chlorinated and aromatic solvents. Good resistance to cuts and abrasions.
Silver Shield	Resists a wide variety of toxic and hazardous chemicals. Provides the highest level of overall chemical resistance.
Natural rubber	Provides flexibility and resistance to a wide variety of acids, caustics, salts, detergents and alcohols. (See Latex Gloves and Related Allergies below).

3.16.1.3. Latex Gloves and Related Allergies

Allergic reactions to natural rubber latex can sometimes occur. The term "latex" refers to natural rubber latex and includes products made from dry natural rubber. Natural rubber latex is found in many products including disposable gloves and other personal protective equipment.

Several chemicals are added to this fluid during the processing and manufacture of commercial latex. Some proteins in latex can cause a range of mild to severe allergic reactions. The chemicals added during processing may also cause skin rashes.

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

In addition to skin contact with the latex allergens, inhalation is another potential route of exposure. The proteins responsible for latex allergies have been shown to fasten to powder that is used on some latex gloves. Latex proteins may be released into the air along with the powders used to lubricate the interior of the glove.

The following actions are recommended to reduce exposure to latex:

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

Once a worker becomes allergic to latex, special precautions are needed to prevent exposures during work. Certain medications may reduce the allergy symptoms, but complete latex avoidance is the most effective approach.

3.16.2. Protective Eyewear

Protective eyewear is *required* whenever there is a reasonable probability that the eyes could be exposed to chemicals. The type of eyewear required depends on the hazard classification of the area and procedure to be performed. Please refer to the IU Eye and Face Protection Program for additional guidance.

3.16.2.1. Types of Protective Eyewear

3.16.2.1.1. Safety Glasses

Safety glasses have shatter resistant lenses made of materials like polycarbonate plastic with side shields attached to the temples that meet the specifications of the American National Standards Institute Standard Z87.1-1989. Safety glasses are designed to stop physical objects or harmful radiation such a laser light from entering the eyes and provide little or no protection from vapors or liquids.

3.16.2.1.2. Goggles

Properly vented safety goggles are the preferred eye protection to be worn when chemicals are handled in the laboratory. These should be worn *over* prescription glasses.

Goggles come in two types: vented and non-vented. Non-vented goggles are used to protect your eyes from vapors, mists, fumes, or other eye hazards that require complete eye coverage with no leaks or perforations.

Vented goggles are used where there are moderate quantities of liquids being used but no vapors or mists are involved. There are several types of vented goggles. The type of vented goggles made for laboratory use has a series of buttons embedded into the plastic. These buttons house a baffle plate that allows air to pass but presents a physical barrier to liquids. Do not use the common vented goggle with simple holes drilled in the sides. This type of vented goggle will not stop liquids from coming in through the holes and is not suitable for laboratory work.

3.16.2.1.3. Face Shields

Face shields are designed to augment other types of eye protection and are not meant to be a stand-alone form of eye protection. Face shields are used to protect your entire face to catch any liquids that might splash onto the face.

3.16.2.2. Hazard Classifications

Areas and operations within research buildings can be classified into three types of hazardous areas based on the following definitions. It is important to recognize that the procedure is classified as well as the area. If a procedure creates a greater hazard than the laboratory classification would indicate, eye and face protection appropriate for the hazard shall be worn. It would be possible to have a Class 3 operation in a Class 2 area. Appropriate additional protection would be required.

3.16.2.2.1. Class 1 – Eye Protection Not Required

This classification includes laboratories that do not use chemicals, biological materials, or physically hazardous materials. Hazards requiring eye protection are seldom encountered in this area. These areas are exempt from the requirement that occupants and visitors must wear industrial safety glasses. Examples include computer or imaging laboratories and other areas such as:

- Offices including enclosed offices within laboratories or protected desk areas. To comply with this requirement there must be a line of sight barrier (for example an office partition) between personnel and any chemicals or any chemical process in the laboratory;
- Conference rooms;
- Libraries and reading rooms;
- Corridors, lobbies, elevators, and stairwells;
- Locker and rest rooms;
- Mail and copier rooms;
- Computer and computer user rooms; and
- Lounges and break rooms.

3.16.2.2.2. Class 2 – Eye Protection Required When Hazards Exist

This classification includes laboratories that use chemicals, biological materials, or physically hazardous materials on an occasional basis. Eye protection must be worn when the hazards exist. Safety eyewear such as industrial safety glasses with side shields are required for workers and visitors in these areas. Examples include laser laboratories and some research laboratories.

3.16.2.2.3. Class 3 – Eye Protection Required At All Times

Specific and predictable eye hazards exist in these areas such as laboratories that routinely use chemicals, biological materials, or machinery. Examples of eye protection required in these areas are acid splash goggles, face shields, welding helmets, and laser goggles. Industrial safety glasses alone may not provide adequate eye protection in these areas. Examples include chemistry teaching laboratories and organic chemistry laboratories.

Note: Contact lenses may complicate treatment in the event of an accident. They may be allowed or prohibited based on the specific laboratory procedures and policy. The use of contact lenses is only allowed in conjunction with appropriate safety eyewear and the laboratory supervisor's approval. Instructors or supervisors must be aware of those wearing contact lenses.

3.16.2.3. Exemption Procedure

Eye protection may need to be removed while viewing materials through a microscope or similar equipment. Eye protection must be replaced after operation is complete. Microscope and similar equipment must be located in an area where removal of eye protection does not place personnel at risk from other hazards in the area.

3.16.2.3.1. Local Safety Procedure Required

State if eye protection can be removed behind a line of sight barrier. Define the line of sight barrier. Any approved exemptions must be identified on the Personal Protective Equipment Hazard Assessment Form LCS-4 in Appendix A.

3.16.3. Protective Clothing

Protective clothing in the form of lab coats, aprons, and closed-toed shoes are required whenever the possibility of chemical contamination to the body exists. Protective clothing that resists physical and chemical hazards should be worn over street clothes.

Lab coats and aprons should be left in the laboratory and not taken home. This prevents the worker from carrying incidental contamination out of the laboratory and presenting a chemical hazard to co-workers, friends, or family.

Disposable outer garments such as Tyvek suits, aprons, and lab coats may be useful when cleaning and decontamination of reusable clothing is difficult.

Shorts, loose clothing (including ties), or torn clothing are inappropriate for work with hazardous chemicals.

3.16.3.1. Lab Coats

Lab coats are appropriate for minor chemical splashes and spills. They must be worn buttoned with the sleeves covering the arms. Do not roll up the sleeves.

3.16.3.2. Aprons

Rubber or plastic aprons are appropriate for handling corrosives or irritating liquids.

3.16.4. Footwear

Safety shoes or other specialized foot protection are generally not required for most laboratory operations. However, shoes must cover the entire foot. Open toed shoes and sandals are inappropriate footwear in laboratories. Fabric and athletic shoes offer little or no protection from chemical spills. Leather shoes or equivalent (chemically resistant shoes) with slip-resistant soles are required. Shoes may have to be discarded if contaminated with a hazardous material.

Chemical resistant overshoes, boots, or disposable shoe coverings ("booties"), may be used to avoid possible exposure to corrosive chemicals or large quantities of solvents or water that might penetrate normal footwear (e.g., during spill cleanup).

Although generally not required in most laboratories, composite-toed safety shoes may be necessary when there is a risk of heavy objects falling or rolling onto the feet, such as in bottle-washing operations, animal care facilities, or if large quantities of liquids are stored and moved in drums.

Please refer to the IU Foot Protection Program for additional guidance.

3.16.5. Respiratory Protection

Respiratory protection is typically provided by using adequate engineering controls such as chemical fume hoods, canopy hoods, snorkel hoods, glove boxes, and appropriately equipped biological safety cabinets. It should be noted that not all biological safety cabinets provide protection from toxic chemical vapors and fumes. These devices should be carefully selected and used only for their intended purpose.

A respirator may only be used when engineering controls, such as general ventilation or a fume hood, are not feasible or do not reduce the exposure of a chemical to acceptable levels. Respirators can only be used in accordance with the Indiana University Respiratory Protection Program. Contact IUEHS for your respective campus for more information or to obtain a respirator and arrange the required respirator fit test and medical examination.

3.16.6. Head Protection

Head protection may be necessary in industrial type laboratories where overhead hazards exist or fluids may splash onto the head. Appropriate head protection in the form of hard hats or fluid barrier hats should be used in these cases. Hooded disposable coveralls may also be used if necessary.

3.17. **Peroxide-Forming Chemicals and Other Time-Sensitive Materials** – Procedures for Safe Handling and Management

Some laboratory chemicals, known as time-sensitive chemicals, can become dangerous with age. This can be due to chemical reactions, over-pressurization of containers, toxicity, and other hazardous properties. For this reason handling and management of time-sensitive chemicals are of particular importance. These chemicals include the following:

- Chemicals that form peroxides upon aging;
- Picric acid and other multi-nitro aromatics;
- Chloroform;
- Anhydrous hydrogen fluoride and hydrogen bromide;
- Liquid hydrogen cyanide;
- Formic acid; and
- Alkali metals (such as potassium, sodium and lithium).

Other relevant sections of this Plan include; SOP 3.2, Procedures for Proper Labeling, Storage, and Management of Chemicals; SOP 3.7, Reactive Chemicals; and the table of Peroxide-Forming Chemicals in Appendix B.

3.17.1. Peroxide-Forming Chemicals

The peroxide-forming chemicals include common organic solvents and can react with atmospheric oxygen to undergo autoxidation or peroxidation, producing unstable and dangerous organic peroxides and hydroperoxides.

Formation of peroxides is accelerated by light and heat. Substances which have undergone peroxidation are sensitive to thermal or mechanical shock and may explode violently. All laboratory workers must learn to recognize and safely handle peroxidizable compounds. Peroxide-forming substances include aldehydes, ethers (especially cyclic ether), compounds containing benzylic hydrogen atoms, compounds containing the allylic structure (including most alkenes), vinyl and vinylidine compounds. A list of these chemicals can be found in Appendix B.

3.17.1.1. Safe Handling and Usage

- The material must be less than 12 months old or less than the expiration date on the label. Labels on peroxide-forming substances must contain the date the container was received and the date it was first opened.
- Include a notice such as **Warning Peroxide-Former** on the container.
- If the material is greater than 12 months old or past the expiration date, it should be assessed for other factors such as; duration of exposure to sunlight, volume of container, security of the seal; and exposure to changes in temperature. If you do not know the answer to any of these questions, find someone who does. **Do not open the container to check for peroxide formation, as the material could be shock-sensitive.** Call IUEHS for your respective campus for technical assistance.
- If the container is more than 12 months old or past the expiration date, do not move the container. Post a sign reading "DANGER: possible shock-sensitive chemical" and contact IUEHS for your respective campus for technical assistance.
- Never use a metal spatula with peroxides. Contamination by metals or disturbance of the crystals can lead to explosive decompositions.
- Store peroxides and peroxide-forming compounds according to the manufacturer's recommendations, away from light and heat.
- If storing peroxide formers in a refrigerator, the refrigerators must be designed for the storage of flammable substances. Do not use domestic refrigerators to store flammable liquids.

- Distilled solvents stored for later use must be dated upon distillation. Distilled solvents placed in storage must be sealed and stored under nitrogen or argon.
- Do not open the container if 1) crystals are visibly present on or in the container or lid, 2) if a precipitate has formed or an oily viscous layer is present, or 3) if the container has been opened and is more than two years old. Call University Environmental Health and Safety (IUEHS) at your respective campus for assistance.

3.17.1.2. **Disposal**

- Dispose of Class A (see table in Appendix B) peroxidizable solvents within 3 months of receipt (or synthesis). Date all containers upon synthesis of the material. See IU Waste Management Program for disposal.
- Dispose of Class B and C peroxide-formers within 12 months of reciept or on or before the If the container has a manufacturer's expiration date on the label.
- Distilled peroxide-forming solvents contain no stabilizer and must be disposed within 3 months of distillation.
- Turn all materials in to IUEHS for your respective campus.
- The lab or department is responsible for any extra charges (i.e. high hazard disposal) that may be incurred in the event that containers of peroxide forming solvents have not been managed properly including management or abandonment of solvents being distilled and stored for later use.
- Additional information can be found in the IU Waste Management Program.

3.17.2. Picric Acid and Other Multi-Nitro Aromatics

Picric acid ($C_6H_3N_3O_7$ and other multi-nitro aromatics) can be extremely dangerous if allowed to dry. Picric acid with a moisture content of greater than 30% is considered a flammable solid by the Department of Transportation (DOT). Picric acid with a moisture content of less than 30% is considered a Class 1.1D explosive by DOT and is very shock sensitive. DO NOT OPEN OR MOVE a container of dry picric acid.

3.17.3. Chloroform

Chloroform ($CHCl_3$) reacts with air to form phosgene gas (CCl_2O) which has a very low IDLH (Immediately Dangerous to Life or Health) value of 2 parts per million. Always open chloroform in a fume hood.

3.17.4. Formic acid

Formic acid (90-100% CH_2O_2) decomposes to form carbon monoxide and water ($CO + H_2O$). Pressure greater than 100 psi can develop with prolonged storage of 1 year or greater which is sufficient to break a sealed glass container. Vent containers frequently and read the product literature. Some have pressure relief caps and some Safety Data Sheets may recommend refrigeration.

3.17.5. Anhydrous Hydrogen Fluoride, Hydrogen Bromide, and Other Corrosive Gases

Anhydrous hydrogen fluoride and hydrogen bromide are in a liquid phase above 15 psi. Stored in carbon steel cylinders (lecture bottles) they can react with the steel to form iron fluoride and hydrogen gas. Lecture bottles have a typical working pressure of 1800 psi and these chemicals have a 2 year shelf life. Several anhydrous hydrogen fluoride cylinders have failed (at interior pressures greater than 2,400 psi) after 14-24 years of storage although there have been no reported problems with hydrogen bromide.

Other corrosive gases such as hydrogen chloride and hydrogen sulfide must be returned for disposal every two years.

3.17.6. Liquid Hydrogen Cyanide

Liquid hydrogen cyanide (CHN) is a liquid that boils at 26^{o} C and is stored in low pressure cylinders. With no stabilizer (e.g. 1% sulfuric acid) present polymerization can occur along with the production of ammonia which also helps catalyze the process. A crust can form on the liquid that, when jarred, can break off and fall into the liquid causing rapid exothermic polymerization and rupture of the cylinder causing fragmentation and release of this acutely toxic gas.

3.17.7. Alkali Metals

The alkali metals (such as potassium, sodium lithium and sodium-potassium alloys) can react with dissolved oxygen when stored under mineral oil to form oxides and superoxides that can catch fire upon cutting. The oxidation forms a yellow or orange crust or coating. Lithium stored under nitrogen can form nitrides and the formation of the nitride is autocatalytic and can eventually autoignite.

3.18. Nanotechnology Safety Procedures

Nanomaterials are defined as ultrafine particles with a dimension of one to 100 nanometers in diameter. One nanometer is one-billionth of a meter.

Low-solubility ultrafine particles are more toxic than larger particles on a mass-for-mass basis. In addition to the hazardous properties of the chemical constituents, their smaller dimensions, larger surface area, and ability to penetrate cell membranes more easily than larger particles add to the hazardous properties of these materials.

Because of their small particle size, they can be deposited deep into the lungs and, once in the bloodstream, may be able to cross the blood-brain barrier. Exposure to these materials during synthesizing processes and use may occur through inhalation, ingestion, and contact with the skin or eyes.

Other hazards to consider are catalytic effects and fire or explosion. Particles in the nanometer size range are currently being evaluated for toxicity and critical exposure levels based on mass, surface area, and the number of particles per unit volume. Until these factors are determined, implement stringent controls on exposure when working with them.

The following guidelines, modified from the American Chemical Society, are provided to educate and protect those working with nanomaterials.

3.18.1. Lab Safety Guidelines for Handling Nanomaterials

- Use good general laboratory safety practices as found in the Laboratory Safety and Chemical Hygiene Plan.
- Wear gloves, lab coats, safety glasses, face shields, and closed-toed shoes. Be sure to consider the hazards of precursor materials in evaluating process hazards. OSHA's "Particularly Hazardous Substances" (such as cadmium) must be handled in a containment such as a fume hood or a glove box.
- Avoid skin contact with nanoparticles or nanoparticle-containing solutions by using appropriate personal protective equipment. Do not handle nanoparticles with your bare skin.
- If it is necessary to handle nanoparticle powders outside of a HEPA-filtered powered-exhaust laminar flow hood, wear appropriate respiratory protection. The appropriate respirator must be selected based on professional consultation with IUEHS from your respective campus. Refer to the IU Respiratory Protection Program for additional information.
- Use fume exhaust hoods to expel fumes from tube furnaces or chemical reaction vessels.
- Dispose of and transport waste nanoparticles according to the hazardous chemical waste guidelines.
- Vacuum cleaners used to clean up nanoparticles must be factory tested, HEPA-filtered units.
- Equipment previously used to manufacture or handle nanoparticles should be evaluated for potential contamination prior to disposal or reuse for another purpose.
- Lab equipment and exhaust systems should also be evaluated prior to removal, remodeling, or repair.
- Given the differing synthetic methods and experimental goals, no blanket recommendation can be made regarding aerosol emissions controls. This should be evaluated on a case by case basis.
- Consideration should be given to the high reactivity of some nanomaterials with regard to potential fire and explosion hazards.

3.19. **Hot Oil Bath and Other Heating Sources** – Procedures for Set-Up and Safe Operation

Personal injury or property damage can result from the use of hot oil or sand baths and other heating sources in the laboratory. Personal hazards include injury and burns from hot surfaces, liquids, vapors or flames. Contact burns may occur and range from minor to severe.

Use of these devices are frequently left unattended and must be monitored. Sources of ignition exist from electrical components, hot surfaces, hot liquids, or open flames. Uncontrolled fire or explosion may result in severe personal injury or injury to others and/or widespread property damage.

The following procedure applies to, but is not limited to, all of the following devices:

- ,Ovens,
- Hot plates,
- Heating mantles and tapes,
- Oil baths,
- Salt baths,
- Sand baths,
- Hot-air guns, and
- Microwave ovens.

3.19.1. Administrative Controls and Set-Up

3.19.1.1. Unattended Operations

- <u>All unattended operations</u> must have <u>prior approval</u> from the Principal Investigator, Lab Manager, or Lab Supervisor.
- Provide for containment of materials in the event of spills or failures.
- Label all containers and process equipment with the name of the material and special hazards.
- Post the contact name and number of the person performing the experiment on the lab door
- Keep lab lights on.

3.19.1.2. Ovens, Furnaces, Heating Mantles, and Other Devices

- Burners, induction heaters, ovens, furnaces, and other heat-producing equipment must be located a safe distance from areas where temperature-sensitive and flammable materials and compressed gases are handled.
- Drying ovens should only be used for their intended purpose and not overloaded with combustible materials.
- Always use the grounded three-prong plug on all electrical devices and when using variable transformers.
- Older models of Variacs will keep whatever is plugged into them electrically live even though the Variac is switched off. Touching this device and ground at the same time could complete a circuit with your body and lead to electrocution. Always disconnect a Variac from the outlet before working with the device plugged into it.
- Check all glassware before using to ensure it is free of cracks and other imperfections. Do not use if in doubt.
- Discard heating mantles if the ceramic is cracked or the fiberglass is brittle or damaged.
- Do not use any electrical equipment if the wire insulation is cracked, frayed or

wires are exposed in any way.

3.19.1.3. Hot Oil and Sand Baths

- Do not leave an operating sand or oil bath unattended unless it is equipped with a high-temperature shutoff and with a warning label.
- Know the flash point of the material when using oil baths. Consult the chemical manufacturer's technical information prior to use. NEVER heat a bath fluid above its flash point. Watch for smoking of the oil; oil that is smoking is too hot and may burst into flames at any moment. If an oil bath starts to produce smoke, turn off the heat immediately.
- Baths should be mounted on a laboratory jack that can be lowered easily without danger of the bath tipping over to cool the bath in an emergency. Equipment should be clamped high enough above a hot plate or oil bath that if the reaction begins to overheat, the heater can be lowered immediately and replaced with a cooling bath without having to readjust the clamps holding the equipment setup.
- Place equipment in a central location in the fume hood such that an uncontrolled fire does not melt the rubber seal surrounding the inspection ports located at the sides of the fume hood.
- When using hot oil or sand for heating, mount the baths in such a way that they cannot be overturned or that water cannot fall into an oil or sand bath causing hazardous splattering.
- Oil expands in volume when heated. Do not overfill.
- Secondary containment for oil baths must be used to contain any possible spills.
- All oil baths must be labeled with the name of the oil and its maximum safe working temperature:

"Hot Mineral (Silicone) Oil"
"Do not allow the temperature to exceed____deg C"

- Store the oil or sand for reuse in a <u>covered</u> secondary container that is <u>labeled</u> with the name and maximum safe working temperature.

3.19.2. Engineering Controls

Use non-mercury thermometers, thermocouples, or bimetallic temperature indicators. Do not use a sand or oil bath unless it is equipped with a thermometer (non-mercury) or other temperature-indicating device.

- Heating equipment with circulation fans shall be equipped with an interlock arranged to disconnect current to the heating elements if the fan fails.
- Heated Constant Temperature Baths**: NEVER** heat a bath fluid above its flash point.
- Electrically heated constant temperature baths shall be equipped with over-temperature shutoff switches in addition to normal temperature controls.

3.19.3. Personal Protective Equipment

- Appropriate gloves, safety glasses and lab coats must be worn when handling chemicals, containers, apparatus, and heating equipment.

3.19.4. Emergency Response

- Regardless of the method used to heat something, a stuck contact, an electrical short circuit, uncontrolled chemical reaction, or other malfunction can cause a reaction to heat to dangerously high temperatures. Do not leave experiments unattended without prior approval, implementing proper precautions, and using the proper fail-safe devices.
- Know where the emergency gas shut off is for your lab when using Bunsen burners.
- Know where the nearest fire alarm pull box is in relation to your lab.
- Know how to use a fire extinguisher. Activate the fire alarm FIRST and use only 1 fire extinguisher (if you have been trained and are comfortable in using the extinguisher) before evacuating the area.

3.20. **Chemical Allergens** – Procedures for Safe Handling and Storage

Allergens include a wide variety of substances that can produce skin and lung hypersensitivity. Examples include diazomethane, chromium, nickel bichromates, formaldehyde, isocyanates, and certain phenols. Many substances of unknown allergic activity can also produce responses.

- Conduct all aerosol-producing activities in a fume hood.
- Use appropriate personal protective equipment in the laboratory for handling these chemicals (e.g., lab coat, safety glasses, and gloves).
- Select suitable gloves based on the chemical resistance to prevent hand contact.
- Remove personnel from exposure if allergic reactions appear.
- Seek medical attention when appropriate. Refer to Section 5.0, Medical Consultations and Examinations.

3.21. **Reproductive Toxins, Mutagens, Teratogens, and Embryotoxins** – Procedures for Safe Handling and Storage

The Occupational Safety and Health Administration (OSHA) establishes the safety standards for use of hazardous chemicals in the workplace including reproductive chemical toxins. The OSHA Laboratory Safety Standard recommends that the Chemical Hygiene Plan include standard operating procedures for handling and storage of reproductive toxins including mutagens, teratogens, and embryotoxins.

Traditional definitions of “reproductive toxins” typically involve any agent that can damage the sperm, egg, fertilization and related processes. Agents that may cause adverse reproductive effects include chemical, biological, and radiological agents. Reproductive and developmental toxicity may affect the ability to reproduce and the development of the fetus and child.

The most recent definition of reproductive toxins according to the *Globally Harmonized System of Chemical Classification and Labelling* includes chemicals that cause adverse effects on sexual function and fertility in adult males and females, as well as adverse effects on development of the offspring including adverse effects on or via lactation. Some reproductive toxic effects cannot be clearly assigned to either impairment of sexual function and fertility or to developmental toxicity however chemicals with these effects are classified as reproductive toxicants also.

The male reproductive system can be affected resulting in reduced sperm count, changes in the shape and performance of the sperm, contaminants being carried by the sperm, decreases in sexual performance, or damage to the sperm chromosomes. Females may experience infertility, subfertility, changes in menstrual cycle, miscarriage or premature births, and changes in the pregnancy, fertilized egg and developing fetus. Birth defects, developmental disorders or childhood cancer may also result. Reproductive hazards may not affect every worker or every pregnancy.

The Center for Disease Control’s (CDC) National Institute for Occupational Safety and Health (NIOSH) Registry of Toxic Effects of Chemical Substances (RTECS) identifies seven major categories with sixty-five specific effects including paternal and maternal effects, fertility effects, effects on the embryo or fetus, developmental effects, tumorigenic effects and effects upon the newborn.

3.21.1. Definitions

Reproductive Toxicity - Adverse effects on the health of the reproductive organs, endocrine system, or gametes (egg or sperm) from exposure to an exogenous agent. This exposure may result in effects such as menstrual dysfunction, impaired fertility, feminization/masculinization, or inability to maintain a pregnancy.

Developmental Toxicity - Adverse effects on the developing organism that may occur anytime from conception to sexual maturity. These effects may include spontaneous abortion, structural or functional defects, low birth weight, or effects that may appear later in life.

Mutagens - Agents that cause change in the genetic material (DNA) of an organism and therefore increase the frequency of mutations above the natural background level. These mutations are passed along as the cell divides sometimes leading to defective cells or cancer. Because the mutations may cause cancer, mutagens are typically also carcinogens.

Not all mutations are caused by mutagens. Spontaneous mutations occur due to errors in DNA replication, repair, and recombination. Chemical mutagens include substances such as ethidium bromide used as a stain for DNA analysis. Because the molecule fits easily in between the strands of DNA it is a potent mutagen.

Embryotoxins - Embryotoxins are, by definition, toxic to embryos. Embryotoxins are agents that may kill, deform, retard the growth, or adversely affect the development of specific functions in the unborn child and cause postnatal functional problems. Embryotoxins include mercury compounds, lead compounds and other heavy metals, and organic compounds such as formamide.

Teratogens - Agents that can disturb or cause a malformation in the development of an embryo or fetus. Teratogens may cause a birth defect in the child or cause termination of the pregnancy.

Reproductive Toxin - Any hazardous substance that damages reproductive organs and can cause sterility or birth defects. The OSHA definition of reproductive toxins are chemicals that cause "adverse effects on sexual function and fertility in adult males and females, as well as adverse effects on development of the offspring."

Particularly Hazardous Substances - Reproductive toxins are included in a category of chemicals identified by OSHA as "Particularly Hazardous Substances" and must be handled in accordance with SOP 3.8, Particularly Hazardous Substances.

Personnel may only handle "particularly hazardous substances" in a containment (i.e., fume hood or glove box) or a closed system (instrument plumbing, syringe, gavage, cannula, etc.). There must be an area designated for use by posting signs or barriers and there must be procedures for decontamination of the tools and area after use and provisions for waste removal.

3.21.2. General Procedures

The presence of any reproductive toxins in the lab does not mean that personnel have been exposed, nor are they likely to experience adverse effects. However, personnel must use proper precautions while handling these substances and those of childbearing age or known pregnancies may need to exercise extra precautions.

It is very important to recognize the potential risks and intervene early because short-term exposures during a critical period can result in long-term health effects. All personnel, both men and women, handling reproductive toxins must follow these general procedures:

- Minimize all chemical exposures.
- Review the chemicals in use to identify these chemicals.
- Read the Safety Data Sheet (SDS) and follow the recommended precautions.
- Review the use of these materials with the principal investigator, lab manager, or lab supervisor.
- Review the continuing use of these chemicals annually or when a procedural change is made.
- Label the containers with the chemical name and the hazard (e.g., reproductive toxin).
- Store in an adequately ventilated area in an unbreakable secondary container.
- Notify supervisors of all incidents of exposure or spills.
- Seek medical attention when appropriate. Refer to Section 5.0, Medical Consultations and Examinations.
- Have a designated area (signs or barriers) for their use.
- Handle these substances only in a closed system (glass apparatus, instrument plumbing, syringe, gavage, cannula, etc.) or in a containment (fume hood or glove box) whose satisfactory performance has been confirmed.
- Use appropriate protective apparel (especially gloves) to prevent skin contact.
- Follow procedures for decontamination of the tools and area after use.
- Follow procedures for waste removal.

3.21.3. Pregnant Individuals

Women expecting a child should follow the general guidelines above and implement the following administrative, engineering, and personal protective equipment hazard controls to help minimize or eliminate chemical exposure.

Individuals may contact IUEHS for their respective campus in confidence to receive safety information about reproductive or developmental hazards posed by potential exposures any time without declaring actual, suspected, or planned pregnancy.

3.21.3.1. Administrative Controls

- Consult your personal physician and inform them of the activities and chemicals used in the laboratory. Follow the instructions provided by the physician explicitly.
- Avoid handling reproductive toxins, mutagens, teratogens, embryotoxins, or carcinogens.
- Avoid <u>all</u> chemical exposure if possible. Many chemicals have not been tested to determine their reproductive or toxicological properties. Therefore, if the Safety Data Sheet (SDS) does not have sufficient information they too should be avoided.
- Minimize the amount of time spent in the lab.
- Use job rotation or transfers to reduce exposures.
- Use substitute personnel to perform specific chemical procedures.
- Substitute a less hazardous agent to eliminate exposure.
- Modify work practices or laboratory procedures to reduce exposure.
- Review the laboratory chemical inventory to identify these chemicals. Contact IUEHS for your respective campus for assistance.
- Read the Safety Data Sheet (SDS) and follow the recommendations provided.
- Review the use of these materials with the research supervisor.
- Label the containers with the chemical name and the hazard (e.g., reproductive toxin).
- Avoid touching work surfaces and equipment, handling waste, and practice good personal hygiene, washing hands after touching surfaces.
- All laboratory personnel practice good chemical hygiene and follow the standard operating procedures found in the Laboratory Safety and Chemical Hygiene Plan.
- All laboratory personnel practice good housekeeping and keep work surfaces clean.
- Be aware that the use of PPE, fume hoods, etc., will minimize the risk of exposure but does not completely eliminate the risk.
- Leave the area immediately in the event of an accident or spill.

3.21.3.2. Engineering Controls

- Ensure that all laboratory personnel perform all chemical manipulations in fume hood.
- Ensure that the fume hood is operating properly. Check the latest evaluation sticker. Monitor the velocity meter (if present) and/or tape a tell-tale indicator (tinsel, yarn, or light weight string or thread) to the sash that visually indicates air flow.
- Ensure that all personnel use fume hoods properly with the sash in the proper operating position, not fully open, and closed when not in use.

3.21.3.3. Personal Protective Equipment

- Ensure that all laboratory personnel use personal protective equipment (PPE), gloves, lab coat, and eye protection.
- Gloves must be removed and placed in a closed waste bag prior to exiting the lab.
- Lab coats should remain in the laboratory at the end of the day and not taken home.

3.22. **Chemicals with Moderate Chronic and High Chronic Toxicity**- Procedures for Safe Handling and Storage

The Occupational Safety and Health Administration (OSHA) Laboratory Standard recommends that the Chemical Hygiene Plan include standard operating procedures for handling and storage of 1) chemicals with moderate chronic or high acute toxicity and 2) chemicals with high chronic toxicity. Procedures for chemicals of high acute toxicity are found in SOP 3.8, Particularly Hazardous Substances.

This procedure provides information for the handling chemicals with moderate chronic or high chronic toxicity. Chronically toxic chemicals may include reproductive toxins, those that cause chronic organ damage, other human carcinogens or substances with high carcinogenic potency in animals. Some of these, such as human carcinogens and reproductive toxins, may also be considered "particularly hazardous substances" and must be handled in accordance with SOP 3.8.

3.22.1. Definitions

Acute – Sudden effects that occur rapidly as a result of a single exposure or several exposures over a short period of time.

Chronic - Gradual effects that occur as a result of frequent exposure over a long period of time.

***Toxicity* –** The ability of a substance to damage an organism including a description of the effect and the conditions or concentration under which the effect takes place.

Using the National Fire Protection Associations (NFPA) health hazard classifications, chemicals with "high toxicity" can generally be identified as those having an NFPA health hazard rating of 3 and 4 and chemicals with "moderate toxicity" as those having an NFPA rating of 1 or 2. Chemicals of "low toxicity" can be identified as those having an NFPA health hazard rating of 0.

Route of Entry	**NFPA 704 Health Hazard Classifications**				
	4	3	2	1	0
Oral LD_{50}	0-5 mg/kg	>5-50	>50-500	>500-2000	>2000
Skin Contact LD_{50}	0-40 mg/kg	>40-200	>200-1000	>1000-2000	>2000
Inhalation LC_{50}	0-1000 ppm	>1000-3000	>3000-5000	>5000-10,000	>10,000

Comparing the former OSHA definition to the Globally Harmonized System (GHS) of chemical classification and labeling, the GHS acute toxicity ratings of 1 and 2 account for the chemicals with 'high acute toxicity". Therefore, the GHS acute toxicity ratings of 3 and 4 can generally be used to identify chemicals that are considered "moderately toxic." Those with toxicity ratings greater than those found under GHS category 4 (i.e. > 2000 mg/kg, etc.) as chemicals of "low toxicity."

Route of Entry	**GHS Acute Toxicity Ratings**			
	1	2	3	4
Oral LD_{50}	0-≤5 mg/kg	>5-<50	50-<300	300-<2000
Skin Contact LD_{50}	0-≤50 mg/kg	>50-≤200	>200-≤1000	>1000-≤2000
Inhalation (gas) LC_{50}	0-≤100 ppm	>100-≤500	>500-≤2500	>2500-≤5000
Inhalation (vapors) LC_{50}	0-≤0.5 mg/l	>0.5-≤2.0	>2.0-≤10.0	>10.0-≤20.0
Inhalation (dust & mist) LC_{50}	0-≤0.05 mg/l	>0.05-≤0.5	>0.5-≤1.0	>1.0-≤5.0

3.22.2. Procedures for Chemicals with Moderate Chronic Toxicity

- Minimize exposure to these toxic substances by any route using all reasonable precautions.
- Consult one of the standard compilations that list toxic properties of known substances and learn what is known about the substance that will be used. Follow the specific precautions and procedures for the chemical.
- Use and store these substances only in designated (restricted access) areas placarded with appropriate warning signs.
- Use a hood or other containment device for procedures which may result in the generation of aerosols or vapors; trap released vapors to prevent their discharge with fume hood exhaust.
- Avoid skin and eye contact by using gloves, safety glasses, and lab coats.
- Always wash hands and arms immediately after working with these materials.
- Maintain chemical inventories, amounts used, and the names of the personnel involved.
- Be prepared for accidents and spills. At least two people should be present at all times if compounds in use are highly toxic or of unknown toxicity.
- Store breakable containers in chemically resistant trays.
- Work and mount apparatus above trays or absorbent, plastic backed paper.
- If a major spill occurs outside the hood evacuate the area and call for assistance.
- Assure that cleanup personnel wear suitable protective apparel and equipment.
- Thoroughly decontaminate or dispose of contaminated clothing or shoes. If possible, chemically decontaminate by chemical conversion to a less toxic product.
- Store contaminated waste in closed, suitably labeled, impervious containers.

3.22.3. Procedures for Work with Chemical of High Chronic Toxicity

The following supplemental procedures are provided, in addition to those mentioned above, for work with substances of known high chronic toxicity (in quantities above a few milligrams to a few grams, depending on the substance):

- ***Access:*** Conduct all transfers and work with these substances in a ''controlled area'': a restricted access hood, glove box, or portion of a lab, designated for use of highly toxic substances, for which all people with access are aware of the substances being used and necessary precautions.
- ***Approvals:*** Prepare a plan for use and disposal of these materials and obtain the approval of the principal investigator, lab manager, or laboratory supervisor.
- ***Decontamination:*** Protect vacuum pumps against contamination using scrubbers or HEPA filters and vent them into the hood. Decontaminate vacuum pumps or other contaminated equipment, including glassware, in the hood before removing them from the controlled area. Decontaminate the controlled area before normal work is resumed there.
- ***Exiting:*** On leaving a controlled area, remove any protective apparel (placing it in an appropriate, labeled container) and thoroughly wash hands, forearms, face, and neck.
- ***Housekeeping***: Use a wet mop or a vacuum cleaner equipped with a HEPA filter instead of dry sweeping if the toxic substance was a dry powder.
- ***Medical surveillance:*** If frequently using such a substance on a regular basis (e.g., 3 times per week), consult a qualified physician concerning desirability of

regular medical surveillance. See Section 5.0 for additional information.

- ***Records:*** Keep accurate records of the amounts of these substances stored and used, the dates of use, and names of users.
- ***Signs and labels:*** Assure that the controlled area is conspicuously marked with warning and restricted access signs and that all containers of these substances are appropriately labeled with identity and warning labels.
- ***Spills:*** Assure that contingency plans, equipment, and materials to minimize exposures of people and property in case of accident are available.
- ***Storage:*** Store containers of these chemicals only in a ventilated, limited access area in appropriately labeled, unbreakable, chemically resistant, secondary containers.
- ***Glove boxes***: For a negative pressure glove box, ventilation rate must be at least 2 volume changes/hour and pressure at least 0.5 inches of water. For a positive pressure glove box, thoroughly check for leaks before each use. In either case, trap the exit gases or filter them through a HEPA filter and then release them into the hood.
- ***Waste***: Use chemical decontamination whenever possible; ensure that containers of contaminated waste (including washings from contaminated flasks) are transferred from the controlled area in a secondary container.

3.23. Animal Work with Chemicals of High Toxicity – Safety Procedures

All researchers administering chemicals to animals must identify and understand the hazards of the chemicals used in their research, select the proper procedures, hazard controls, personal protective equipment, and provide protocol-specific training to protect those handling the chemicals. University Environmental Health and Safety (IUEHS) will provide the OSHA compliant laboratory chemical safety training.

The chemicals of concern include anesthetics, drugs, controlled substances, carcinogens, allergens, intoxicants, reproductive toxins, embryotoxins, chemical toxins, and novel substances such as synthesized experimental drugs, chemicals, or mixtures. Less hazardous substances such as saline solution and buffers are not chemicals of concern and should be handled using standard chemical handling procedures.

Principal investigators may use the "Principal Investigators Chemical Hazard Assessment for Animal Research" form in Appendix A to perform a chemical hazard assessment for the chemicals in use. Use the guidelines below to determine if the chemical is a "particularly hazardous substance" and follow the required procedures. IUEHS will perform a chemical hazard evaluation during the protocol safety review process and provide guidance on personal protective equipment, regulatory compliance and safety procedures based on the hazardous properties of the chemicals.

Note: Safety Data Sheets for all laboratory chemicals are required to be maintained in the laboratory or on-line. The pertinent information for chemical hazard analysis is found on the Safety Data Sheet (SDS) and in the *Laboratory Safety and Chemical Hygiene Plan*. The SDS for the exact chemical or mixture must be used and provided by the manufacturer of the product.

3.23.1. Particularly Hazardous Substances

If the chemical is a carcinogen, reproductive toxin, or a chemical with a high degree of acute toxicity, the Occupational Safety and Health Administration (OSHA) defines it as a "particularly hazardous substance" (*Laboratory Safety and Chemical Hygiene Plan*, Section 3.8). In addition, novel chemicals including those synthesized in research laboratories, that have not been tested explicitly for carcinogenic or toxic properties must be handled as "particularly hazardous substances" until the hazards have been evaluated because their hazards are unknown.

3.23.1.1. Carcinogen

A substance that either causes cancer in humans or, because it causes cancer in animals, is considered capable of causing cancer in humans. OSHA identifies those that pose the greatest carcinogenic hazards as "select carcinogens" and includes carcinogens identified by OSHA, the National Toxicology Program (NTP) or the International Agency for Research on Cancer (IARC). The list is provided in the Laboratory Safety and Chemical Hygiene Plan, Appendix B.

3.23.1.2. Reproductive Toxin

A substance that causes chromosomal damage or genetic alterations (mutagens) or substances that cause lethal or physical malformations or defects in a developing fetus or embryo (teratogens) and is given on the Safety Data Sheet (SDS).

3.23.1.3. Chemicals with a High Degree of Acute Toxicity

These chemicals include both "highly toxic" and "toxic" chemicals with acutely toxic effects and are based on the route of entry and lethal dose (LD50) or concentration (LC50) given on the Safety Data Sheet (SDS).

3.23.1.4. Chemicals with High Chronic Toxicity

These chemicals include both “highly toxic” and “toxic” chemicals under the OSHA Hazard Communication Standard prior to 2012 with chronic toxic effects. This group may include human carcinogens or reproductive toxins and therefore must be handled as “particularly hazardous substances” also.

Route of Entry	Highly Toxic	Toxic
Oral LD_{50} (albino rats)	≤ 50 mg/kg	>50-500 mg/kg
Skin Contact LD_{50} (albino rabbits, 24 hour)	≤ 200 mg/kg	>200-1000 mg/kg
Inhalation LC_{50} (albino rats, 1-hour) as vapor	≤ 200 ppm	>200-2000 ppm
Inhalation LC_{50} (albino rats, 1-hour) as dust, mist, or fumes	or ≤ 2 mg/liter	or >2-20 mg/liter

The current OSHA definition under to the Globally Harmonized System (GHS) of chemical classification and labeling would include GHS acute toxicity ratings of 1 or 2 to account for chemicals with ‘high acute toxicity”.

For practical purposes, these chemicals may also be identified using the National Fire Protection Associations (NFPA) health hazard classifications found on the bottle label and Safety Data Sheet (SDS). In general, a chemical with a 3 or 4 in the blue diamond of the NFPA label can be considered to be a “particularly hazardous substance” (excluding cryogenics and <u>some</u> corrosives).

Route of Entry	NFPA 704 Health Hazard Classifications				
	4	**3**	2	1	0
Oral LD_{50}	0-5 mg/kg	>5-50	>50-500	>500-2000	>2000
Skin Contact LD_{50}	0-40 mg/kg	>40-200	>200-1000	>1000-2000	>2000
Inhalation LC_{50}	0-1000 ppm	>1000-3000	>3000-5000	>5000-10,000	>10,000

3.23.2. General Procedures

- ***Access and facilities:*** For large scale studies, special facilities with restricted access are preferable. IUEHS conducts annual chemical safety inspections of the facilities and evaluation of safety equipment. Animal facilities must be posted with a sign to indicate that particularly hazardous substances are used in the area and to provide safety instructions. The “Animal Facility Safety Information” sign found in Appendix A is an example that shows the chemicals present, personal protective equipment, and any other special requirements for entry.
- ***Administration of the toxic substance:*** When possible, administer the substance by injection or gavage instead of in the diet. If administration is in the diet, use a caging system under negative pressure or under laminar air flow directed toward HEPA filters.
- ***Aerosol suppression:*** Devise procedures, such as lightly spraying bedding with water, which minimize formation and dispersal of contaminated aerosols, including those from food, urine, and feces (e.g., use HEPA filtered vacuum equipment for cleaning, moisten contaminated bedding before removal from the cage, mix diets

in closed containers in a hood).

- ***Personal protection:*** When working in the animal room, wear plastic or rubber gloves, fully buttoned laboratory coat or jumpsuit and, if needed because of incomplete suppression of aerosols, other apparel and equipment (shoe and head coverings, respirator).
- ***Waste disposal:*** Package contaminated animal tissues and excreta appropriately for disposal by IUEHS or waste disposal vendor. See "Waste Disposal and Handling" below.

3.23.3. Chemical Handling

- These chemicals must be used in a designated area. This includes live animals and open cages with chemically contaminated bedding. Signs must be posted to designate that the entire laboratory or portion of the laboratory such as a specific fume hood, glove box, or adjacent room as the designated area for that chemical use. This may be accomplished by using the emergency door sign and identifying the chemical groups used in the laboratory (i.e., carcinogen, reproductive toxin, highly toxic or toxic chemical).
- The chemical must be handled in a containment (if decanted or exposed to the open air) or within a closed system. This includes live animals and open cages with chemically contaminated bedding. Containment devices include chemical fume hoods, glove boxes, or biosafety cabinets that are vented outside of the building. Closed systems include plumbing within instruments, cannulas, syringes, gavages, etc., as long as the chemical is not exposed to the atmosphere. If no containment is available then personal protective equipment assigned to the protocol during the safety review must be utilized by all personnel in the area.
- Only the minimum quantity of the material should be used.
- Appropriate personal protective equipment (e.g., gloves, lab coat, and eye protection) must be used when handling these hazardous substances.
- Procedures for waste removal must be established prior to use. Follow standard IUEHS chemical disposal procedures. Follow biological waste disposal guidelines below for animals and bedding.
- Decontamination procedures must be developed for the tools and area.
- The principal investigator listed on the protocol is responsible for establishing the experimental procedure, determining the hazard controls to be utilized, and providing protocol-specific training for the staff. Prior approval from the principal investigator or supervisor is required for the experiment to begin (see Laboratory Safety and Chemical Hygiene Plan Section 2.1.1 Prior Approval of Hazardous Operations).
- University Environmental Health and Safety (IUEHS) will provide the OSHA compliant laboratory chemical safety training. All personnel that handle any chemicals in the laboratory must attend chemical safety training required by the OSHA Laboratory Standard from IUEHS. Only laboratory personnel that have received IUEHS laboratory chemical safety training and protocol specific training from the principal investigator may work with these substances, and only within the designated area. These chemicals may not be decanted or exposed to the atmosphere outside a containment or closed system.

3.23.4. Chemical Storage and Labeling

- Acutely toxic chemicals, carcinogens and reproductive toxins must be stored designated areas for “particularly hazardous substances.”

- Storage areas should be clearly marked with the appropriate hazard warning signs.
- All containers of these substances (even in small quantities such as 0.1%) must be clearly labeled with the chemical name or components of the mixture and should be labeled with hazard information.
- Chemical storage areas should be secure to avoid spills or broken containers.
- Storage areas or laboratory rooms must be locked when laboratory personnel are not present.
- For more information, refer to Section 3.2, Procedures for Proper Labeling, Storage, and Management of Chemicals.

3.23.5. Waste Disposal and Handling

- Waste handlers must wear standard personal protective equipment (PPE) required for laboratory work, lab coat or gown, safety glasses, gloves and closed toed shoes.
- Respiratory protection is not required if procedures do not produce aerosols or if a fume hood, ventilated cage dump station, or biosafety cabinet is utilized but may be used voluntarily to protect against fugitive dust emissions.
- All waste including biological tissues and fluid, chemicals, contaminated materials, sharps, and other items must be properly disposed as detailed in the IU Biosafety Manual.
- Empty containers, with the exception of acutely toxic waste, may be triple rinsed and disposed of as sanitary waste.
- Chemical waste and contaminated materials are disposed of in accordance with the IU Waste Management Program.
- All animal carcasses and tissues are disposed of as medical waste to prevent unacceptable conditions in the sanitary waste containers and to ensure that transgenic animals are disposed of as regulated medical waste.
- Animal use protocols are reviewed by the IUEHS staff to identify any rare or unusual circumstances that would affect waste disposal or occupational safety.
- Animal carcasses must be frozen for disposal. Place materials in a biohazard bag with a biohazard symbol. Double bag if necessary to prevent perforations. Place the bag in a freezer and contact IUEHS for your respective campus for pickup (except for the IUPUI campus and IUSOM locations where the carcasses are picked up for disposal by an approved vendor).
- Animal bedding is sanitary waste and is disposed of with other sanitary waste from the facility.
- Even though animal bedding is not typically an EPA hazardous waste or biohazardous waste it must be handled carefully for occupational safety purposes. Animal bedding from chemically dosed animals may contain dosed uneaten food or water and shedding or excretions that contain very small amounts of hazardous chemicals or their metabolites.
    a) If the bedding is known to contain small amounts of chemicals in dosed food or otherwise, the bedding must be handled using fully buttoned lab coats or gowns, gloves, safety glasses in a ventilated dump station, biosafety cabinet, fume hood or with respiratory protection.
    b) If it is unknown or inconclusive that the bedding contains these hazardous substances then the bedding must be handled as if it does using fully buttoned lab coats or gowns, gloves, safety glasses in a ventilated dump station, biosafety cabinet, fume hood or with respiratory protection.

c) If the researcher can demonstrate the bedding or excreta does not contain hazardous amounts of these substances then the waste handling requirements may be modified.

- Empty cage bedding from dosed animals into a waste bag using a ventilated dump station or <u>within</u> a chemical fume hood or biosafety cabinet. Place the cage within the bag. Remove the lid. Empty the cage into the bag and remove the cage from the bag. Close and secure the bag.

3.24. Chemical Transportation Procedures

Movement or transportation of chemicals used in laboratories can occur for many purposes and to various destinations. They include the transportation of chemicals:

- Between laboratories or within a building (intra-building).
- Between buildings or departments (inter-building).
- Between IU campuses and properties.
- Into the field for research.
- To and from other institutions or agencies.
- To commercial waste facilities.
- To and from manufacturers or commercial facilities.
- To and from other institutions or agencies.

The procedures and additional training requirements for transporting chemicals for these purposes can be found in the IU Hazardous Materials Transportation Program.

3.25. Laboratory Closeout Procedures

Proper transfer or disposal of hazardous materials is required whenever a Principal Investigator or researcher with assigned laboratory space leaves the University or transfers to a different laboratory.

Plan the transfer or disposal of hazardous materials carefully. Hazardous materials such as chemicals, microorganisms, tissues, and radioactive materials can injure faculty, students, staff, contractors and visitors if handled inappropriately.

Failure to adhere to these procedures and manage hazardous materials properly during the lab closure may result in sanctions such as the loss of laboratory privileges or the recovery of the cost of disposal of unknown, unlabeled, or poorly managed hazardous chemicals. Any charges for improperly managed waste or excessive cleanouts will be assessed to the responsible department.

The primary responsibility for the proper management of all hazardous materials used in laboratories lies with the principal investigator or researcher assigned to the space. If the principal investigator is not the responsible individual for purposes of these procedures, documentation identifying the responsible individual must be provided on the Laboratory Decommissioning/Closeout Checklist (Appendix A, Form LCS-8). The department or unit is responsible for ensuring that the principal investigator manages and disposes of these materials properly. University Environmental Health and Safety (IUEHS) provides guidance and disposal services for the principal investigator and department or unit. Refer to the IU Waste Management Program for disposal information.

3.25.1. Notification and Inspection Process

3.25.1.1. Notify

Use the Researcher Departure/Lab Closeout Notification to notify IUEHS for the respective campus at least 30 days in advance:

a) That your laboratory is relocating on-campus or off-campus, or
b) That your laboratory is closing down, or
c) That a researcher within your laboratory group is departing.

3.25.1.2. Complete Checklist

Print and complete the following checklist to ensure that you have completed all activities required to properly prepare for your departure or move located in Appendix A, Form LCS-8.

3.25.1.3. Schedule Lab Clearance Inspection

Once you have completed all items on the checklist, and all chemical transportation and waste removal has been arranged, sign the checklist, and submit the online Lab Clearance/Closeout Inspection Request to IUEHS.

Have the checklist ready to go over with the Laboratory Safety personnel who conduct your clearance inspection. Final clearance will not be given until all decontamination and hazardous material removal is complete.

3.25.2. General Closeout Guidelines

- Package and move items only during normal business hours (8:00 a.m. to 5:00 p.m., Monday through Friday) so IUEHS staff will be available to assist in case of a spill or accident.
- Never transport hazardous materials alone.
- Follow the IU Hazardous Materials Transportation Program for all chemical transportation.
- Wear appropriate personal protective equipment for the materials being handled.
- Review the location of safety showers, eyewashes, fire extinguishers, and exits if the closeout involves moving to another campus lab.

3.25.3. Departing Student Researchers

- Turn in all waste bottles to IUEHS for disposal prior to departure. See the IU Waste Management Program.
- Dispose of all samples or identify, label, and transfer ownership.
- Turn in their unused chemicals to IUEHS, or
- Transfer the responsibility for the chemicals to someone remaining in the lab (i.e., identify/document who the new Responsible Individual is for the chemicals on the Laboratory Decommissioning/Closeout Checklist, Form LCS-8) and identify substances by chemical name in case of a need for future disposal.

3.25.4. Chemicals

- Determine if any chemicals are usable* and if you or anyone at IU would like to keep them. Document transfer of responsibility for any identified chemicals to a party willing to accept them using the *checklist*. If you are not going to keep them and a new user cannot be found, dispose of the materials through IUEHS by following the procedures in the IU Waste Management Program.

  * Chemicals that ***cannot*** be considered usable and transferred to another user include the following:

  - Leaking containers.
  - Handwritten labels (Chemicals in primary or secondary containers with handwritten labels can be retained, but cannot be transferred to another user.).
  - Deteriorating or illegible labels.
  - Cracked or poorly sealing lids.
  - Non-commercial mixtures/solutions
  - Expired chemicals
  - Compressed gases or pressurized liquids (unless specific approval has been given by IUEHS).
  - Mercury in any form
  - Samples (unless they have been identified and labeled with a full proper chemical name – no abbreviations, acronyms, chemical structures, or reference numbers or initials).
  - Waste containers

- Refer to the IU Waste Management Program for waste disposal procedures. Do NOT evaporate chemicals, flush hazardous chemicals down the drain, or discard them in the trash.
- Characterize any "unknown" substances found in the lab according to standard procedures or knowledge of the substances. IUEHS can provide guidance upon request.
- Label all chemical containers with the proper chemical name. Abbreviations, chemical formulas or structures are not acceptable.
- Ensure that all containers are securely closed. Empty all beakers, flasks, evaporating dishes, etc. into appropriate containers with tight-fitting lids. Parafilm can be used to minimize odors as needed, but is not an acceptable lid.
- Remove all chemicals from refrigerators, freezers, fume hoods, bench tops, shelves and storage cabinets.
- Prepare all chemicals for disposal according to IU Waste Management Program. This process may take quite some time. Start at least one month before planned departure from the laboratory. Complete chemical waste removal before vacating the laboratory. At IUB and IUPUI allow two weeks for waste collection to occur after notifying IUEHS that the waste is properly prepared for pickup.
- Refer to the IU Hazardous Materials Transportation Program for any chemicals being kept or transferred that need to be moved.
- Clean all areas of chemical use and storage, including benchtops, storage cabinets, fume hoods, incubators, refrigerators, freezers, etc. Soap and water, or surfactant-based cleaners are effective for most contamination.
- Collect broken glass, sharps, and other laboratory waste.

3.25.5. Shared Storage Areas

- Shared facilities include storage units such as stock rooms, walk-in refrigerators, constant temperature rooms, shared refrigerators, freezers, flammable liquid cabinets, waste collection areas, etc.
- They are of special concern if more than one person manages the area.
- Carefully inspect any shared facility in order to locate and appropriately dispose of the hazardous materials for which that researcher is responsible.

3.25.6. General Laboratory Cleaning

- Wash off fume hood surfaces and clean counter tops.
- Notify your department and IUEHS for the respective campus when laboratory clean-up is complete to arrange a closeout or clearance inspection.

3.25.7. Controlled Substances

- The U.S. Drug Enforcement Agency (DEA) issues controlled substance registrations to individual researchers. Refer to the IU Controlled Substances Program for additional information.
- Abandonment of a controlled substance is a violation of the DEA permit under which it was held.
- Permission to transfer a registration for a controlled substance to another individual must be approved and documented by the DEA.

- Relocation of controlled substance inventories to any new campus location or to a new research institution is prohibited unless the Indiana Board of Pharmacy and the US DEA are notified first. Contact IUEHS for more information.

3.25.8. Gas Cylinders

- Remove gas connections, replace cylinder caps, and return cylinders to suppliers or prepare them for transfer if you will be moving them to a new location within IU. Refer to the IU Compressed Gas Cylinder Safety Program ~~IU Compressed Gas Cylinder Safety Programl~~ for additional guidance on cylinder management and to the IU Hazardous Materials Transportation Program for information about cylinder transportation.
- If cylinders are non-returnable, please refer to the IU Waste Management Program for disposal guidance of waste compressed gases and pressurized liquids.
- Refer to SOP 3.9, Compressed Gases, for additional information.

3.25.9. Animal and Human Tissues

- Determine if any biological materials are usable and if you or anyone at IU would like to keep them. Document transfer of responsibility for any identified materials to a party willing to accept them using the *checklist* (Appendix A, Form LCS-8).
- Refer to the IU Biosafety Manual for disposal guidance for all biological waste materials that are not being kept or transferred.
- Refer to the IU Hazardous Materials Transportation Program for any biological materials being kept or transferred that need to be moved.
- If tissue was stored in a refrigerator or freezer - defrost, clean and disinfect the refrigerator and freezer after it has been emptied. Use an appropriate disinfectant.
- Questions or concerns regarding biological materials should be directed to IUEHS Biosafety for your respective campus.

3.25.10. Microorganisms and Cultures

- Notify IUEHS Biosafety for your respective campus of any transfer of NIH Risk Group 2 agents or higher.
- Notify IUEHS Biosafety for your respective campus of the intent to transfer NIH Risk Group 2 agents or higher from the University. Because such transfers may fall under Department of Transportation (DOT) shipping regulations and/or require additional permits, they must be arranged well in advance.
- Refer to the IU Biosafety Manual for waste decontamination and disposal guidance.

3.25.11. Mixed Hazards

- Occasionally it is necessary to dispose of materials that may contain more than one hazard. Contact IUEHS for information on the disposal of any combination of chemically contaminated, biohazardous materials, and/or radioactive materials.

3.25.12. Sharps

- Refer to the IU Waste Management Program for guidance on sharps disposal based on the type of contamination on the sharps.

3.25.13. Radioactive Materials

- Contact the Radiation Safety Office to relocate any radioactive materials to another laboratory, to remove these materials from the University or the radioactive material inventory, for decontamination of the work area, and to conduct a final survey of the vacated area.
- Authorized radioactive materials use permit holders are responsible for notifying the Radiation Safety Officer for their authorized location of any changes that would affect their permit, such as departure from the University, change of personnel authorized as users of radioactivity under the permit, and changes in authorized inventory, including purchase, disposal, and transfers.
- Only Radiation Safety personnel can conduct a final radiation clearance on a radioactive materials use area and remove the radioactive materials door sign.

3.25.14. Equipment

- Alert IUEHS and/or Facilities Management if any exhaust or filtration equipment was used with heated perchloric acid digestion.
- Clean and disinfect laboratory equipment that is staying before departing. This includes refrigerators, freezers, drying ovens, incubators, centrifuges, etc. For equipment in which biohazardous material or microbial agents were used or stored, use an effective disinfectant. Cleaned equipment must be marked as clean.
- If moving biological safety cabinets, decontaminate before moving and recertify before use in the new location.
- Deface or cover hazard labels on equipment to be moved or discarded.
- Repair any damaged equipment (i.e. frayed wires, missing guards, etc.) that will remain in service. No damaged equipment should be moved. Use the laboratory downtime to accomplish previously undiscovered or neglected repairs.
- Contact Surplus Stores/Property on your respective campus to arrange disposal of equipment that can be effectively decontaminated and is functional. If equipment cannot be effectively decontaminated, contact IUEHS. All equipment disposed through Surplus must be decontaminated, marked as clean, and have all hazard warning labels removed prior to transfer to Surplus.
- When discarding laboratory equipment, remove capacitors, transformers, mercury switches, mercury thermometers, radioactive sources, chemicals and biohazards before disposal. Contact IUEHS for your respective campus for any equipment that may contain asbestos or any of these materials.

4. TRAINING REQUIREMENTS

The OSHA Lab Standard requires that individuals who will be working with chemicals in the laboratory be provided with sufficient training to enable them to conduct their work safely. Training must be provided prior to the time when individuals begin their duties involving chemicals and whenever there is a significant change in the types or quantities of chemicals used. Departments and, ultimately, principal investigators, lab managers or lab supervisors are responsible for ensuring that all individuals working in their laboratories have been adequately trained.

Indiana University Environmental Health and Safety (IUEHS) provides L*aboratory Safety and Chemical Hygiene* training to the university community. Contact your campus representative for training (see Laboratory Safety Contacts). This comprehensive training is designed to cover the topics required by the OSHA Lab Standard and more.

This training, however, is not intended to be the sole means of training laboratory workers but must be supplemented by additional safety instruction from the principal investigator (lab manager or laboratory supervisor) on the potential hazards associated with an individual's specific duties. This individualized training should also include a review of the laboratory's safety features and equipment (Appendix A, Form LCS-2 can assist in this process).

4.1. Required Training Content

The general training topics required by the Lab Standard are the:

- Content of the Lab Standard.
- Location and availability of the *Laboratory Safety and Chemical Hygiene Plan* (i.e., Chemical Hygiene Plan).
- Permissible exposure limits (PELs) for OSHA regulated substances (see 1910.1000, Appendix A) or recommended limits for other materials that have no OSHA limits.
- Signs and symptoms associated with chemical exposure.
- Location and availability of known reference material on the hazards, safe handling, storage, and disposal of chemicals. This includes, but is not limited to, Safety Data Sheets (SDS).
- Methods to detect the presence or release of chemicals.
- Physical and health hazards of chemicals.
- Measures that laboratory workers can take to protect themselves from chemical hazards, including control measures, personal protective equipment, SOPs, and emergency procedures.

4.2. Training Resources

Additional training resources and the guidelines are also available. For information on other safety training resources available from IUEHS (such as specialized training sessions, videotapes, safety guides, chemical references, and Safety Data Sheets (SDS), individuals should contact IUEHS for their respective campus for assistance.

4.3. Training Documentation

Departments, principal investigators, laboratory managers and laboratory supervisors, are responsible for documenting the safety training provided to individuals working within their laboratories. For each individual, maintain a record not only for formal training sessions attended such as the *Laboratory Safety and Chemical Hygiene training*, but also for informal safety instruction or training provided in the laboratory (Appendix A, Form LCS-3 may be used for this purpose).

Indiana University Environmental Health and Safety (IUEHS) maintains training records of everyone that attends the required introductory Laboratory Safety and Chemical Hygiene training provided by IUEHS. Contact the IUEHS representative for your respective campus for records assistance.

5. MEDICAL CONSULATATION AND EXAMINATIONS

In accordance with the requirements of the OSHA Lab Standard, Indiana University provides all employees who work with chemicals the opportunity to receive medical consultation and examinations, when the conditions identified in section 5.2 present, under the supervision of a licensed physician. Medical examinations are provided without cost to the employee, without loss of pay, and at a reasonable time and place.

5.1. Medical Facilities

5.1.1. The medical care facilities and hours of operation for your respective campus can be found at IU Human Resources.

5.2. Examination Criteria

Medical examinations are available to employees who work with chemicals in the laboratory whenever:

- An employee develops signs or symptoms associated with a chemical to which exposure may have occurred in the laboratory;
- Exposure monitoring reveals an exposure level routinely above the action level (or in the absence of an action level, the PEL) for an OSHA regulated substance for which there are exposure monitoring and medical surveillance requirements; or
- A spill, leak, explosion, or other event occurs in the laboratory resulting in the likelihood of chemical exposure.

5.3. Information to the Physician

The employee's department, principal investigator, laboratory manager, or laboratory supervisor must provide the physician with the following information regarding the employee's potential exposure:

- The identity of the chemicals to which the employee may have been exposed.
- The Safety Data Sheet for the chemical(s) the employee may have been overexposed (caution: do not delay obtaining medical attention while securing the proper safety data sheets); and
- A description of the employee's symptoms.

5.4. Physician's Written Opinion

Upon completion of the employee's consultation or examination, the department, principal investigator, laboratory manager, or laboratory supervisor must obtain a written opinion from the examining physician that includes the following information:

- Any recommendations for further medical follow-up;
- Results of the medical examination and associated tests;
- Any medical condition found as a result of the examination that may place the employee at increased risk from further chemical exposure in the laboratory; and
- A statement that the employee has been informed by the physician of the results of the consultation or examination.
- The physician's written opinion shall not reveal specific findings of diagnoses unrelated to occupational exposure.

5.5. Medical Services

5.5.1. Reporting Procedures for Medical Attention

For any work-related injury (whether or not the individual elects to seek medical attention) the principal investigator, laboratory manager, or laboratory must complete an Employee Occupational Injury-Illness Report Form.

For treatment the supervisor or PI must also complete an Employer Notification for Treatment Form (IUB and Regional Campuses). All forms for all campuses are found at University Human Resource Services (http://hr.iu.edu/workers/).

1. Notify your Principal Investigator, Lab Manager, or Lab Supervisor immediately;
2. The Principal Investigator, Lab Manager, or Lab Supervisor must complete the electronic Notification for Treatment form before the injured employee receives care. The required form can be found at the IU Human Resources website;
3. Within twenty-four (24) hours, fill out and submit an Occupational Injury/Illness form found at the IU Human Resources website;
4. Report to the Designated Medical Services Provider for your respective campus;
5. For life threatening injuries or illnesses, call 911 for ambulance assistance.

6. LABORATORY SAFETY EQUIPMENT

The availability and use of a number of types of safety equipment is essential to the practice of safe science. Safety equipment should be present in well-marked, highly visible, and easily accessible locations in or near all laboratories that use hazardous chemicals. For more information regarding safety equipment or specific regulatory requirements, please call Indiana University Environmental Health and Safety for your respective campus.

Laboratory personnel should contact the Facility Services/Physical Plant for your respective campus for assistance with equipment malfunctions, maintenance and repairs.

6.1. Chemical Fume Hoods

Chemical fume hoods are one of the most important items of equipment used for the protection of workers in the laboratory. A standard fume hood is a chemical and fire-resistant enclosure with a movable window (sash) at the front to allow the user access to the interior. Chemical fume hoods capture, contain, and expel chemical emissions. In addition, chemical fume hoods (with the sash down) provide a protective barrier between laboratory personnel and chemicals or chemical processes. Unless the hood is designed to draw a low-volume, a properly functioning standard hood draws air from the laboratory at a velocity of 100 feet per minute (±10 to 20%) with the sash half open or at the designed operating height (at the stopper). The storage of large numbers of chemical bottles or other items within the hood can dramatically impair this functioning. To ensure that fume hoods are operating properly, Indiana University Environmental Health and Safety conducts annual inspections. Facility Services/Physical Plant for your respective campus service any hoods that are not functioning properly immediately. (See SOP 3.3 *Chemical Fume Hoods - Procedures for Proper and Safe Use*.)

6.2. Safety Showers

Safety showers are required in areas where hazardous chemicals are used. Safety showers provide an effective means of initial treatment in the event of chemical contamination of the skin or clothing. The shower area must be readily accessible, clear of obstructions, and clearly labeled. Safety showers are tested annually by IUEHS or Facility Services/Physical Plant to ensure that the proper flow is provided according to the ANSI Standard, Z358.1. In the event of chemical contamination of an individual's body, immediately flush the body for 15 minutes under the shower, remove all clothing, and seek medical attention.

6.3. Eyewash Stations

Eyewash stations are required in areas where hazardous chemicals are used. Eyewashes must be easily accessible, unobstructed, and clearly labeled. The use of the hands must not be required to activate and maintain the water flow. Plumbed eyewash units are best and strongly recommended. Eyewashes are tested annually by IUEHS or Facility Services/Physical Plant to ensure that the proper flow is provided according to the ANSI Standard, Z358.1. Eyewashes should be activated weekly by laboratory personnel to ensure that they are working properly. It is recommended that weekly eyewash testing be documented by the laboratory.

In the event of chemical contamination of the eyes or face, immediately flush the eyes/face for 15 minutes and seek medical attention.

6.4. Fire Extinguishers

Laboratory personnel should know the locations of all fire extinguishers in the laboratory, the type of fires for which they are appropriate, and be trained on how to operate them correctly. The Office of Insurance, Loss Control & Claims (INLOCC) provides fire safety training to IU employees (http://inlocc.webhost.iu.edu).

Fire extinguishers in the laboratory should be the appropriate type for the expected fire emergency. Extinguishers are classified according to a particular fire type.

Note: Classification of fires and extinguishers - Class A, ordinary combustibles; Class B, flammable liquids and gasses; Class C, live electrical equipment; Class D, combustible metals and metal alloys. Most laboratories are equipped with combination Class ABC fire extinguishers. Some also have carbon dioxide Class B and Class C fire extinguishers for flammable liquids, gases, and electrical fires. A bucket of dry sand (marked "Class D Fire Extinguisher") or commercial Class D fire extinguisher must be present in laboratories where water reactives and combustible metals and metal alloys are used or stored.

Fire extinguishers should be easily accessible, mounted properly on a wall, and unobstructed. The Office of Insurance, Loss Control & Claims (INLOCC) is responsible for the inspection of fire extinguishers. Used fire extinguishers must be immediately serviced. Contact INLOCC for assistance.

6.5. Fire Blankets

Fire blankets are recommended in all laboratories that use flammable liquids. Fire blankets should be easily accessible and unobstructed. In the event that a person's body or clothing catches fire, the person should immediately drop to the floor and roll to help extinguish the fire (STOP-DROP-and-ROLL method). A fire blanket should be used only as a last resort to help smother a body or clothing fire. Fire blankets can also be used to keep shock victims warm.

6.6. Flammable Liquid Storage Cabinets

Flammable liquids in quantities exceeding a total of 10 gallons in a laboratory must be stored in flammable liquid storage cabinets or safety cans. Flammable storage cabinets shall be designed to meet NFPA (National Fire Protection Agency) and Indiana Fire Code guidelines. Cabinets are generally made from No. 18 gage sheet steel with double-walled construction or one-inch exterior grade plywood. Approved cabinets should be marked in conspicuous lettering "FLAMMABLE KEEP FIRE AWAY."

Flammable cabinets are not required to be vented (cabinets are generally vented only if the flammable liquids generate noxious fumes), but if venting is desired it shall meet NFPA and Indiana Fire Code requirements (contact IUEHS or the Office of Insurance, Loss Control & Claims (INLOCC) for details on venting requirements). Only flammable and combustible material should be stored in flammable storage cabinets.

6.7. Safety Cans

A safety can is a container of not more than five-gallon capacity, having a spring-closed lid, spout cover, and flame arrestor and so designed that it will safely relieve internal pressure. Safety cans must be UL (Underwriters' Laboratories, Inc.) listed and must be compatible with the chemical that they are to contain. Safety cans with damaged parts such as corroded spark arrestor screens or insufficient springs must be taken out of service and replaced immediately.

6.8. Laboratory-Safe and Explosion-Proof Refrigeration Equipment

The use of domestic refrigeration equipment for the storage of flammable liquids presents a significant hazard to the laboratory work area. Refrigerator temperatures are commonly higher than the flash points of the flammable liquids stored within them. In addition, domestic refrigerators contain exposed sources of ignition such as thermostats, lights, and heater strips that can ignite flammable vapors released inside the refrigerator and cause a fire or explosion. Domestic refrigerators can only be used to store non-flammable chemicals and samples.

Flammable liquids must only be stored in one of two types of laboratory refrigerators: laboratory-safe and explosion-proof refrigerators.

Laboratory-safe refrigeration equipment (also called flammable-safe or explosion-safe) is designed to eliminate sources of ignition on the inside of the storage compartment only, even though other safety design features like self-closing doors, magnetic door gaskets, and compressors and circuits located at the top of the refrigeration unit have been incorporated. They plug into a standard three-prong wall outlet in the laboratory.

Explosion-proof refrigeration equipment is designed to protect against ignition of flammable vapors both inside the storage compartment and outside the refrigerator. They are intended for use in high-hazard occupancies where an exterior source of ignition must be eliminated. Explosion-proof refrigerators are hardwired, using electrical conduit, into the buildings electrical service and do not have standard three-prong electrical plugs.

All flammable liquids that need to be stored in a cool environment should be stored in one of these two types of approved refrigerators. Containers must be tightly closed to minimize the amount of vapor released. Every laboratory refrigerator must be clearly marked to indicate what may (or may not) be stored in the refrigerator. Modification of domestic refrigerators to hold flammable liquids is not permitted.

6.9. First Aid Kits and CPR

First aid kits should be easily accessible to all laboratory personnel. If a first-aid kit is placed in a drawer or cabinet, the drawer or cabinet must be labelled “First-Aid Kit.” First aid kits must be regularly inspected and restocked as necessary. First aid kits can be purchased through any laboratory safety supply vendor. For additional information please visit the IU First Aid, CPR, and AED Program.

The University provides or can arrange Red Cross-certified First Aid, CPR, and AED training to all IU employees. Contact your campus IUEHS representative for your respective campus for more information.

6.10. Chemical Spill Kits

Every laboratory that uses hazardous chemicals should have access to a spill control kit. The keys to an effective spill kit are location and contents. Spill kits should be strategically located around work areas in fixed spots so they will be easily accessible. If a spill kit is placed in a drawer or cabinet, the drawer or cabinet must be labelled “Spill Kit.”

In general, a spill kit should contain absorbent material, appropriate personal protective equipment, a container for spill residue, and a plastic dustpan and scoop. Laboratories that use mercury or mercury-filled thermometers and manometers should also have a mercury spill kit available. Once a spill kit has been used it should be immediately restocked.

Spill kits can be purchased through most vendors that sell chemicals or safety supplies. In addition, spill kits can be obtained from IUEHS for your respective campus. The following is a list of recommended items that should be contained in a chemical spill kit. However, it is important that spill kits be tailored to meet the specific spill control needs of each laboratory.

6.10.1. Absorbents

- Universal Spill Absorbent Material – 1:1 mixture of sodium bicarbonate (baking soda): Flor-Dri (or unscented kitty litter) or alternatively, a 1:1:1 mixture of Flor-Dri (or unscented kitty litter): Sodium Bicarbonate: Sand. This all-purpose absorbent material is good for most chemical spills including solvents, acids, and bases.
- Acid Spill - Sodium Bicarbonate, Sodium Carbonate, or Calcium Carbonate
- Alkali (Base) Spill - Sodium Bisulfate
- Solvents/Other Organic Liquids - Inert absorbents such as vermiculite, clay, sand, Flor-Dri, and Oil-Dri

6.10.2. Personal Protective Equipment

- Goggles and Face Shield
- Plastic Vinyl Booties
- Disposable Coveralls and Apron
- Disposable Vinyl Gloves and Heavy Neoprene Gloves

6.10.3. Clean-Up Material

- Plastic Dust Pan and Scoop
- Plastic Bags (30 gallon, 3 mil thick)
- One empty 5 gallon, plastic bucket with lid for spill and absorbent residues

6.10.4. Other Examples

- Hydrofluoric Acid Antidote Gel - Calcium Gluconate
- Mercury Spill Kit

6.11. Portable Safety Shields

Portable safety shields can provide limited protection against explosions, fires, and chemical splash hazards. When a hood sash cannot provide proper shielding, portable safety shields should be used. It should be noted that portable safety shields do not provide protection on the sides and back of equipment and therefore work best if used in conjunction with a fume hood. Laboratory equipment/chemical apparatus should be shielded on all sides so that there is no line-of-sight exposure to laboratory personnel.

APPENDIX A – FORMS

Indiana University

University Environmental, Health, and Safety

LABORATORY SAFETY AUDIT CHECKLIST

Department:________________________ **Building/Room No.: ______________________**

Principal Investigator:_______________ **Lab Safety Officer: _______________________**

Audited by:_________________________ **Date Surveyed: _________________________**

The Administration of Indiana University supports a safe research community that is expected to comply with applicable federal, state and local regulatory requirements. To ensure compliance with these regulations, University Environmental Health and Safety conducts regular Laboratory Safety Audits designed to identify potential r OSHA or EPA violations.

	General Laboratory Safety	Yes	No	Comments/Corrections
1.	Emergency information and proper warning signs are posted.			
2.	Safety training has been completed by all lab personnel.			
3.	The Laboratory Safety and Chemical Hygiene Plan is available to all personnel in the laboratory in paper or electronic format.			
4.	Safety Data Sheet information is available to all personnel in the lab.			
5.	Up-to-date Spill Response Guide and stocked spill kit are present in a visible location.			
6.	First Aid Kit is stocked, available, and visible.			
7.	Personal Protective Equipment (PPE) is available and worn at time of inspection.			
8.	Food or drinks are stored and consumed in separate designated areas outside of the lab.			
9.	Ice machines are labeled “Not for human consumption.”			
10.	Microwaves in labs are labeled “For lab use only” and those outside labs in food consumption areas are labeled “For human food only.”			
11.	Food items used in labs are properly labeled “For lab use only.”			
12.	Good housekeeping is practiced throughout the lab.			
13.	Exits and aisles are clear and unobstructed.			
14.	Fire doors and lab doors are not obstructed or wedged open.			
15.	Fire extinguishers are present (within 75 ft.), secure, unobstructed, and up-to-date.			
16.	Combustibles are not stored too close to ceilings and fire sprinklers (18 inches if sprinklered and 24 inches if un-sprinklered).			
17.	Approved eyewash and shower are available and unobstructed.			
18.	Eyewash and shower have been inspected and are working properly.			
19.	Fume hood has been inspected and is working properly.			
20.	Fume hood is not being used for excess storage of chemicals or equipment.			
21.	Machine guarding is on all belts, pulleys, and mechanical devices.			
22.	Electrical cords are not frayed.			
23.	Electrical outlets are not overloaded, piggybacked or cascaded.			
24.	Outlets, cords and extension cords are grounded.			
25.	Bench tops are not cluttered with materials and chemicals.			
26.	Glass apparatus is assembled properly with all water/liquid hose line connections clamped.			

Chemical Labeling, Handling, and Storage		**Yes**	**No**	**Comments/Corrections**
27.	All containers, primary and secondary (wash bottles, carboys, etc.) are labeled correctly.			
28.	All chemical storage areas such as refrigerators and cabinets are labeled with hazard warnings.			
29.	All chemical containers are kept closed.			
30.	Chemicals are not stacked or stored on their sides			
31.	All chemical containers and lids are in good condition.			
32.	All container labels are in good condition and legible.			
33.	Chemicals are segregated by hazard class and chemical compatibility.			
34.	Chemicals are not stored on the floor.			
35.	No chemicals are stored near desks or electrical equipment.			
36.	Flammable liquids are in an approved cabinet (if >10 gal. in lab)			
37.	Refrigerated flammables are stored in a properly labeled fireproof refrigerator.			
38.	All chemical storage freezers are defrosted.			
39.	No chemicals stored near sinks and drains or close to eyewashes and emergency showers.			
40.	Hazardous or corrosive liquids are not stored above eye level.			
41.	Explosive and temperature sensitive chemicals are stored properly.			
42.	Reactive and time-sensitive chemicals are stored properly, dated, and are not expired.			
43.	Controlled substances are secure and inventoried.			
44.	Perchloric acid digestions are being performed in a perchloric acid fume hood or other non-fuming device.			
45.	Gas cylinders are secured and stored properly.			
46	Cryogenics and open chemical containers are not stored in cold rooms.			
Waste and Hazardous Waste		**Yes**	**No**	**Comments/Corrections**
47.	Sharps and/or broken glass are stored and/or disposed of properly.			
48.	All waste containers are labeled properly (i.e. non-hazardous vs. hazardous waste).			
49.	All chemical waste containers are kept closed.			
50.	Full waste containers are being delivered to IUEHS or picked up.			
51.	All liquid waste is being disposed of properly (no drain or evaporation).			
52.	No excessive storage of combustibles (boxes, paper, plastic) in the lab or fume hood.			

LABORATORY SAFETY REVIEW

Indiana University

<u>SAFETY ITEMS</u>	**<u>Location</u>**
Policy Documentation:	
_____Laboratory Safety and Chemical Hygiene Plan	____________________________
_____Hazardous Waste Management Guide	____________________________
_____Spill Response Guide (except for IUPUI)	____________________________
_____Other	____________________________
Information:	
_____Safety Data Sheets	____________________________
_____Other Reference Material	____________________________
Safety Equipment:	
_____Fire Extinguisher(s)	____________________________
_____Emergency Eyewash	____________________________
_____Safety Shower	____________________________
_____Chemical Spill Control Kit	____________________________
_____First Aid Kit	____________________________
_____Fire Alarm & Fire Blanket (if present)	____________________________
_____Emergency Telephones (and phone numbers)	____________________________
_____Personal Protective Equipment (gloves, safety glasses, etc.)	____________________________
_____Fume Hoods	____________________________
_____Other	____________________________
General Safety Items:	
_____Emergency Exits	____________________________
_____Emergency Contacts/Telephone Numbers	____________________________
_____Electrical Panels/Circuit Breakers	____________________________
_____Gas Shut-Off Valves or Emergency Switch	____________________________
_____Other	____________________________

Special Safety Equipment:	**Location**
_____Describe:	____________________________
_____Describe:	____________________________

I have reviewed the location and function of the above safety items:

Signature:________________________________ Date:____________________________

(Please document the successful completion of this training on form LCS-3 *Laboratory Safety Training*.)

Keep this form on file in Appendix A of the *Laboratory Safety and Chemical Hygiene Plan.* <u>Do not</u> return this form to Indiana University Environmental Health and Safety.

APPENDIX A **FORM LCS-3**

LABORATORY SAFETY TRAINING
INDIVIDUAL DOCUMENTATION

Indiana University

Supervisor/PI_____________________________ **Phone** _________________________

Department______________________________ **Building/Room #** _______________

The Occupational Safety and Health Administration (OSHA) under the laboratory safety standard (29 CFR 1910.1450) requires that each laboratory employee be made aware of the location and content of the *Laboratory Safety and Chemical Hygiene Plan*. By signing below, you acknowledge that you have read and understood the contents of this P~~p~~lan and know its location within the laboratory.

The laboratory standard further requires that employees be provided with sufficient safety training which covers the specific topics described in Section 4.0 *Training Requirements* of the *Laboratory Safety and Chemical Hygiene Plan*. This training must be provided prior to the time of the employee's initial assignment and whenever there is a significant change in the types or quantities of chemicals used by the employee.

Training and supervision of laboratory specific procedures are provided by the Principal Investigator, lab supervisor, or others that are qualified and authorized by the PI. This form can also be used to document that or any other training provided in the laboratory.

Type of Training	Name (print clearly)	Date	Provided by

This form should be kept on file in Appendix A of the *Laboratory Safety and Chemical Hygiene Plan.* Do not return this form to Indiana University Environmental Health and Safety.

Laboratory Chemical Personal Protective Equipment Guidance Form

The Occupational Safety and Health Administration (OSHA) requires a personal protective equipment hazard assessment for any tasks that require personal protective equipment (e.g., gloves, safety glasses). Please check all activities that apply to your area. If a task is not listed add a new task at the bottom with the associated hazards and personal protective equipment (PPE). Please complete the hazard assessment for your laboratory and keep it in Appendix A of the *Laboratory Safety and Chemical Hygiene Plan*.

Date:__________ Supervisor/PI:________________________ Assessment by: ______________
Department:______________ Building/Room Number(s): __________________________

Chemical Health Hazards			
Check All That Apply	**Task**	**Potential Hazard**	**Recommended PPE**
☐	Working with small quantities of less toxic hazardous chemicals, dilute aqueous solutions, irritants, or sensitizers (solid or liquid).	Lower risk of potential skin or eye damage, or chronic poisoning.	Safety glasses, light chemically resistant gloves, lab coat, pants, and closed toed shoes.
☐	Working with large quantities of less toxic hazardous chemicals, dilute aqueous solutions, irritants, or sensitizers (solid or liquid).	Higher risk of potential skin or eye damage, or chronic poisoning.	Goggles, light chemically resistant gloves, lab coat, pants, and closed toed shoes.
☐	Working with small quantities moderately toxic hazardous chemicals (solid or liquid).	Lower risk of potential skin or eye damage, and acute or chronic poisoning.	Safety glasses, light chemically resistant gloves, lab coat, pants, and closed toed shoes.
☐	Working with large quantities moderately toxic hazardous chemicals (solid or liquid).	Higher risk of potential skin or eye damage, and acute or chronic poisoning.	Goggles, light chemically resistant gloves, lab coat, pants, and closed toed shoes.
☐	Working with small quantities of acutely toxic chemicals, reproductive toxins, or carcinogens (solid or liquid).	Lower risk of potential skin or eye damage, and acute poisoning.	Safety glasses, appropriate chemically resistant gloves, lab coat, pants and closed toed shoes. Note: Must be handled in a chemical fume hood.
☐	Working with large quantities of acutely toxic chemicals, reproductive toxins, or carcinogens (solid or liquid).	Higher risk of potential skin or eye damage, and acute poisoning.	Safety goggles, appropriate heavy chemically resistant gloves, lab coat, pants or coveralls, and closed toed shoes (and booties if necessary). Note: Must be handled in a chemical fume hood.
Chemical Physical Hazards			
☐	Working with small volumes of organic solvents (< 1 liter).	Lower risk of potential skin or eye damage, poisoning, or fire.	Safety glasses or goggles, light chemically resistant gloves, lab coat, pants, and closed toed shoes.
☐	Working with large volumes of organic solvents (> 1 liter), very dangerous solvents, or work which creates a splash hazard.	Higher risk of potential skin or eye damage, poisoning, or fire.	Safety goggles and face shield, heavy chemically resistant gloves, all-cotton or fire-resistant lab coat, closed shoe, pants, and chemically resistant apron. Note: No synthetic fabric street clothes.
☐	Working with small volumes of corrosive liquids (< 1 liter).	Lower risk of potential skin or eye damage, and/or poisoning.	Safety glasses or goggles, light chemically resistant gloves, lab coat, pants, closed toed shoes.
☐	Working with large volumes of corrosive liquids (> 1 liter), acutely toxic corrosives, or work which creates a splash hazard.	Higher risk eye or skin damage over a large surface area, and/or poisoning	Safety goggles and face shield, heavy chemically resistant gloves, lab coat, pants, closed toed shoe, and chemically resistant apron.
☐	Working with pyrophorics, explosives, or highly reactive chemicals.	Higher risk of skin or eye damage from fire, chemical exposure, uncontrolled reactions, or flying projectiles.	Blast shield, safety goggles, full face shield, chemically resistant gloves, fire-resistant lab coat, chemically resistant apron, pants, and closed toed shoes. Note: No synthetic fabric street clothes.

Check All That Apply	Task	Potential Hazard	Recommended PPE
☐	Working with cryogenic liquids.	Risk of major skin, tissue, or eye damage.	Safety glasses or goggles for large volumes, heavy insulated gloves, lab coat, pants, and closed toed shoes.
☐	Working with very cold equipment or dry ice.	Risk of frostbite by skin or eye contact or hypothermia in a cold environment.	Safety glasses, insulated gloves and warm clothing, lab coat, pants, and closed toed shoes.
☐	Working with hot liquids, equipment, open flames (autoclave, bunsen burner, water bath, oil bath).	Risk of burns resulting in skin or eye damage.	Safety glasses or goggles for large volumes, insulated gloves, lab coat, pants, and closed toed shoe.
☐	Working with chemical dusts.	Risk of skin or eye damage, or respiratory exposure, irritation, or damage.	Safety glasses or goggles, appropriate gloves, lab coat, closed toed shoes or boots if necessary, pants, and approved respiratory protection (call IUEHS).
☐	Working with nuisance dusts.	Risk of skin or eye damage, or respiratory exposure, irritation, or damage.	Safety goggles, appropriate gloves, lab coat, closed toed shoes or boots if necessary, pants, and a NIOSH approved dust mask or other respiratory protection (contact IUEHS).
☐	Chemical spill cleanup.	Risk of skin or eye damage and chemical exposure by any route of entry.	Safety glasses or goggles, appropriate gloves, lab coat, closed toed shoes or boots if necessary, pants, and approved respiratory protection (contact IUEHS).
General Laboratory Hazards			
☐	Glassware washing.	Potential for lacerations or dermatitis.	Rubber gloves, lab coat, pants, and closed toed shoes.
☐	Instrument repair.	Potential for eye damage from foreign objects.	Safety glasses, no loose clothing or jewelry, and hair restrained.
☐	Working with loud equipment, noises, sounds, alarms, or high frequencies, etc.	Potential for ear damage and hearing loss.	Ear plugs or headphones as necessary (>85 dB requires compliance with the Hearing Conservation Program, contact IUEHS)
☐	Metal or woodworking.	Potential eye or skin damage from foreign objects, lacerations, or metal splinters.	Safety glasses or goggles, gloves, and pants. No loose clothing, hair or jewelry.

New Tasks or Other Hazards

Check All That Apply	Task	Potential Hazard	Recommended PPE
☐			
☐			
☐			

Exempted Areas (Use the following space to describe protected lab areas where PPE is not required)

Check All That Apply	Lab Area	Physical Barrier (i.e. wall, curtain, lab bench)	Exemption (eyewear, gloves, etc.)
☐			
☐			
☐			

APPENDIX A

FORM LCS-5

Principal Investigators Chemical Hazard Assessment for Animal Research

Principal Investigator:__________________________Date:________________

Building and Laboratory:________________________Protocol #:____________

	A.	B.	C.	D.	E.		F.	G.	H.	I.
	Chemical Agents	Select Carc-inogen y/n	Repro-ductive Toxin y/n	Chemical Toxicity LD_{50} or LC_{50} mg/kg, ppm, or other unit	Acute Toxicity or Health Hazard Rating NFPA GHS		Novel Substance or Particularly Hazardous Substance y/n	Route(s) of Administration and Dose	Shedding or Excretion % and/or Duration	Other Health Hazards, Chemical Concerns, CAS# or Comments
Ex.	*Isoflurane*	*No*	*No*	*Oral rat 4770 mg/kg*	*0-2*		*No*	*Vapor chamber*	*0.17%*	*CAS# 26675-46-7*
1.										
2.										
3.										
4.										
5.										
6.										
7.										
8.										
9.										
10.										

Column Notes:

A. List all anesthetics, drugs, controlled substances, carcinogens, allergens, intoxicants, reproductive toxins, chemical toxins, and "novel" synthesized experimental drugs, chemicals, or mixtures. For novel substances provide as much information as possible and note the chemical as "novel" on the form.

B. Refer to the list of Select Carcinogens provided in Appendix B, Indiana University *Laboratory Safety and Chemical Hygiene Plan*. (www.ehs.indiana.edu/lab_safety.shtml). The list includes known, probable, or possible carcinogens listed by IARC, NTP, or OSHA.

IARC = International Agency for Research on Cancer (Group 1, 2a, and 2b carcinogens)

NTP = National Toxicology Program

OSHA = Occupational Safety and Health Administration

C. Identify reproductive toxins including both mutagens and teratogens. Refer to the Safety Data Sheet for the specific chemical or preparation being used.

D. Provide the Lethal Dose (LD_{50}) or Lethal Concentration (LC_{50}) and route of entry (oral, skin, inhalation, or "LD_{50} unknown") for "rats" whenever possible. Refer to the Safety Data Sheet for the specific chemical or preparation being used.

E. Provide NFPA Health Hazard rating or GHS rating if possible.

F. Determine if the substance is a new (novel) substance with unknown toxicity or an OSHA "Particularly Hazardous Substance".

OSHA "Particularly Hazardous Substances" include the select carcinogens (human), reproductive toxins, and acutely toxic chemicals (those with an NFPA rating of 3 or 4, or a GHS acutely toxic rating of Category 1 or 2).

Route of Entry	National Fire Protection Association NFPA 704 Health Hazard Classifications		OSHA Hazard Communication Standard (29 CFR 1910.1200) Globally Harmonized System of Chemical Classification GHS Acute Toxicity Ratings	
	4	3	1	2
Oral LD_{50}	0-5 mg/kg	>5-50	0-5 mg/kg	>5-50
Skin Contact LD_{50}	0-40 mg/kg	>40-200	0-50 mg/kg	>50-200
Inhalation LC_{50}	0-1000 ppm	>1000-3000	0-100 ppm	>100-500

"Particularly Hazardous Substances" must be handled with standard laboratory PPE and precautions **plus:**

1. Must be handled in a containment (fume hood or glovebox) if exposed to the air or closed system (instrument plumbing, glassware, cannula, gavage, syringe).
2. Must be posted with a sign designating the area as a location where carcinogens, reproductive toxins or acutely toxic chemicals are present.
3. Must decontaminate area after use.
4. Must have provisions for waste removal (lab waste, animals, and bedding).

G. Route of administration planned in Animal Use Protocol. Include inhalation, ingestion, skin contact, and injection as lab prepared food, premixed food, in water, nose, anesthetic chamber, syringe, gavage, etc.

F. Provide any information known about the potential for shedding or excretion of the substance in urine, feces, or vomit into the animal bedding as the administered chemical or as a metabolite. If unknown, state "probable," "unlikely," "inconclusive," or "unknown" to describe the potential.

G. Provide any other health or physical hazard associated with the substance such as corrosivity, reactivity, flammability, explosively, or any other property.

ANIMAL FACILITY SAFETY INFORMATION (IUB Only)

Protocol(s) Number: #______________________ Building/Department:__________________
PI/Supervisor:_____________________________ Phone:_____________________________
Office Room #:____________________________ Lab Room #: _________________________
Alternate Contact:__________________________ Phone:_____________________________

Laboratory Animal Resources Phone: 855-2356
Environmental Health and Safety Phone: 855-6311
IU Police Department Phone: **911** or 855-4111(non-emergencies)

Minimum Required PPE:____

BIOLOGICAL HAZARDS:

Animal Biosafety Level ☐ ABSL 1 ☐ ABSL 2 ☐ ABSL 3
☐ Infectious Agent or Toxin Identity: ______________________________________

Biological Hazard Special Instructions

Animal Room: ____
Hallways/elevators:____
Required Enhanced PPE (in addition to minimum): ____________________________
☐ Hair Cover ☐ Safety Glasses ☐ Splash Goggles ☐ Surgical Mask
☐ N-95 ☐ N-100 ☐ Respirator with____________________Cartridge ☐ Other __________

CHEMICAL HAZARDS:

☐ Human Carcinogens Chemical Name(s):____________________________________
☐ Reproductive Toxins Chemical Name(s): ____________________________________
☐ Acutely Toxic Chemicals Chemical Name(s):____________________________________
☐ Other (Novel Substances or Experimental Chemicals): _________________________

Chemical Hazard Special Instructions

Animal Room: ____
Hallways/elevators:____
Required Enhanced PPE (in addition to minimum): ____________________________
☐ Hair Cover ☐ Safety Glasses ☐ Splash Goggles ☐ Surgical Mask
☐ N-95 ☐ N-100 ☐ Respirator with____________________Cartridge ☐ Other __________
☐ Other Instructions for use of PPE:____

OTHER SPECIAL INSTRUCTIONS:

☐ Occupational Health Requirements/Vaccinations: ______________________________
☐ Entry/Exit Procedures: ____

WASTE STREAM:

☐ Sanitary Waste ☐ Autoclave then Sanitary (Biological Hazards Only) ☐ Medical Incineration

Chemical Reaction Hazard Assessment Form   Reaction number:

New experiment? (circle one) Yes / No

Assessment applies from lab book page: through page: (Complete a new assessment for each new reaction)

Standard protocol followed? (please give reference)

Write your reaction here including work-up and purification method (*e.g.* chromatography). Use the form below to assess hazards for ALL associated reactions and process conditions (*e.g.* heating, cooling, vacuum), specify hazards (*e.g.,* exothermic, gas evolution, flooding, asphyxiation, burns - hot or cold, explosion), quench procedures, waste disposal procedures as well as the chemicals to be used, including your expected product, solvents, and known by-products. **Note:** Synthesis of reactive or energetic compounds may not exceeed 100 mg and the PI's supervision and written approval (signature) is required.

Reactants						Route of Exposure				Chemical Hazard										
Compound	Formula Weight:	Density:	Quantity:	Moles or millimoles:	Equivalents:	Skin or eye contact:	Inhalation:	Ingestion:	Injection (needle, scalpel, glass):	Carcinogen, mutagen or teratogen:	Highly toxic or toxic:	Irritant or sensitizer:	Explosive:	Pyrophoric (water or air):	Highly flammable or flammable:	Oxidizer:	Corrosive:	Lachrymator:	Other (specify):

Reaction conditions and processes (heat, cool, pressure, vacuum, etc.) and potential hazards (fire, explosion, spill, etc.)

Will reaction proceed unattended? (circle one) Yes / No   If so, (PI approval is required) PI initials:

Hazard Control Measures					
	Administrative controls (check all that apply)		Controlled access:	Restricted access:	No visitors:
	Engineering controls (check all that apply)		Fume hood:	Blast Shield:	Other:
	Personal protective equipment: (check all that apply)	Eye Protection	Glasses:	Goggles:	Other:
		Hand Protection	Nitrile:	Latex:	Other:
		Skin Protection	Lab Coat:	Flame resistant:	Apron:
		Foot Protection	Leather Shoes:	Boots:	Other:
		Respiratory Protection	None:	Respirator:	Other:

Are specific emergency response procedures necessary for this experiment? (circle one) Yes / No   If yes, give details:

Reaction and/or reagent quench:
(give quench type and possible hazard)

Waste disposal (check all that apply)	Hydrocarbon waste:	Halogenated waste:	Silica waste:	Toxic:
	Biological waste:	Radioactive waste:	Heavy metals:	Other (specify):

Signature: Date:

PI/Supervisor signature: Date:

APPENDIX A

Laboratory Close-Out Checklist

PLEASE CHECK REFRIGERATORS, FREEZERS, FUME HOODS, BENCH TOPS, STORAGE CABINETS, CLOSET SPACES, AND SHARED STORAGE AREAS FOR WASTE AND HAZARDOUS MATERIALS.		
PRELIMINARY INSPECTION AND CONSULTATION		
FOR QUESTIONS OR ASSISTANCE CONTACT THE LAB SAFETY CONTACT FOR YOUR RESPECTIVE CAMPUS		**Date Completed**
At least ***one month prior*** to close-out contact the following offices to request a preliminary consultation and inspection to determine the necessary steps to take prior to cleaning out the laboratory.		
Contact the Radiation Safety Office first to clear the area of radiological hazards		
Contact the Biosafety Office second to clear the area of biological hazards		
Contact the Waste Management Program third for instructions and assistance, if necessary, removing chemicals from the laboratory		
Contact the Laboratory Safety Program last to ensure the area is clear of chemicals and chemical hazards		
CHEMICALS (SOLIDS, LIQUIDS, GASES)		
CHEMICALS:		
•	Checked laboratory and all shared rooms for chemical materials/waste.	
•	Identified any usable materials to be moved or transferred.	
•	Followed procedures in the Hazardous Materials Transportation Program for materials to be moved.	
•	Label all containers (bottles, beakers, flasks, test tubes, vials, etc.) with the chemical contents (use the full chemical name(s)).	
•	Close all containers securely to prevent leaks or spills.	
•	Segregate incompatible materials.	
•	Store flammable liquid containers in flammable storage cabinets until removal.	
•	If transferring chemicals to another lab, prepare inventory and move chemicals to: (Name)____________________________(Location)____________________________	
•	If transporting chemicals to another institution, prepare inventory, inform department chair/dean that inventory will be transported to a facility outside IU. (Packaging of the containers, shipment, and documentation must be in accordance with Department of Transportation regulations.)	

COMPRESSED GASES:		
•	Identified compressed gas cylinders and ensured they are labeled.	
•	Removed pressure regulators on cylinders and replaced protective valve caps.	
•	Return cylinders to the gas supplier or Chemistry Stockroom. (Do not leave in lab.)	
CONTROLLED SUBSTANCES:		
•	Contact IUEHS for guidance terminating the registration and disposition of remaining substances.	
•	Notify the State Board of Pharmacy and DEA of termination, or transfer of registration, or relocation of inventory. DO NOT move inventory anywhere without notifying and receiving permission from the State Board of Pharmacy and the DEA.	
FUME HOODS, EQUIPMENT, LAB FURNITURE, GENERAL SAFETY/SECURITY:		
•	Decontaminate fume hoods, bench tops, shelves, and equipment or furniture to be left in lab.	
•	Contact IUEHS ~~Laboratory Safety and Chemical Hygiene Office~~ for information regarding contaminated equipment.	
•	Decontaminate and mark all fume hoods, bench tops, shelves, and equipment or furniture to be left in lab. Equipment shall have chemicals safely removed, drained or discharged from the equipment. Biological materials shall be removed from the equipment. Clean all surfaces with warm soapy water. Disinfect surfaces that may be contaminated with biological agents by cleaning with a bleach and water solution consisting of one part of bleach to ten (1:10) parts of water. As a final step, wipe equipment down with a 70% alcohol solution is recommended.	
•	Arrange for transfer of ownership of equipment to remain with the Principal Investigator.	
•	Arrange for transfer of ownership and removal of clean equipment to remain or be transferred to surplus.	
•	Arrange for removal of unwanted, broken, or obsolete equipment. Notified IUEHS of any transformers, capacitors, mercury switches, thermometers, or radioactive sources removed prior to disposal.	
•	Check all shared areas, freezers, incubators, and cold rooms for hazardous materials/waste.	
•	Return computers, peripherals, software, data disks to chair/dean or facility manager.	
•	Return keys to departmental business office or facility manager.	
HAZARDOUS WASTE:		
•	Identify and label all waste containers (bottles, beakers, flasks, test tubes, vials, etc.) with the chemical contents (use the full chemical name(s)).	
•	Dispose of hazardous waste through the IUEHS laboratory waste disposal service on your campus (see Laboratory Safety Contacts).	
•	Collect and containerize all sharps, needles, razor blades, surgical blades, and glass for disposal in accordance with the IU Waste Management Program.	

•	Contact IUEHS Environmental Management to request bulk removal of chemicals and waste prior to final inspection.	
	<u>FINAL CLEARANCE INSPECTION</u>	
•	Contact IUEHS Laboratory Safety Program to request a final Clearance Inspection prior to custodial cleaning, maintenance or renovations.	

I certify that I have followed proper procedures established for the transfer or disposal of hazardous materials from my laboratory and for the proper decontamination and/or decommissioning of all equipment in my laboratory that was used to store or process hazardous materials:

NAME:______________________________SIGNATURE:___________________________DATE: ___________________________________

APPENDIX B – REFERENCES

SELECT CARCINOGENS

The Occupational Safety and Health Administration (OSHA) defines a “select carcinogen” as a substance that meets one of the following criteria:

1. Is regulated by OSHA as a carcinogen;
2. Is listed under the category “known to be a carcinogen” or “reasonably anticipated to be a carcinogen” in the Annual Report on Carcinogens published by the National Toxicology Program (NTP); or
3. Is listed under Group 1 (“carcinogenic to humans”) or under Group 2A (‘probably carcinogenic to humans”) or 2B (“possibly carcinogenic to humans”) by the International Agency for Research on Cancer (IARC).

This list includes other potential carcinogens including processes with hazardous byproducts which are typically not present in laboratories at Indiana University but may be used or generated during experimental procedures.

SUBSTANCE	OSHA	IARC	NTP
A-α-C (2-amino-9*h*-pyrido [2,3-*b*] indole)			x
Acetaldehyde		x	x
Acetamide		x	
2-Acetylaminofluorene		x	
x			
Acrylamide		x	x
Acrylonitrile	x	x	x
Actinolite	x		
Adriamycin		x	x
AF-2 [2-(2-furyl)-3-(5-nitro-2-furyl) acrylamide]		x	
Aflatoxins (naturally ocurring)		x	x
Aflotoxins M1		x	
2-Aminoanthraquinone			x
p-Aminoazobenzene		x	
o-Aminoazotoluene		x	x
4-Aminobiphenyl	x	x	
x			
1-Amino-2,4-dibromoanthraquinone			x
2-Amino-3,4-dimethylimidazo[4,5-*f*]quinoline (MEIQ)			x
2-Amino-3,8-dimethylimidazo[4,5-*f*]quinoxaline (MEIQx)			x
1-Amino-2-methylanthraquinone			x
2-Amino-3-methylimidazo [4,5-*f*]quinoline (IQ)			x
2-Amino-1-methyl-6-phenylimidazo[4,5-*b*]pyridine (PhIP)		x	x
2-Amino-5-(5-nitro-2-furyl)-1,3,4-thiadiazole		x	
Amitrole			
x			
Amsacrine		x	
Androgenic (anabolic) steroids		x	
o-Anisidine		x	
o-Anisidine hydrochloride			x

SUBSTANCE	OSHA	IARC	NTP
Anthraquinone			x
Antimony trioxide		x	
Aramite®		x	
Aristolochic acids (naturally occurring mixtures of)		x	x
Arsenic and inorganic arsenic compounds	x	x	x
Arsenobetaine and other organic arsenic compounds			x
Asbestos (all forms)	x	x	x
Auramine		x	
Azacitidine		x	x
Azaserine		x	
Azathioprine		x	x
Aziridine (dimethyleneimine)		x	
Basic Red 9 monohydrochloride			x
Benzene	x	x	x
Benzidine, benzidine based dyes, and dyes metabolized to benzidine	x	x	x
Benzo[*a*]anthracene		x	x
Benzo[j]ancanthrylene		x	
Benzo[*b*]fluoranthene		x	x
Benzo[*j*]fluoranthene		x	x
Benzo[*k*]fluoranthene		x	x
Benzofuran		x	
Benzo[c]phenanthrene		x	
Benzophenone		x	
Benzo[*a*]pyrene		x	x
Benzotrichloride			x
Benzyl violet 4B		x	
Beryllium and beryllium compounds		x	x
Betel quid with and without tobacco		x	
N,N-Bis(2-cloroethyl)-2-naphthylamine (Chlornaphazine)		x	
Bischloroethyl nitrosourea		x	x
Bleomycins		x	
Bracken fern		x	
Bromochloroacetic acid		x	
Bromodichloromethane		x	x
2,2-bis-(Bromomethyl)-1,3-propanediol		x	x
Busulfan		x	
1,3-Butadiene		x	x
1,4-Butanediol dimethyl-sulfonate (Myleran)		x	x
Butylated hydroxyanisole (BHA)		x	x
β-Butyrolactone		x	
Cadmium and cadmium compounds	x	x	x
Caffeic acid		x	
Captafol		x	x
Carbazole		x	
Carbon black		x	
Carbon tetrachloride		x	x
Catechol			x
Ceramic fibers (respirable size)		x	x

APPENDIX B

SUBSTANCE	OSHA	IARC	NTP
Chloral		x	
Chloral hydrate		x	
Chlorambucil		x	x
Chloramphenicol		x	x
Chlordane		x	
Chlordecone (Kepone)		x	
Chlorendic acid		x	x
Chlorinated paraffins (C_{12}, 60% Chlorine)			x
α-Chlorinated toluenes (benzyl chloride, benzalchloride, benzotrichloride)		x	x
Chlornaphazine		x	
p-Chloroaniline		x	
3-Chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone		x	
1-(2-Chloroethyl)-3-cyclohexyl-1-nitrosourea (CCNU)		x	x
1,(2-Chloroethyl) -3- (4 methylcyclohexyl)-1-nitrosourea (MECCNU)		x	x
bis-Chloroethyl nitrosourea			x
Chloroform		x	x
bis-Chloromethyl ether (Dimethyl-1,1'-dichloro ether)	x	x	x
Chloromethyl methyl ether (Methyl chloromethyl ether)	x		x
1-Chloro-2-methylpropene			x
3-Chloro-2-methylpropene			x
Chlorophenoxy herbicides			x
4-Chloro-*o*-phenylenediamine		x	x
Cloroprene		x	x
p-Chloro-o-toluidine and p-chloro-o-toluidine hydrochloride			x
Chlorothalonil		x	
Chlorozotocin		x	x
Chromium, metallic and chromium [VI] compounds		x	x
Chrysene		x	
CI Acid Red 114 (see 3,3 dimethylbenzidine)		x	x
CI Direct Black 38 (see benzidine)			x
CI Basic Red 9 monohydrochloride		x	
CI Direct Blue 6 (see benzidine)			x
CI Direct Blue 15 (see 3,3 dimethoxybenzidine)		x	x
CI Direct brown 95 (see benzidine)			x
Ciclosporin		x	
Cisplatin		x	x
Citrus red no. 2		x	
Coal tars and coal tar pitches		x	x
Cobalt and cobalt compounds		x	x
Cobalt metal with tungsten carbide		x	x
Cobalt metal without tungsten carbide		x	
Cobalt sulfate			x
Cobalt-tungsten carbide (powders and hard metals)			x
p-Cresidine		x	x
Cumene		x	
Cupferron			x
Cycasin		x	
Cyclopenta[cd]pyrene		x	
Cyclophosphamide		x	x

APPENDIX B

Cyclosporin A (ciclosporin)		x
Dacarbazine	x	x
Danthron (chrysazin 1,8-dihydroxyanthraquinone)	x	x
Daunomycin	x	

APPENDIX B

SUBSTANCE	OSHA	IARC	NTP
N,N'-Diacetylbenzidine		x	
2,4-Diaminoanisole		x	
2,4-Diaminoanisole sulfate			x
4,4'-Diaminodiphenyl ether		x	
2,4-Diaminotoluene		x	x
Dibenz[*a,h*]acridine		x	x
Dibenz[*a,j*]acridine		x	x
Dibenz[*c,h*]acridine		x	
Dibenz[*a,h*]anthracene		x	x
7*h*-Dibenzo[*c,g*]carbazole		x	x
Dibenzo[*a,e*]pryrene		x	x
Dibenzo[*a,h*]pyrene		x	x
Dibenzo[*a,i*]pyrene		x	x
Dibenzo[*a,l*]pyrene		x	x
Dibromoacetic acid		x	
Dibromoacetonitrile		x	
Diazoaminobenzene (DAAB)		x	
1,2-Dibromo-3-chloropropane	x	x	x
1,2-Dibromoethane (Ethylene dibromide)			x
2,3-Dibromo-1-propanol		x	x
tris (2,3-Dibromopropyl) phosphate			x
Dichloroacetic acid		x	
1,4-Dichlorobenzene			x
p-Dichlorobenzene	x	x	
3,3'-Dichlorobenzidine	x	x	x
3,3'-Dichlorobenzidine dihydrochloride			x
3,3'-Dichloro-4,4^{1}-diaminodiphenyl ether		x	
Dichlorodiphenyltrichloroethane (DDT)		x	x
1,2-Dichloroethane (Ethylene dichloride)		x	x
Dichloromethane (Methylene chloride)	x	x	x
1,3-Dichloro-2-propanol		x	
1,2 Dichloropropane		x	
1,3-Dichloropropene		x	x
Dichlorvos		x	
Diepoxybutane			x
Diesel fuel, marine		x	
Diethanolamine		x	
Di(2-Ethylhexyl)phthalate		x	x
1,2 Diethylhydrazine		x	
Diethylstilbestrol		x	x
Diethyl sulfate		x	x
Diisopropyl sulfate		x	
Diglycidyl resorcinol ether		x	x
Digoxin		x	
Dihydrosafrole		x	
3,3'-Dimethoxybenzidine (*o*-dianisidine) & dyes metabolized to 3,3 dimethoxybenzidine		x	x
4-Dimethylaminoazobenzene	x		x

APPENDIX B

SUBSTANCE	OSHA	IARC	NTP
p-Dimethylaminoazobenzene		x	
trans-2-[(Dimethylamino)methylamino] -5- 2-(5-nitro-2-furyl)-vinyl]-1,3,4-oxidiazole		x	
2,6-Dimethylaniline (2,6-Xylidine)		x	
Dimethylarsenic acid		x	
3,3'-Dimethylbenzidine (*o*-tolidine) & dyes metabilized to 3,3'-dimethylbenzidine		x	x
Dimethylcarbamoyl chloride		x	x
1,1-Dimethylhydrazine		x	x
1,2-Dimethylhydrazine		x	
Dimethylstilbestrol			x
Dimethyl sulfate		x	x
Dimethylvinyl chloride			x
3,7-Dinitrofluoranthene		x	
3,9-Dinitrofluoranthene		x	
1,3-Dinitropyrene		x	
1,6-Dinitropyrene		x	x
1,8-Dinitropyrene		x	x
2,4-Dintrotoluene		x	
2,6-Dintrotoluene		x	
1,4-Dioxane		x	x
Disperse Blue 1		x	x
Dyes metabolized to 3,3'-Dimethoxybenzidine		x	x
Dyes metabolized to 3,3'-Dimethylbenzidine		x	x
Dyes metabolized to benzidine		x	x
Epichlorohydrin		x	x
1,2 Epoxybutane		x	
Erionite		x	x
Estrogens, nonsteroidal		x	
Estrogens, steroidal		x	x
Ethyl acrylate		x	
Ethylbenzene		x	
Ethylene dibromide		x	
Ethyleneimine		x	
N-ethyl-N-nitrosourea		x	
Ethylene oxide	x	x	x
Ethylene thiourea			x
di(2-Ethylhexyl) phthalate			x
Ethyl methanesulfonate		x	x
Etoposide		x	
Formaldehyde (gas)	x	x	x
2-(2-Formylhydrazino)-4-(5-nitro-2-furly) thiazole		x	
Fumonisin B1		x	
Furan		x	x
Fusarium moniliforme, toxins derived from (fumonisin B1, fumonisin B2, and fusarin C)		x	
Galium arsenide		x	
Gasoline		x	
Glass wool (respirable size)			x

APPENDIX B

SUBSTANCE	OSHA	IARC	NTP
Glu-P-2 (2-aminodipyrido[1,2-a:3',2'-*d*]imidazole		x	
Glu-P-1 (2-amino-6-methyldipyrido-1,2-a:3',2'-*d*]imidazole)		x	
Glycidaldehyde		x	
Glycidol		x	x
Griseofulvin		x	
HC Blue No. 1		x	
Heptachlor		x	
Hexachlorobenzene		x	x
Hexachlorocyclohexanes		x	
Hexachloroethane		x	x
2,4-Hexadienal		x	
Hexamethyl-phosphoramide		x	x
Hydrazine and hydrazine sulfate		x	x
Hydrazobenzene		x	
Hydrochlorothiazide		x	
1-Hydroxyanthraquinone		x	
Indeno [1,2,3-*cd*] pyrene		x	x
Indium phosphide		x	
Iron dextran complex		x	x
IQ (2-amino-3-methylimidazo[4,5-*f*]quinoline		x	
Isoprene		x	x
Kepone (Chlordecone)			x
Lasiocarpine		x	
Lead and lead compounds, inorganic		x	x
Lindane and other hexachlorocyclohexane isomers			x
Magenta (containing CI Basic red 9)		x	
MeA-aplha-c (2-amino-3-methyl-9*h*-pyrido-[2,3-*b*] indole		x	
Medroxyprogesterone acetate		x	
MeIQ (2-amino-3,4-dimethylimidazo [4,5-*f*] Quinoline)		x	
MeIQx (2-amino-3,8-dimethylimidazo[4,5-*f*] quinoxaline)		x	
Melphalan		x	x
Merphalan		x	
Methoxsalen with ultraviolet A therapy (PUVA)		x	x
5-Methoxypsoralen (methoxsalen)		x	
8-Methoxypsoralen (methoxsalen)		x	
Methylarsenic acid		x	
2- Methylaziridine (propyleneimine)		x	x
Methylazoxymethanol acetate		x	
5-Methylchrysene		x	x
Methyl chloromethyl ether		x	x
4,4'-Methylenebis (2-chloroaniline) (MOCA)		x	x
4,4'-Methylenebis (*N,N*-dimethylbenzenamine)		x	x
4,4'-Methylenebis (2-methylaniline)		x	
Methylene chloride (dicholoromethane)	x	x	x
Methylenedianiline	x		
4,4'-Methylenedianiline and its dihydrochloride salt		x	x
Methyleugenol			x
Methyl chloromethyl ether (Chloromethyl methyl ether)	x	x	x
2-Methylimidazole		x	

APPENDIX B

SUBSTANCE	OSHA	IARC	NTP
4-Methylimidazole		x	
Methylisobutyl keytone		x	
Methylmercury compounds		x	
Methyl methanesulfonate		x	x
2-Methyl-1-nitroanthraquinone		x	
N-Methyl-*N'*-nitro-*N*-nitrosoguanidine (MNNG)		x	x
N-Methyl-*N*-nitrosourea		x	
N-methyl-*N'*-nitrosourethane		x	
a-Methylstyrene		x	
Methylthiouracil		x	
Metronidazole		x	x
Michler's base (4,4'-methylenebis(N,N-dimethyl)-benzenamine)		x	x
Michler's ketone (4,4'-(Dimethylamino)benzophenone)			x
Microcystin-LR		x	
Mirex		x	x
Mitomycin C		x	
Mitoxantrone		x	
3-Monochloro-1,2-propanediol		x	
Monocrotaline		x	
MOPP and other combined chemotherapy including alkylating agents		x	
5-Morpholinomethyl)-3-[(5-nitrofurfurylidene)amino-] 2-oxazolidinone		x	
Mustard gas		x	x
Nafenopin		x	
Napthalene		x	x
α-Naphthylamine	x		
β-Naphthylamine	x		
2-Naphthylamine		x	x
Nickel and nickel compounds		x	x
Niridazole		x	
Nitrilotriacetic acid		x	x
5-Nitroacenaphthene		x	
2-Nitroanisole		x	
o-Nitroanisole			x
Nitroarenes (selected)		x	x
Nitrobenzene		x	x
3-Nitrobenzanthrone		x	
4-Nitrobiphenyl	x		
6- Nitrochrysene		x	x
Nitrofen (2,4-Dichlorophenyl-*p*-nitrophenyl ether)		x	x
2-Nitrofluorene		x	
1-[(5-Nitrofurfurylidene)amino]-2-imidazolidinone		x	
N-[4-(5-Nitro-2-furyl)-2-thiazolyl] acetamide		x	
Nitrogen mustard		x	
Nitrogen mustard hydrochloride			x
Nitrogen mustard N-oxide		x	
Nitromethane		x	x
2-Nitropropane		x	x

APPENDIX B

SUBSTANCE	OSHA	IARC	NTP
1-Nitropyrene		x	x
4-Nitropyrene		x	x
N-Nitrosodi-*n*-butylamine		x	x
N-Nitrosodiethanolamine		x	x
N-Nitrosodiethylamine		x	x
N-Nitrosodimethylamine	x	x	x
N-Nitrosodi-*n*-propylamine		x	x
N-Nitroso-*N*-ethylurea			x
3-(*N*-Nitrosomethylamino) propionitrile		x	
4-(*N*-Nitrosomethyl-amino)-1(3-pyridyl)-1-butanone (NNK)		x	x
N-Nitrosomethylethylamine		x	
N-Nitroso-*N*-methylurea			x
N-Nitrosomethylvinylamine		x	x
N-Nitrosomorpholine		x	x
N-Nitrosonornicotine (NNN)		x	x
N-Nitrosopiperdine		x	x
N-Nitrosopyrrolidine		x	x
N-Nitrososarcosine		x	x
O-Nitrotoluene (2-nitrotoluene)		x	x
Norethisterone			x
Ochratoxin A		x	x
Oestrogens, nonsteriodal		x	
Oestrogens, steroidal		x	
Oil orange SS		x	
Oral contraceptives, combined		x	
Oral contraceptives, sequential		x	
Oxazepam		x	
4,4'-Oxydianiline			x
Oxymetholone			x
Palygorskite (attapulgite)		x	
Panfuran S (containing dihydroxmethyl-Furatrizine)		x	
2,3,4,7,8-Pentachlorodibenzofuran		x	
3,4,5,3',4'-Pentachlorobiphenyl (PCB-126)		x	
Pentosan polysulfate sodium		x	
Perfluorooctanoic acid		x	
Phenacetin and analgesic mixtures containing phenacetin		x	x
Phenazopyridine hydrochloride		x	x
Phenobarbital		x	
Phenolphthalein		x	x
Phenoxybenzamine hydrochloride		x	x
Phenyl glycidyl ether		x	
Phenytoin		x	x
Phosphorus–32		x	
Pioglitazone		x	
Plutonium-239		x	
Polybrominated biphenyls (PBBs)		x	x
Polychlorinated biphenyls (PCBs)		x	x
Polychlorophenols and their sodium salts		x	
Ponceau MX		x	

APPENDIX B

SUBSTANCE	OSHA	IARC	NTP
Ponceau 3R		x	
Potassium bromate		x	
Primidone		x	
Procarbazine and procarbazine hydrochloride		x	x
Proflavine salts		x	
Progesterone			x
Progestins		x	
1,3-Propane sultone		x	x
β-Propiolactone	x	x	x
Propylene oxide		x	x
Propylthiouracil		x	x
Pulegone		x	
Radioiodines		x	
Radionuclides (alpha & beta emitting)		x	
Radium-224, 226, 228		x	
Radon-222		x	
Reserpine			x
Riddelliine		x	x
Safrole		x	x
Selenium sulfid			x
Semustine [1-(2-Chloroethyl)-3-(4-methylcyclohexyl)-1-nitrosourea, Methyl-CCNU]		x	
Silca, crystalline (respirable size)		x	x
Sodium-*o*-phenylphenate		x	
Sterigmatocystin		x	
Streptozotocin		x	x
Styrene		x	x
Styrene-7,8-oxide		x	x
Sulfallate		x	x
Sulfasalazine		x	
Sulfur mustard		x	
Talc (containing asbestiform fibers)		x	
Tamoxifen		x	x
Teniposide		x	
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)		x	x
1,1,1,2-Tetrachloroethane		x	
1,1,2,2-Tetrachloroethane		x	
Tetrachloroethylene (Perchloroethylene)		x	x
Tetrafluoroethylene		x	x
Tetranitromethane		x	x
Thioacetamide		x	x
4,4'-Thiodianiline		x	x
Thiotepa		x	x
Thiouracil		x	
Thiourea			x
Thorium-232 & decay products		x	
Thorium dioxide		x	
Titanium dioxide		x	
Toluene diisocyanate		x	x

APPENDIX B

SUBSTANCE	OSHA	IARC	NTP
o-Toluidine and *o*-toluidine hydrochloride		x	x
Toxaphene			x
Tresulfan (treosulfan)		x	
Triamterene		x	
Trichloroacetic acid		x	
Trichloroethylene		x	x
Trichloromethine (trimustine hydrochloride)		x	
2,4,6-Trichlorophenol			x
1,2,3-Trichloropropane		x	x
tris (1-aziridinyl) phosphine sulfide (thiotepa)		x	x
tris (2,3-dibromopropyl) phosphate		x	x
TRP-P-1 (3-amino-1,4-dimethyl-5*h*-pyrido [4,3-*b*] indole)		x	
TRP-P-2 (3-amino-1-methyl-5*h*-pyrido [4,3-*b*] indole)		x	
Trypan blue		x	
Uracil mustard		x	
Urethane		x	x
Vanadium pentoxide		x	
Vinyl acetate		x	
Vinyl bromide		x	x
Vinyl chloride (Chloroethylene)	x	x	x
4-Vinylcyclohexene		x	
4-Vinylcyclohexene diepoxide		x	
4-Vinyl-1-cyclohexene diepoxide			x
Vinyl fluoride		x	x
Zalcitabine		x	
Zidovudine (AZT)		x	

APPENDIX B

SUBSTANCE	OSHA	IARC	NTP
Mixtures, processes, biological agents and other materials:			
Acid mists, strong inorganic		x	
Alcoholic beverages		x	
Aluminum production		x	
Analgesic mixtures containing phenacetin		x	
Areca nut		x	
Betal quid (betal leaf mixture)		x	
Biomass fuel (primarily wood), indoor emissions from household combustion		x	
Bitumens		x	
BK Polyomavirus (BKV)		x	
Carrageenan, degraded		x	
Carbon electode manufacture		x	
Chlorinated paraffins of average carbon chain length C_{12} and approximately 60% chlorination		x	
Clonorchis sinensis (infection with)		x	
Coal gasification		x	
Coal tars and coal tar pitches		x	x
Coal tar distillation		x	
Coke oven emissions	x		x
Creosotes		x	
Diesel engine exhaust		x	
Diesel exhaust particulates			x
Engine exhaust, gasoline		x	
Epstien-Barr virus		x	x
Fission products, including strontium-90		x	
Frying, emissions from high temperatures		x	
Fuel oils, residual (heavy)		x	
Gamma radiation and X-radiation		x	x
Glass manufacturing (art glass, containers, pressed ware)		x	
Helicobacter pylori (infection with)		x	
Hematite mining (underground)		x	
Hepatitis B virus		x	x
Hepatitis C virus		x	x
Human immunodeficiency virus type 1 (infection with)		x	x
Human immunodeficiency virus type 2 (infection with)		x	
Human papillomavirus (types 16, 18, 31, 33, 35, 39, 45, 51, 52, 58, 59)		x	x
Human papillomavirus (types 26, 53, 66, 67, 70, 73, 82)		x	
Human papillomavirus (types 30, 34, 68, 69, 85, 97)		x	
Human papillomavirus (types 5, 8 in patients with epidermodysplasia verruciformis)		x	
Human papillomaviruses: some genital-mucosal types		x	x
Human T-cell lymphotropic virus (type 1)		x	x
Ionizing radiation		x	x
Isopropyl alcohol manufacture using strong acids		x	
JC Polyomavirus (JCV)		x	
Kaposi sarcoma herpes virus		x	x
Leather dust		x	
Magnetic Fields (extremely low frequency)		x	

APPENDIX B

SUBSTANCE	OSHA	IARC	NTP
Mixtures, processes, biological agents and other materials:			
Maté, hot (Yerba)		x	
Merkel cell polyomavirus (MCV)		x	x
Mineral oils, untreated and mildly treated		x	x
Neutrons		x	
Nitrate or nitrite (ingested) under conditions that result in endogenous nitrosation		x	
Non-arsenical insecticides (spraying and application)		x	
Opisthorchis viverini (infection with)		x	
Petroleum refining (occupational exposures in)		x	
Plasmodium falciparum (malaria)		x	
Polybrominated biphenyls (PBBs)		x	
Polychlorinated biphenyls (PCBs)		x	
Radiofrequency electromagnetic fields		x	
Radionuclides (alpha & beta emitting)		x	
Refractory ceramic fibres		x	
Schistosoma haematobium (infection with)		x	
Schistosoma japonicum (infection with)		x	
Shale-oils		x	
Solar radiation (and sunlamps)		x	
Soots			x
Special purpose fibres such as E-glass and ‘475’glass fibres		x	
Strong inorganic acid mists containing sulfuric acid			x
Tobacco smoke, environmental tobacco smoke, & smokeless tobacco		x	x
Toxaphene (chlorinated camphenes)		x	
Toxins derived from *fusarium moniliforme*		x	
Ultraviolet radiation (broad spectrum)	x	x	x
Ultraviolet radiation A, B, & C		x	x
Welding fumes		x	
Wood Dust		x	x

APPENDIX B

REPRODUCTIVE TOXINS[1]

Drugs and Environmental Chemicals

Acetaldehyde
Acetonitrile
Acrolein
Aminopterin
Androgenic hormones
Arsenic (elemental/organic)
Benzene
Benzo(*a*)pyrene
Boric acid
Busulfan
tert-Butly alcohol
Cadmium
Calcium arsenate
Carbon Disulfide
Chlorobiphenyls
Chloroform
Coumarin anticoagulants
Cyclophosphamide
DDT
Dibenzofuran
Diethylstilbestrol
Dimethyl mercury
Dinitrogen pentoxide
Diphenylhydantoin
Ethidium Bromide
Ethylene glycol
Ethylene oxide
Ethylene dibromide
Ethyl methane sulfonate
Etretinate
5-Fluorouracil
Glycol ether
Hydrazine
Isocyanate, Methyl-
Lead compounds
Lithium
Methotrexate
Methylaminopterin
Methylene chloride
Methylmercury
Mercury, organic
Penicillamine
Phthalate, dubutyl-
Perchloroethylene
Polychlorinated biphenyls
13-cis-Retionic acid (Isotretinoin and Accutane)
Tetracyclines
Thalidomide
Toluene
Trimethadoine
Valproic acid
Vinyl chloride
Xylene, *o-, m-, p-*
Zinc sulfate

Infectious Agents

Cytomegalovirus (CVM)
Parvovirus B-19
Rubella virus
Syphilis
Toxoplasmosis

Varicella virus
Venezuelan equine encephalitis virus

Radiation

Ionizing radiation

[1]References: Shepard, T.H., *Catalog of Teratogenic Agents*, 8th eds. Baltimore: John Hopkins University Press, 1995.

Jankovic, J. and Drake, F., A screening method for occupational reproductive health risk, *American Industrial Hygiene Association Journal*, 57:641-649, 1996.

ACUTELY TOXIC CHEMICALS

EXAMPLES	Physical State (@ 20°C)	IDLH[1] (ppm)	LD_{50}[2] (mg/kg)	LC_{50}[3] (ppm)
Acrolein	liquid	2	46	
Arsine	gas	3		390 mg/m^3
Chlorine	gas	10		299
Chlorine trifluoride	gas	20		299
Cisplatin	solid	4 mg/m^3	26	
Diazomethane	gas	2		175
Diborane	gas	15		40
Dieldrin	solid	0.25 mg/m^3	38	
Dinitro-o-cresol	solid	5 mg/m^3	7	
Fluorine	gas	25		185
Hydrogen cyanide	gas	50		160
Hydrogen fluoride	gas/liquid	30		1276
Mercury (organo) alkyl compounds	liquid	2 mg/m^3	51	258 mg/m^3
Methyl hydrazine	liquid	20 ppm	32	
Methyl isocyanate	liquid	3	51	6
Nickel carbonyl	liquid	2		35
Nicotine	liquid	5 mg/m^3	50	
Nitrogen dioxide	gas/liquid	20		88
Ozone	gas	5		5
Parathion	liquid	10 mg/m^3	2	
Potassium cyanide	solid	25 mg/m^3	5	
Phosgene	gas	2		25
Sodium azide	solid	20	27	37
Sodium cyanide (as CN)	solid	25 mg/m^3	6	
Tetraethyl lead	liquid	40 mg/m^3	12	
Toxaphene	solid	200 mg/m^3	50	

[1] IDLH - Immediately Dangerous to Life and Health (IDLH), values based on a tiered analysis of acute human and animal toxicity data, National Institute of Occupational Safety and Health (NIOSH), *Pocket Guide to Chemical Hazards*, 2010.

[2] LD_{50} - Lethal Dose's from National Institute of Health (NIH) U.S. National Library of Medicine, TOXNET Toxicology Data Network (http://toxnet.nlm.nih.gov), ChemID*plus/*Hazardous Substance Data Bank (HSDB). Note: The OSHA/GHS* Category 1 and 2 acutely toxic substances with an LD_{50} less than or equal to 50 mg/kg are considered acutely toxic by oral ingestion (rat). OSHA/GHS* Category 3 substances with values from 50 - 300 mg/kg can also be considered acutely toxic if they can be fatal or cause damage to target organs as the result of a single exposure of short duration.

[3] LC_{50} - Lethal Concentration's from National Institute of Health (NIH) U.S. National Library of Medicine, TOXNET Toxicology Data Network (http://toxnet.nlm.nih.gov), ChemID*plus/*Hazardous Substance Data Bank (HSDB). Note: The OSHA/GHS* Category 1, 2, and 3 substances with an LC_{50} less than or equal to 2500 ppm are considered acutely toxic by inhalation (rat).

* OSHA/GHS (Occupational Safety and Health Administration and the Globally Harmonized System of Chemical Classification and Labelling).

CHEMICALS THAT CAN FORM PEROXIDES UPON AGING*

Class A: Chemicals that form explosive levels of peroxides without concentration.

Organic:

- Butadiene
- Chlorobutadiene (Chloroprene)
- Divinyl ether
- Divinyl acetylene
- Isopropyl ether
- Tetrafluoroethylene
- Vinylidene chloride

Inorganic

- Potassium amide
- Potassium metal
- Sodium amide (sodamide)

Class B: The following chemicals are a peroxide hazard upon concentration (distillation/ evaporation). Test for peroxides if concentration is intended or suspected.

- Acetal
- Cumene
- Cyclohexene
- Cyclooctene
- Cyclopentene
- Diacetylene
- Dicyclopentadiene
- Diethylene glycol dimethyl ether (diglyme)
- Diethyl ether (Ethyl ether)
- Dioxane (*p*-dioxane)
- Ethylene glycol dimethyl ether (glyme)
- Furan
- Methyl acetylene
- Methyl cyclopentane
- Methyl-isobutyl ketone
- Tetrahydrofuran
- Tetrahydronaphthalene (Tetraline)
- Vinyl ethers

Class C: Unsaturated monomers that may polymerize as a result of peroxide accumulation if inhibitors have been removed or depleted.

- Acrylic acid
- Butadiene
- Chlorotrifluoroethylene
- Ethyl acrylate
- Methyl methacrylate
- Styrene
- Vinyl acetate
- Vinyl chloride
- Vinyl pyridine

* These lists are illustrative, not comprehensive.

Reference: National Research Council, *Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards*, Table 4.8, p. 72, 2011.

Additional reference: Furr, A. Keith, *CRC Handbook of Laboratory Safety*, Table 4.6, p. 258-259, 2000.

CHEMICAL INCOMPATABILITIES

PARTIAL LIST

Chemical	Incompatible Chemicals
Acetic acid	Chromic acid, nitric acid, peroxides, permanganates, hydroxyl compounds, ethylene glycol, perchloric acid
Acetic anhydride	Hydroxyl-containing compounds (e.g., ethylene glycol, perchloric acid)
Acetone	Concentrated nitric and sulfuric acid mixtures, hydrogen peroxide
Acetylene	Chlorine, bromine, copper, silver, fluorine, mercury
Alkali and alkaline earth as sodium, magnesium, calcium, powdered aluminum	Water, carbon dioxide, carbon tetrachloride, other metals, such chlorinated hydrocarbons, halogens, potassium, lithium, chemical extinguishers (water, foam, and dry)
Ammonia (anhydrous)	Mercury, chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid (anhydrous)
Ammonium nitrate	Acids, metal powders, flammable liquids, chlorates, nitrites, sulfur, finely divided organics, combustibles
Aniline	Nitric acid, hydrogen peroxide
Arsenical materials	Any reducing agent
Azides	Acids
Bromine	Ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), sodium carbide, turpentine, benzene, hydrogen, finely divided metals
Calcium oxide	Water
Carbon (activated)	Calcium hypochlorite, all oxidizing agents
Chlorates	Ammonium salts, acids, metal powders, sulfur, finely divided organics, combustibles
Chromic acid and chromium trioxide	Acetic acid, naphthalene, camphor, glycerol, turpentine, alcohol, other flammable liquids
Chlorine	Ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), sodium, carbide, turpentine, benzene, hydrogen, finely divided metals
Chlorine dioxide	Ammonia, methane, phosphine, hydrogen sulfide
Copper	Acetylene, hydrogen peroxide
Cumene hydroperoxide	Acids
Cyanides	Acids
Flammable liquids	Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, perchloric acid, sodium peroxide, halogens
Fluorine	Isolate from everything
Hydrazine	Hydrogen peroxide, nitric acid, other oxidants
Hydrocarbons (benzene, propane, gasoline, etc.)	Fluorine, chlorine, bromine, chromic acid, butane, peroxides

APPENDIX B

CHEMICAL INCOMPATABILITIES

PARTIAL LIST
(continued)

Chemical	**Incompatible Chemicals**
Hydrocyanic acid	Nitric acid, alkalis
Hydrofluoric acid	Ammonia (aqueous or anhydrous)
Hydrogen Peroxide	Copper, chromium, iron, most metals or their salts, alcohols, acetone, organic materials, aniline, nitromethane, combustible material
Hydrogen Sulfide	Fuming nitric acid, oxidizing gases
Iodine	Acetylene, ammonia (aqueous or anhydrous), hydrogen
Mercury	Acetylene, fulminic acid, ammonia
Nitrates	Sulfuric acid
Nitric Acid (concentrated)	Acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids, flammable gases, copper, brass, any heavy metals
Nitrites	Acids
Nitroparaffins	Inorganic bases, amines
Oxalic acid	Silver, mercury
Oxygen	Oils, greases, hydrogen, flammable liquids, solids, or gases
Perchloric acid	Acetic anhydride, acetic acid, bismuth and its alloys, alcohol, paper, wood, greases, oils, flammables
Peroxide, organic	Acids (also avoid friction, store cold)
Phosphorus (white)	Air, oxygen, alkalis, reducing agents
Potassium	Carbon tetrachloride, carbon dioxide, water
Potassium chlorate	Sulfuric and other acids
Potassium perchlorate	Sulfuric and other acids
Potassium permanganate	Glycerol, ethylene glycol, benzaldehyde, sulfuric acid
Selenides	Reducing agents
Silver	Acetylene, oxalic acid, tartartic acid, ammonium compounds, fulminic acid
Sodium	Carbon tetrachloride, carbon dioxide, water
Sodium nitrate	Ammonium nitrate and other ammonium salts
Sodium peroxide	Ethyl or methyl alcohol, glacial acetic acid, acetic anhydrite, benzaldehyde, carbon disulfide, glycerine, ethyl acetate, methyl acetate, furfural
Sulfides	Acids
Sulfuric acid	Potassium chlorate, potassium perchlorate, potassium permanganate (similar compounds of light metals such as sodium and lithium)

APPENDIX B

SUMMARY OF THE MAXIMUM ALLOWABLE QUANTITY OF HAZARDOUS MATERIALS IN STORAGE PER FIRE CONTROL AREAa POSING A PHYSICAL OR HEALTH HAZARD

Hazardous Material[e]	Class[e]	IBC Hazard Group[f] when Quantity is Exceeded	Maximum Allowable Quantity in Storage[b] per Fire Contol Area in Accordance with the Uniform Fire Code[c] (UFC)			Maximum Allowable Quantity in Storage[b] per Fire Control Area in Accordance with the International Fire Code[d] (IFC)		
			Solid pounds (cubic feet)	Liquid gallons (pounds)	Gas (cubic feet)	Solid pounds (cubic feet)	Liquid gallons (pounds)	Gas (cubic feet)
Combustible liquid	II IIIA IIIB	H-2 or H-3 H-2 or H-3		120[h] 330[h] 13,200[h,i]			120[g,h] 330[g,h] 13,200[h,i]	
Combustible fiber	Loose Baled	H-3	(100) (1,000)			(100) (1,000)		
Consumer Fireworks (Class C, Common)	1.4G	H-3				125[g,h,q]		
Cryogenics, flammable		H-2		45			45[g]	
Cryogenics, Oxidizing		H-3		45			45[g]	
Explosives		H-1	1[h]	(1)[h]		1[h,j]	(1)[h,j]	
Flammable gas	Gaseous	H-2			750[g,h]			1,000[g,h]
	Liquefied			15[g,h]			30[g,h]	
Flammable liquid	1A 1B 1C	H-2 or H-3		30[h] 60[h] 90[h]			30[g,h] 60[g,h] 90[g,h]	
Combination Flammable Liquid (1A,1B,1C)		H-2 or H-3		120[h]			120[g,h,k]	
Flammable solid		H-3	125[g,h]			125[g,h]		
Organic peroxide	UD I II III IV V	H-1 H-2 H-3 H-3	1[h,j] 5[g,h] 50[g,h] 125[g,h] 500 [g,h] NL	(1)[h,j] (5)[g,h] (50)[g,h] (125)[g,h] (500) [g,h] NL		1[h,i] 5[g,h] 50[g,h] 125[g,h] NL NL	(1)[h,j] (5)[g,h] (50)[g,h] (125)[g,h] NL NL	
Oxidizer	4 3[j] 2 1	H-1 H-2 H-3 H-3	1[h,j] 10[g,h] 250[g,h] 4,000[g,h]	(1)[h,j] (10)[g,h] (250)[g,h] (4,000)[g,h]		1[h,j] 10[g,h] 250[g,h] 4,000[g,h]	(1)[h,j] (10)[g,h] (250)[g,h] (4,000)[g,h]	
Oxidizing gas	Gaseous	H-3			1500[g,h]			1500[g,h]
	Liquefied			15[g,h]			15[g,h]	
Pyrophoric material		H-2	4[h,j]	(4)[h,j]	50[h,j]	4[h,j]	(4)[h,j]	50[h,j]
Unstable (reactive)	4 3 2 1	H-1 H-1 or H-2 H-3	1[h,j] 5[g,h] 50[g,h] NL	(1)[h,j] (5)[g,h] (50)[g,h] NL	10[h,j] 50[g,h] 250[g,h] 750[g,h]	1[h,j] 5[g,h] 50[g,h] NL	(1)[h,j] (5)[g,h] (50)[g,h] NL	10[g,j] 50[g,h] 250[g,h] NL
Water reactive	3 2 1	H-2 H-3	5[g,h] 50[g,h] 125[h,i]	(5)[g,h] (50)[g,h] (125)[h,i]		5[g,h] 50[g,h] NL	(5)[g,h] (50)[g,h] NL	
Corrosive			5000[g,h]	500[g,h]	810[g,h]	5000[g,h]	500[g,h]	810[g,o]
Highly Toxic			10[g,h]	(10)[g,h]	20[g,p]	10[g,h]	(10)[g,h]	20[g,p]
Toxic			500[g,h]	(500)[g,h]	810[g,h]	500[g,h]	(500)[g,h]	810[g,h]
Irritants			NL	NL	810 [g,h,i]			
Sensitizers			NL	NL	810 [g,h,i]			
Other Health Hazards			NL	NL	810 [g,h,i]			

NL = Not Limited SI equivalents: 1 cubic foot = 0.023 m^3, 1 pound = 0.454 kg, 1 gallon = 3.785 L

APPENDIX B

SUMMARY OF THE MAXIMUM ALLOWABLE QUANTITY OF HAZARDOUS MATERIALS IN STORAGE PER FIRE CONTROL AREAa POSING A PHYSICAL OR HEALTH HAZARD

(CONTINUED)

Notes: a. A control area is a space within a building bounded by exterior walls, fire walls, fire barriers, and roofs, or a combination thereof, where hazardous materials are stored, dispensed, or handled in amounts not exceeding the maximum allowable quantities.

b. The aggregate quantity in use and storage shall not exceed the quantity listed for storage.

c. *Uniform Fire Code*, 1997, Article 80, Hazardous Materials, Section 8001, Tables 8001.15-C & 8001.15-D.

d. *International Fire Code*, 2000, Chapter 27, Hazardous Materials – General Provisions, Tables 2703.1.1(1) & 2703.1.1(2).

e. See definitions below.

f. Hazard groups are defined in the International Building Code, 2000, [F] Section 307, and require specific design criteria.

g. Maximum quantities shall be increased 100% for buildings equipped throughout with an automatic sprinkler system. Where note h applies, the increase for both shall be applied accumulatively.

h. Quantities shall be increased 100% when stored in approved cabinets, gas cabinets, exhausted enclosures, or safety cans as specified by the *International Fire Code*. Where note g applies, the increase for both shall be applied accumulatively.

i. The permitted quantities shall not be limited in buildings equipped throughout with an automatic sprinkler system and provided with exhaust ventillation.

j. Permitted only in building equipped throughout with an automatic sprinkler system.

k. Containing not more than the maximum allowable quantity per control area of Class 1A, 1B, or 1C flammable liquids.

l. Quantities in parentheses indicate quantity units in parentheses at the head of each column.

m. A maximum quantity of 200 pounds of solid or 20 gallons of liquid Class 3 oxidizers is allowed when such materials are necessary for maintenance purposes.

n. Net weight of the pyrotechnic composition. Where net weight is unknown, 25% of the gross weight including packaging shall be used.

o. A single cylinder per control area containing 150 pounds of anhydrous ammonia shall be considered the maximum in and unsprinklered building or two cylinders containing 150 pounds each in a building equipped throughout with an automatic sprinkler system.

p. Allowed only when stored in approved exhausted gas cabinets or exhausted enclosures.

q. Net weight of the pyrotechnic composition. Where the net weight is unknown 25% of the gross weight shall be used including packaging.

Definitions:

Combustible Liquids: Class II. Liquids having a closed cup flash point at or above 100ºF (38ºC) and below 140ºF (60ºC).

Class IIIA. Liquids having a closed cup flash point at or above 140ºF (60ºC) and below 200ºF (93ºC).

Class IIIB. Liquids having a closed cup flash point at or above 200ºF (93ºC).

Flammable Liquids: Class IA. Liquids having a flash point below 73ºF (23ºC) and having a boiling point below 100ºF (38ºC).

Class IB. Liquids having a flash point below 73ºF (23ºC) and having a boiling point above 100ºF (38ºC).

Class IC. Liquids having a flash point at or above 73ºF (23ºC) and below 100ºF (38ºC).

Highly Toxic:

1. A chemical that has a lethal dose (LD_{50}) 50 mg/kg or less orally in rats.
2. A chemical that has a lethal dose (LD_{50}) 200 mg/kg or less by contact in rabbits.
3. A chemical that has a lethal concentration (LC_{50}) in air of 200 ppm (gas or vapor) or 2 mg/l (mist, fume, or dust) or less by inhalation in rats.

Organic Peroxides: UD. Unclassified detonable. Organic peroxides that are capable of detonation. Extremely high explosion hazard through rapid explosive decomposition.

I. Formulations capable of deflagration but not detonation.

II. Formulations that burn very rapidly and pose a moderate reactivity hazard.

III. Formulations that burn rapidly and pose a moderate reactivity hazard.

iV. Formulations that burn in the same manner as ordinary combustibles and pose minimal reactivity hazards.

SUMMARY OF THE MAXIMUM ALLOWABLE QUANTITY

APPENDIX B

OF HAZARDOUS MATERIALS IN STORAGE PER FIRE CONTROL AREAa POSING A PHYSICAL OR HEALTH HAZARD

(CONTINUED)

V. Formulations that burn with less intensity than ordinary combustibles or do not sustain combustion and pose no reactivity hazard.

Oxidizers: Class 1. An oxidizer whose primary hazard is that it slightly increases the burning rate but does not cause spontaneous ignition when it comes in contact with combustible materials.

Class 2. An oxidizer that will cause a moderate increase in the burning rate or that causes spontaneous ignition when it comes in contact with combustible materials.

Class 3. An oxidizer that will cause a severe increase in the burning rate of combustibles with which it comes into contact or that will undergo vigorous self-sustained decomposition due to contamination or exposure to heat.

Class 4. An oxidizer that will undergo an explosive reaction due to contamination or exposure to thermal or physical shock and will enhance the burning rate and cause spontaneous ignition of combustibles.

Toxic: 1. A chemical that has a lethal dose (LD_{50}) 50 mg/kg but not more than 500 mg/kg orally in rats.

2. A chemical that has a lethal dose (LD_{50}) 200 mg/kg but not more than 1000 mg/kg by contact in rabbits.

3. A chemical that has a lethal concentration (LC_{50}) in air of more than 200 ppm (gas or vapor) or 2 mg/l (mist, fume, or dust) but not more than 2000 ppm (or 20 mg/l) by inhalation in rats.

Unstable (reactive): Class 1. Materials that are normally stable but can become unstable at elevated temperatures and pressures.

Class 2. Materials that are normally unstable and readily undergo violent chemical change but do not detonate and includes materials that can undergo chemical change with the rapid release of energy at normal temperatures and pressures and that undergo violent chemical change at elevated temperatures and pressures.

Class 3. Materials capable of detonation or explosive decomposition or explosive reaction but require a strong initiating source or must be heated under confinement before initiation and includes materials sensitive to mechanical or localized thermal shock at elevated temperatures and pressures.

Class 4. Materials readily capable of detonation or explosive decomposition or explosive reaction at normal temperatures and pressures and includes materials that are sensitive to mechanical or localized thermal shock at normal temperatures and pressures.

Water reactive: Class 1. Materials that react with water with some release of energy but not violently.

Class 2. Materials that may form potentially explosive mixtures with water.

Class 3. Materials that react explosively with water without requiring heat or confinement.

APPENDIX B

EXAMPLES OF LIQUID AND SOLID OXIDIZER CLASSIFICATIONS[1]

Class 1: Oxidizers that **do not moderately increase**[1] or cause a slight increase[2] in the burning rate of the combustible materials with which they come into contact:

All inorganic nitrites
Ammonium persulfate
Barium peroxide
Calcium peroxide
Hydrogen peroxide solutions (8-27.5%)
Lead dioxide
Lithium hypochlorite (<39% avail. chlorine)
Lithium peroxide
Magnesium peroxide
Manganese dioxide
Nitric acid (≤ 40% conc.)
Perchloric acid solutions (<50% by weight)
Potassium dichromate
Potassium percarbonate
Potassium persulfate
Sodium carbonate peroxide
Sodium dichloro-*s*-triazinetrione dihydrate
Sodium dichromate
Sodium perborate (anhydrous)
Sodium perborate monohydrate
Sodium perborate tetrahydrate
Sodium percarbonate
Sodium persulfate
Strontium peroxide
Trichloro-*s*-triazinetrione (trichloroisocyanuric) (acid all forms)
Zinc peroxide

Class 2: Oxidizers that **do moderately increase** the burning rate of the combustible materials with which they come into contact:

Barium bromate
Barium chlorate
Barium hypochlorite
Barium perchlorate
Barium permanganate
1-Bromo-3-chloro-5,5-dimethylhydantoin (BCDMH)
Calcium chlorate
Calcium chlorite
Calcium hypochlorite (≤ 50% by weight)
Calcium perchlorate
Calcium permanganate
Chromium trioxide
Copper chlorate
Halane (1,3-dichloro-5,5-dimethylhydantoin)
Hydrogen peroxide (27.5-52%)
Lead perchlorate
Lithium chlorate
Lithium hypochlorite (>39% avail. chlorine)
Lithium perchlorate
Magnesium bromate
Magnesium chlorate
Magnesium perchlorate
Mercurous chlorate
Nitric acid (40-86% conc.)
Nitrogen tetroxide
Perchloric acid solutions (50-60% conc.)
Potassium perchlorate
Potassium permanganate
Potassium peroxide
Potassium superoxide
Silver peroxide
Sodium chlorite (≤ 40% by weight)
Sodium perchlorate
Sodium perchlorate monohydrate
Sodium permanganate
Sodium peroxide
Strontium chlorate
Strontium perchlorate
Thallium chlorate
Urea hydrogen peroxide
Zinc bromate
Zinc chlorate
Zinc permanganate

APPENDIX B

EXAMPLES OF LIQUID AND SOLID OXIDIZER CLASSIFICATIONS[1]

(continued)

Class 3: Oxidizers that **will cause a severe increase** in the burning rate of the combustible materials with which they come into contact **or** that **will undergo vigorous self-sustained decomposition** due to contamination or exposure to heat:

Ammonium dichromate

Ammonium nitrate[2]

Calcium hypochlorite (>50% by weight)

Chloric acid (10% max. conc.)

Hydrogen peroxide solutions (52-91%)

Mono-(trichloro)-tetra-(monopotassium dichloro)-penta-*s*-triazinetrione

Nitric acid, fuming (>86% conc.)

Perchloric acid solutions (60-72% by weight)

Potassium bromate

Potassium chlorate

Potassium dichloro-*s*-triazinetrione (potassium dichloroisocyanurate)

Sodium bromate

Sodium chlorate

Sodium chlorite (>40% by weight)

Sodium dichloro-*s*-triazinetrione (sodium dichloroisocyanurate)

Class 4: Oxidizers that **will cause a severe increase** in the burning rate of the combustible materials with which they come into contact **and** will **undergo an explosive reaction** due to contamination or exposure to thermal or physical shock:

Ammonium perchlorate (> 15 micron particle size, <15 microns is classified explosive)

Ammonium permanganate

Guanidine nitrate

Hydrogen peroxide solutions (>91%)

Tetranitromethane

[1] National Fire Protection Association, *Code for Storage of Liquid and Solid Oxidizers,* NFPA 430, 2000.

[2] International Code Council, *International Building Code,* Section 307, High-Hazard Group H, 2000.

APPENDIX B

CENTER FOR DISEASE CONTROL (CDC) and U.S. DEPARTMENT OF AGRICULTURE (USDA) SELECT AGENTS AND TOXINS[1]

The CDC and USDA define biological agents and toxins that have the potential to pose a severe threat to public health and safety as "Select Agents and Toxins." Because the "Select Toxins" are used as chemical biotoxins in laboratories, these substances are included in this chemical hygiene plan for informational purposes. The "Select Agents" (organisms) are not included in this chemical hygiene plan.

Exclusions for limited quantities of these toxins does not require registration as a Select Agent or Toxin. Researchers must <u>not</u> exceed the excluded quantities under any circumstances and must contact EHS for disposal of unwanted quantities.

<u>Toxins</u>

1. Abrin
2. Conotoxins (Short, paralytic alpha conotoxins containing the following amino acid sequence $X_1CCX_2PACGX_3X_4X_5X_6CX_7$)
3. Diacetoxyscirpenol
4. Ricin
5. Saxitoxin
6. Tetrodotoxin
7. Botulinum neurotoxins
8. Staphylococcal enterotoxins (subtypes A-E)
9. T-2 toxin

Genetic Elements, Recombinant Nucleic Acids, and Recombinant Organisms

The Select Toxins also include 1) any listed toxins that have been genetically modified or, 2) recombinant and/or synthetic nucleic acids that encode for the functional form(s) of any of the toxins if the nucleic acids can a) be expressed *in vivo* or *in vitro*, or b) are in a vector or recombinant host genome and can be expressed *in vivo* or *in vitro.*

<u>Exclusions</u>

1. Select toxins in their naturally occurring environment and have not been intentionally introduced, cultivated, collected, or otherwise extracted from its natural source.
2. Non-viable or non-functional toxins
3. Abrin (≤100 mg)
4. Botulinum neurotoxin (≤ 0.5 mg)
5. Conotoxins (≤100 mg)
6. Diacetoxyscirpenol (≤1000 mg)
7. Ricin (≤100 mg)
8. Saxitoxin (≤100 mg)
9. Staphylococcal enterotoxins (≤5 mg)
10. T-2 toxin (≤ 1000 mg)
11. Tetrodotoxin (≤100 mg)

[1] References: Electronic Code of Federal Regulations, e-CFR, (www.ecfr.gov)
Title 42 (Public Health), Code of Federal Regulations, Part 73.3, May 12, 2014
Title 7 (Agriculture), Code of Federal Regulations, Part 331.3, May 12, 2014
Title 9 (Animal and Animal Products), Code of Federal Regulations, Part 121.3, May 12, 2014

APPENDIX B

Chemicals That May Be Absorbed By Skin or Eye Contact

The following chemicals have been identified by the Occupational Safety and Health Administration (OSHA)[1] and/or the American Conference of Governmental Industrial Hygienists (ACGIH)[2] as chemicals that require skin protection (or the use of other methods) to prevent or reduce skin exposure.

OSHA provides a "skin designation" to serve as a warning that cutaneous absorption should be prevented in order to avoid exceeding the absorbed dose received by inhalation at the permissible exposure limits (PEL). ACGIH provides a "skin" designation to refer to danger of cutaneous absorption and a potential for significant contribution to the overall exposure by the cutaneous route including the mucous membranes and the eyes.

Many chemicals not listed here also require the use of gloves because of other hazardous characteristics such as skin corrosivity.

Always refer to the glove manufacturers glove selection guides when choosing gloves for use with any chemical. Chemicals that are not listed may not have been tested. Some chemicals may not have an acceptable glove material based on the permeation and degradation tests. In this case, engineering controls, work practice controls or other methods must be used to prevent or reduce skin exposure to these chemicals. For more information refer to SOP 3.16, Personal Protective Equipment – Procedures for Selection and Use.

Manufacturer's glove selection guides are available at the glove manufacturer's websites or through the EHS websites. Additional references[3] are also available that provide guidance for selecting glove materials or contact EHS for more information (see Laboratory Safety Contacts, pgs. ix-xi).

Chemical	CAS Number	Reference	
		OSHA[4]	ACGIH[5]
Acetone cyanohydrin	75-86-5		x
Acetonitrile	75-05-8		x
Acrolein	107-02-8		x
Acrylamide	79-06-1	x	x
Acrylic acid	79-10-7		x
Acrylonitrile	107-13-1	P	x
Adiponitrile	111-69-3		x
Aldrin	309-00-2	x	x
Allyl alcohol	107-18-6	x	x
Allyl bromide	106-95-6		x
Allyl chloride	107-05-1		x
4-Aminodiphenyl	92-67-1		x
Ammonium perfluorooctanoate	3825-26-1		x
Aniline	62-53-3	x	x
(o-,p-) Anisidine	90-04-0/104-94-9	x	x
ANTU	86-88-4		x
Azinphos-methyl	86-50-0	x	x
Benzene	71-43-2		x
Benzidine	92-87-5		x
Benzotrichloride	98-07-7		x
Beryllium, soluble compounds	7440-41-7		x
Bromoform	75-25-2	x	
2-Butoxyethanol (EGBE)	111-76-2	x	
n- Butylamine	109-73-9	x	x
tert-Butyl chromate (as CrO_3)	1189-85-1	x	x
n-Butyl glycidyl ether	2426-08-6		x
o-sec-Butylphenol	89-72-5		x
Captafol	2425-06-1		x
Carbaryl	63-25-2		x

Chemicals That May Be Absorbed By Skin or Eye Contact
(continued)

Chemical	CAS Number	Reference	
		OSHA[4]	ACGIH[5]
Carbon disulfide	75-15-0		x
Carbon tetrachloride	56-23-5		x
Catechol	120-80-9		x
Chlordane	57-74-9	x	x
Chlorinated camphene	8001-35-2	x	x
Chloroacetone	78-95-5		x
Chloroacetyl chloride	79-04-9		x
o-Chlorobenzylidene malononitrile	2698-41-1		x
Chlorodiphenyl	53469-21-9/11097-69-1		x
β-Chloroprene	126-99-8	x	x
1-Chloro-2-propanol	127-00-4		x
2-Chloro-1-propanol	78-89-7		x
2-Chloropropionic acid	598-78-7		x
Chloropyrifos	2921-88-2		x
Citral	53-9240-5		x
Coumaphos	56-72-4		x
(o-,m-,p-) Cresol	1319-77-3; 95-48-7;108-39-4; 106-44-5	x	x
Crotonaldehyde	4170-30-3		x
Cumene	98-82-8	x	
Cyanide salts	592-01-8; 151-50-8; 143-33-9	x	x
Cyclohexanone	108-94-1		x
Cyclonite	121-82-4		x
2,4-D	94-75-7		x
Decaborane	11702-41-9	x	x
Demeton	8065-48-3		x
Demeton-S-methyl (Systox)	919-86-8	x	x
Diazinon	333-41-5		x
1,2-Dibromo-3-chloropropane		P	
2-*N*-Dibutylaminoethanol	102-81-8		x
Dibutyl phenyl phosphate	2528-36-1		x
Dibutyl phosphate	107-66-4		x
Dichloroacetic acid	79-43-6		x
3,3'-Dichlorobenzidine	91-94-1		x
1,4-Dichloro-2-butene	764-41-0		x
Dichlorodiphenyltri-chloroethane (DDT)	50-29-3	x	
Dichloroethyl ether	111-44-4	x	x
1,3-Dichloropropene	542-75-6		x
Dichlorvos (DDVP)	62-73-7	x	x
Dicrotophos	141-66-2		x
Dieldrin	60-57-1	x	x
Diesel fuel	68334-30-5; 68476-30-2; 68476-31-3; 68476-34-6; 77650-28-3		x
Diethanolamine	111-42-2		x
Diethylamine	109-89-7		x
2-Diethylaminoethanol	100-37-8	x	x
Diethylene triamine	111-40-0		x
Diisopropylamine	108-18-9	x	x
N,N-Dimethyl acetamide	127-19-5	x	x
bis (2-Dimethylaminoethyl) ether	3033-62-3		x
Dimethylaniline	121-69-7	x	x
Dimethyl carbamoyl chloride	79-44-7		x
Dimethyl disulfide	624-92-0		x
Dimethylformamide	68-12-2	x	x
1,1-Dimethylhydrazine	57-14-7	x	x
Dimethyl sulfate	77-78-1	x	x
(*o-,m-,p-)* Dinitrobenzene	528-29-0; 99-65-0; 100-25-4	x	x
Dinitro-o-cresol	534-52-1	x	x
Dinitrotoluene	25321-14-6	x	x
1,4-Dioxane (Diethylene dioxide)	123-91-1	x	x
Dioxathion	78-34-2		x
Dipropylene glycol methyl ether	34590-94-8	x	
Diquat	2764-72-9		x
Disulfoton	298-04-4		x
Endosulfan	115-29-7		x
Endrin	72-20-8	x	x

Chemicals That May Be Absorbed By Skin or Eye Contact
(continued)

Chemical	CAS Number	Reference OSHA[4]	Reference ACGIH[5]
Epichlorohydrin	106-89-8	x	x
EPN	2104-64-5	x	x
Ethion	563-12-2		x
2-Ethoxyethanol (Cellosolve)	110-80-5	x	x
2-Ethoxyethyl acetate (Cellosolve acetate)	111-15-9	x	x
Ethyl acrylate	140-88-5	x	
Ethylamine	75-04-7		x
Ethyl bromide	74-96-4		x
Ethyl chloride	75-00-3		x
Ethylene chlorohydrin	107-07-3	x	x
Ethylenediamine	107-15-3		x
Ethylene dibromide	106-93-4		x
Ethylene glycol dinitrate	628-96-6	x	x
Ethylenimine	151-56-4		x
Ethyl isocyanate	109-90-0		x
N-Ethylmorpholine	100-74-3	x	x
Fenamiphos	22224-92-6		x
Fensulfothion	115-90-2		x
Fenthion	55-38-9		x
Fonofos	944-22-9		x
Formaldehyde	50-00-0	x	
Formamide	75-12-7		x
Furfural	98-01-1	x	x
Furfuryl alcohol	98-00-0		x
Heptachlor & heptachlor epoxide	76-44-8; 1024-57-3	x	x
Hexachlorobenzene	118-74-1		x
Hexachlorobutadiene	87-68-3		x
Hexachloroethane	67-72-1	x	x
Hexachloronaphthalene	1335-87-1	x	x
Hexafluoroacetone	684-16-2		x
Hexamethylphosphoramide	680-31-9		x
n-Hexane	110-54-3		x
Hydrazine	302-01-2		x
Hydrogen cyanide	74-90-8	x	x
Hydrogen fluoride	7664-39-3		x
2-Hydroxypropyl acrylate	999-61-1		x
Isooctyl alcohol	26952-21-6		x
2-Isopropoxyethanol	109-59-1		x
N-Isopropylaniline	768-52-5		x
Kerosene	8008-20-6		x
Latex, natural rubber latex as total proteins	9006-04-6		x
Lindane	58-89-9	x	x
Malathion	121-75-5	x	x
Manganese cyclopentadienyl tricarbonyl	12079-65-1		x
Mercury (Inorganic)	7439-97-6		x
Mercury (Organic):	7439-97-6		x
Methanol	67-56-1		x
Methomyl	16752-77-5		x
2-Methoxyethanol; (Methyl cellosolve)	109-86-4	x	x
2-Methoxyethyl acetate (Methyl cellosolve acetate)	110-49-6	x	x
bis-(2-Methoxypropyl) ether (DPGME)	34590-94-8		x
Methyl acrylate	96-33-3	x	x
Methylacrylonitrile	126-98-7		x
N-Methyl aniline	100-61-8		x
Methyl bromide	74-83-9	x	x
Methyl n-butyl ketone	591-78-6		x
Methyl chloride	74-87-3		x
o-Methylcyclohexanone	583-60-8	x	x
2-Methylcyclopentadienyl manganese tricarbonyl	12108-13-3		x
Methyl demeton	8022-00-2		x
4,4'-Methylene bis(2-chloroaniline)	101-14-4		x
4-4'-Methylene dianiline	1071-77-9		x
Methyl hydrazine	60-34-4	x	x
Methyl iodide	74-88-4	x	x
Methyl isobutyl carbinol	108-11-2	x	x

Chemicals That May Be Absorbed By Skin or Eye Contact
(continued)

Chemical	CAS Number	Reference	
		OSHA[4]	ACGIH[5]
Methyl isocyanate	624-83-9	x	x
1-Methylnaphthalene	90-12-0		x
2-Methylnaphthalene	91-57-6		x
Methyl parathion	298-00-0		x
Methyl vinyl ketone	78-94-4		x
Mevinphos (Phosdrin)	7786-34-7		x
Monochloroacetic acid	79-11-8		x
Monocrotophos	6923-22-4		x
Monomethyl aniline	100-61-8	x	
Morpholine	110-91-8	x	x
Naled	300-76-5		x
Naphthalene	91-20-3		x
Nicotine	54-11-5	x	x
p-Nitroaniline	100-01-6	x	x
Nitrobenzene	98-95-3	x	x
p-Nitrochlorobenzene	100-00-5	x	x
4-Nitrodiphenyl	92-93-3		x
Nitroglycerin	55-63-0	x	x
N-Nitrosodimethylamine	62-75-9		x
(*o*-,*m*-,*p*-) Nitrotoluene	88-72-2; 99-08-1; 99-99-0	x	x
Octachloronaphthalene	2234-13-1	x	x
Paraquat	4685-14-7	x	
Parathion	56-38-2	x	x
Pentachloronaphthalene	1321-64-8	x	x
Pentachlorophenol	87-86-5	x	x
2,4-Pentanedione	123-54-6		x
Phenol	108-95-2	x	x
Phenothiazine	92-84-2		x
Phenyl glycidyl ether	122-60-1		x
p-Phenylene diamine	106-50-3	x	
Phenylhydrazine	100-63-0	x	x
Phenyl mercaptan	108-98-5		x
Phorate	298-02-2		x
Phosdrin (Mevinphos)	7786-34-7	x	
Picric acid (2,4,6-trinitrophenol)	88-89-1	x	
Propargyl alcohol	107-19-7		x
Propylene glycol dinitrate	6423-43-4		x
Propylenimine	75-55-8	x	x
Sodium fluoroacetate	62-74-8	x	x
Sulfotep (TEDP)	3689-24-5	x	x
Sulprofos	35400-43-2		x
Temephos	3383-96-8		x
Terbufos	13071-79-9		x
1,1,2,2-Tetrachloroethane	79-34-5	x	x
Tetrachloronaphthalene	1335-88-2	x	
Tetraethyl lead	78-00-2	x	x
Tetraethyl pyrophosphate (TEPP)	107-49-3	x	x
Tetrahydrofuran	109-99-9		x
Tetramethyl lead	75-74-1	x	x
Tetramethyl succinonitrile	3333-52-6	x	x
Tetryl (2,4,6-Trinitrophenylmethylnitramine)	479-45-8	x	
Thallium, soluble compounds	7440-28-0	x	x
Thioglycolic acid	68-11-1		x
Tin (organic compounds)	7440-31-5		x
Tolidine	119-93-7		x
(*o*-,*m*-,*p*-) Toluidine	95-53-4; 108-44-1; 106-49-0	x	x
1,1,2-Trichloroethane	79-00-5	x	x
Trichloronaphthalene	1321-65-9	x	x
1,2,3 Trichloropropane	96-18-4		x
Triethylamine	121-44-8		x
Trimellitic anhydride	552-30-7		x
2,4,6-Trinitrotoluene (TNT)	118-96-7	x	x
Triorthocresyl phosphate	78-30-8		x

Chemicals That May Be Absorbed By Skin or Eye Contact
(continued)

Chemical	CAS Number	Reference	
		OSHA[4]	ACGIH[5]
Triorthocresyl phosphate	78-30-8		x
Vinyl cyclohexene dioxide	106-87-6		x
m-Xylene α,α'-diamine	1477-55-0		x
Xylidine (mixed isomers)	1300-73-8	x	x

Notes: 1. Title 29, Code of Federal Regulations, Part 1910.1000 (29 CFR Part 1910.1000), Air Contaminants, Table Z-1, Limits for Air Contaminants.

2. American Conference of Governmental Industrial Hygienists (ACGIH), Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices, 2014.

3. Refer to manufacturer's permeation and degradation charts for glove selection. Glove thicknesses vary and will provide different levels of protection. Not all chemicals have been tested for glove type. Contact EHS if glove type is not listed for a particular chemical. The following references provide additional information regarding glove materials and chemical resistance.

   a. McConville, Francis X., The Pilot Plant Real Book, 2002, pg. 9-13, Glove Selection Guide.

   b. Furr, A. Kieth, CRC Handbook of Laboratory Safety, 5th Ed., 2000, Table 6.2, Resistant Properties of Selected Materials by Class, pg 742-743.

4. Skin Designation (OSHA): Skin exposure to substances listed by OSHA with "Skin Designation" must be reduced or prevented by the use of gloves, coveralls, goggles, or other appropriate personal protective equipment, engineering controls, or work practices. "P" – Dermal (skin) or eye exposure prohibited by regulation.

5. Skin Notation (ACGIH): The ACGIH "Skin Notation" refers to the potential for significant contribution to the overall exposure by the cutaneous route, including mucous membranes and the eyes, either by contact with vapors or, of probable greater significance, by direct skin contact with the substance. Vehicles present in mixtures can also significantly enhance potential skin absorption. It should be noted that while some materials are capable of causing irritation, dermatitis, and sensitization in workers, these properties are not considered relevant when assigning the ACGIH skin notation. The development of a dermatological condition, however, can significantly affect the potential for dermal absorption. Use of the skin designation is intended to alert the reader that air sampling alone is insufficient to accurately quantify exposure and that measures to prevent significant cutaneous absorption may be required.