Laboratory Safety Manual

CASE WESTERN RESERVE UNIVERSITY

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THE OSHA LABORATORY STANDARD AND THE UNIVERSITY LABORATORY SAFETY MANUAL

In January 1990, the Occupational Safety and Health Administration (OSHA) released its final ruling on occupational exposure to hazardous chemicals in laboratories. This ruling, commonly referred to as the Laboratory Standard (29 CFR 1910.1450), was to be implemented by January 31, 1991. The Laboratory Standard is a generic, performance-based standard, emphasizing safe handling and use of hazardous chemicals through procedures to be established by the employer and outlined in a written Chemical Hygiene Plan (CHP).

In order to comply with the regulations of this standard, Case Western Reserve University's (CWRU) Department of Occupational & Environmental Safety (EHS), in coordination with the Laboratory Safety Committee, has written this Laboratory Safety Manual (LSM). It is further required that Principal Investigators (PIs) develop CHPs specific to their laboratories. This manual can serve as a basic model from which all PIs can create more specific documents. The details of this requirement are outlined below.

EHS is comprised of two divisions: Radiation Safety, and Biological/Chemical Safety. Biological/Chemical Safety will be hereafter referred to in this document as "Safety Services."

SCOPE AND APPLICATION

Laboratories are covered by the Laboratory Standard if they meet all of the following requirements:

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

29 CFR 1910.1450 supersedes the requirements of all other OSHA standards applicable to laboratories, except for the requirement to maintain employee exposures below permissible exposure limits (PELs). PELs are maximum air concentrations of hazardous chemicals to which an employee can be exposed to within an 8-hour work shift. If atmospheric concentrations are routinely high, then specific exposure monitoring and medical surveillance requirements may apply. In addition, if any regulated chemical under SARA Title 313 Appendix A is being used or stored, applicable standards must be followed (see *Appendix A*).

CHEMICAL HYGIENE PLAN

The basic requirement of the Laboratory Standard for employers is to establish a written Chemical Hygiene Plan. The Chemical Hygiene Plan (CHP) describes: Standard operating procedures for using hazardous chemicals; hazard-control techniques; equipment-reliability measures; employee information and training programs; conditions under which the employer must approve operations, procedures, and activities before implementation; and medical consultations and examinations. The CHP also designates personnel responsible for implementing the CHP, and specifies the procedures used to provide additional protection to employees exposed to particularly hazardous chemicals. The PI is ultimately responsible for implementing the CHP. It is recommended that a committee comprised of the PI and researchers write the CHP jointly. The recommended format for the CHP is available on the EHS website (http://case.edu/ehs) under "Forms/Manuals," and this LSM may be used as a reference.

Outlined below are the major elements that must be included in each laboratory's CHP:

1. Standard operating procedures

   Included in this LSM are approved operating procedures for dealing with hazardous chemicals. These procedures shall be adopted by individual laboratories to meet the requirements of the Laboratory Standard. In addition, the Material Safety Data Sheets (MSDSs) for every chemical in use in the laboratory must be available to all employees of that laboratory at all times. The MSDS provides essential information on chemical handling, containment, labeling procedures, and emergency medical information. MSDSs are available on the EHS website (http://case.edu/ehs) under "MSDS."

2. Control measures

   Criteria to determine and implement specific control measures such as engineering controls, administrative controls, and personal protective equipment (PPE). This LSM addresses specific control measures such as engineering controls and PPE. Safety Services will assist with training and special needs as they arise.

3. Chemical hoods

   Safety Services tests chemical hoods at least once a year. This is a requirement to ensure that chemical hoods are functioning properly. ASHRAE 110 Tracer Gas testing is performed on every chemical hood that is new, moved from one location to another or is repaired. The chemical hood is velocity tested during the other four years to ensure that it has not deviated from the conditions under which it passed the ASHRAE 110 Tracer Gas test. Contact Safety Services (368.2907) if you have any questions about the chemical hoods in your area.

4. Information and training requirements

   Employee training is a central element of the Laboratory Standard. The training shall be appropriate for each specific laboratory and take into account the level of education and knowledge of the individuals being trained. EHS offers general radiation, X ray, laser, chemical, and biological safety training programs, as well as hazardous materials shipment and respirator training, both in person and online. Training class schedules can be obtained by calling Radiation Safety (368.2906) or Safety Services (368.2907). Training class schedules are also available on the EHS website (http://case.edu/ehs) under “Training.”

5. Circumstances under which a particular laboratory operation shall require prior approval from the employer

   In most cases, the “employer” will be the PI. The PI may wish to institute procedures for prior approval for the use of certain extremely hazardous chemicals. A list of extremely hazardous chemicals, as defined by OSHA, can be found in Appendix B of this LSM.

   Except for Class IA flammable liquids (those having flash points below 73ºF and a boiling point below 100ºF), Safety Services does not require prior approval for the possession of any chemicals (check with Safety Services for exceptions). However, an approved laboratory chemical protocol is required as part of the University Laboratory Standard.

6. Provisions for medical consultation and medical exams whenever:

    a. An employee develops signs or symptoms of exposure to a hazardous chemical;

    b. Medical surveillance reveals routine exposure above the action level or PEL; or

    c. A hazardous chemical spill, leak, or explosion occurs. Employers shall provide employees an opportunity to receive medical attention, including any follow-up exams with University Health Services. University Health Services will address Laboratory Standard related medical consultations and medical exams. Call University Health Services (368.2450) for additional information. Call Safety Services (368.2907) immediately if a hazardous exposure occurs during the course of your work (between 8:30 a.m. and 5:00 p.m.). Between 5:00 p.m. and 8:30 a.m., weekends, and holidays, call Protective Services (368.3333).

7. Chemical Hygiene Officer

    OSHA regulations stipulate that a Chemical Hygiene Officer (CHO) must be designated for each laboratory. Since PIs hold the primary responsibility for safety in their laboratory, the PI will therefore be designated as CHO. The department chairperson may, under special circumstances, designate an alternate person to assume this responsibility.

8. Protective measures

    The Laboratory standard 29 CFR 1910.1450 also covers requirements for development of additional employee protection when working with particularly hazardous substances such as select carcinogens, reproductive toxins, and substances with a high degree of acute toxicity. Protective measures include the following:

    a. Establishment of a designated area (such as a chemical hood)
    b. Use of containment devices
    c. Procedures for safe removal of hazardous waste
    d. Decontamination procedures

    The effectiveness of the CHP must be reviewed annually within each laboratory and submitted to Safety Services for review. Additionally, Safety Services conducts safety inspections to ensure chemical hygiene and laboratory safety procedures are up-to-date and in compliance.

This introduction summarizes the requirements of the OSHA Laboratory Standard, Code of Federal Regulations (CFR), Chapter 29, Section 1910.1450 entitled: “Occupational Exposure to Hazardous Chemicals in Laboratories.” If you have any questions as to what is required for the development of the CHP, or wish to obtain a copy of the Laboratory Standard or information on any aspect of the Standard, contact Safety Services (368.2907).

GENERAL CONSIDERATIONS

CWRU SAFETY POLICY

This LSM has been written to acquaint all laboratory personnel with an important phase of their responsibility – safety, or accident prevention. Accident prevention must be included in the performance of every task. It cannot be considered a separate entity but is an integral part of everyone's work. Safety is made possible by careful planning of all work based on an understanding of the hazards involved and a knowledge of the work area and safe working procedures. Accident prevention pays in the injuries it prevents, the research time it saves, and the healthy attitude it creates.

The objective of this LSM is two-fold:

1. To provide general guidelines and recommendations for safe laboratory practices, and

2. To comply with OSHA's Laboratory Standard, 29 CFR 1910.1450.

This manual is not intended to be, nor can it be, complete and all-inclusive.

RESPONSIBILITY

The implementation of this policy is the responsibility of the managerial and supervisory staff of the University. Vice Presidents, Deans, Chairpersons, Directors, Heads of Units, Laboratory Supervisors, PIs, and all other supervisory personnel will be accountable for the health and safety of employees engaged in activities under their supervision. This responsibility cannot be delegated. Supervisors must realize that it is their responsibility to ensure that workers are educated about safety issues and comply with safety rules. Supervisors must continuously promote and insist upon safety.

Safety Services will assist supervisory personnel in establishing and maintaining a safe working environment. EHS interprets the standards and regulations to ensure the safety, education, information monitoring, and recommendations for improvements. EHS will initiate the establishment of standards and regulations for safety, education, information monitoring, and recommendations for improvements. Safety Services will also maintain and provide general safety training, while PIs provide site-specific training.

EMERGENCIES AND HAZARDOUS CHEMICAL SPILLS

Emergencies

Each laboratory should develop its own protocol for emergency situations, taking into account the following information:

1. CWRU emergency telephone numbers:

Emergency (injury, fire, life-endangering spill)	216.368.3333
CWRU Protective Services	216.368.3333
University Circle Police Department	216.368.2222
University Hospitals Protective Services	216.844.4357
CWRU EHS Radiation Safety	216.368.2906
CWRU EHS Safety Services	216.368.2907

2. General emergency procedures:

    a. Alert those working in the critical area(s):

    b. Call 216.368.3333) or University Hospitals (844.4357), for laboratories in UH. Clearly give a description and location of the event, indicate if an ambulance is needed, specify location where ambulance attendants, fire fighters or police will be met by the caller, and do not hang up the telephone.

3. In case of an injury or chemical splash:

    a. Remove the source of the chemical hazard and any contaminated clothing.

    b. In case of a chemical splash, flush affected area for a minimum of 15 minutes using the appropriate safety shower or eyewash station. If the exposed individual is a student, they must go to University Health Services for further examination. If the exposed individual is a member of the faculty or staff, they must visit their primary care physician. For immediate help with serious injuries, everyone must go to University Hospitals ER or call 216.368.3333 for help.

4. In case of an accident, serious illness or injury, do not attempt to move the injured person. Call Security (368.3333). Remember: All injuries are potentially dangerous. It is better to err conservatively and have the injury inspected as soon as possible by medical personnel.

5. Report all incidents to your PI or supervisor and, in writing, to Safety Services.

6. Students who suffer injuries in the laboratory must report to their supervisor (professor) or teaching assistant after receiving medical assistance. Minor injuries can be treated at University Health Services (368.2450). For serious injuries and/or need for an ambulance, call Security (368.3333).

7. Faculty or staff members who suffer relatively minor injuries during working hours (8:30 a.m. to 5:00 p.m.) can receive treatment at University Health Services (368.2450). At all other times, report to the Emergency Room of University Hospitals.

Hazardous Chemical Spills

Accidents involving hazardous chemicals require special consideration. The following steps **MUST** be taken:

1. **Immediately evacuate the affected area.**

2. **Call Security at 368.3333 at any time, 24/7,** and they will contact the proper authorities, including Safety Services.

3. **DO NOT RE-ENTER THE AREA** until the proper authorities indicate that it is safe to re-enter.

    a. The importance of keeping everyone out of the area where the accident occurred cannot be overemphasized. If a hazard exists and the area must be entered, safety personnel can re-enter in protective clothing, allowing them to work safety in contaminated environments.

    b. Remember that even though an area looks safe, it may still be dangerous. Chemical spills may evaporate rapidly or may remain for a longer time. The probability of fire or explosion is high when flammable chemicals are spilled and ignition sources are present.

    c. Any incident in University Hospitals that involves CWRU personnel must be reported to Safety Services (368.2907) in addition to University Hospitals Protective Services (844.4357).

4. Post signs: “DANGER – DO NOT ENTER, CONTAMINATED AREA.” Notify Safety Services (368.2907) of the circumstances and that the sign has been posted.

    a. Safety Services will assist supervisors in cleaning up the spill, as well as directing exposed persons to treatment and check-up facilities.

    b. Supervisors are responsible for submitting appropriate accident reports to Safety Services and University Hospitals Protective Services.

5. For clean-up of small spills that can be managed by laboratory personnel, refer to Appendix E (Small Spill Clean-up Guidelines). Contact Safety Services for guidelines on disposal of spent material or other post-management concerns.

<u>Decontamination Procedures</u>

1. Chemical spill response

   General spills of many innocuous laboratory chemicals can be handled by laboratory personnel with appropriate procedures (see *Appendix E*). If laboratory personnel have knowledge of the chemical involved and can discern that the spill does not pose a hazard, clean-up may begin without the presence of EHS specialists from Safety Services. If at any time there is doubt as to the nature or extent of the hazard, call Safety Services (368.2907). Laboratories at University Hospitals, must call UH Protective Services for assistance (844.4357). UH Protective Services will then notify Safety Services. Regardless of the nature of the spill, contact Safety Services before proceeding with any decontamination or clean-up.

2. Chemical spill kit

   Spill kits should be available in every laboratory. Spill kits suitable for responding to typical laboratory spills are available from commercial vendors. Alternatively, you may prepare your own spill kits. A spill kit should contain the following items:

    a. Spill pillows
    b. Silicon-based absorbent such as Oil-Dry, kitty litter, or vermiculite
    c. Dust pan

d. Broom or brush
e. Plastic bags
f. Hazardous waste labels
g. Rubber gloves (check chemical compatibility before use)
h. Rubber boots or foot protectors
i. Chemical splash goggles

LABORATORY DECOMMISSIONING PROCEDURES

Safety Services has developed certain decommissioning procedures for PIs whose research at CWRU will terminate. PIs who are leaving CWRU are responsible for proper disposal (or transfer to another PI with appropriate paperwork) of all commercial chemicals and research products. Contact Safety Services (368.2907) to arrange for disposal of hazardous waste.

The guidelines for decommissioning and relocation are located on the EHS website (http://case.edu/ehs) under “Forms/Manuals,” and pertain to PIs who are transferring their laboratory to another location either within or outside the University.

This form also covers clearances for equipment disposal.

Contact Safety Services (368.2907) if you have any questions concerning the above procedures. Procedures for decommissioning laboratories using radioactive materials are available in the Radiation Safety Lab User Manual (available on the EHS website http://case.edu/ehs under “Forms/Manuals”). It is important that these items be completed before equipment is disposed of, or you leave the University.

SAFETY RULES FOR LABORATORIES

STANDARD OPERATING PROCEDURES

Introduction to Safe Laboratory Practices

A number of rules for safe laboratory practices are outlined below. This listing is intended to provide a practical base line for laboratories required to handle hazardous chemicals. Because of the nature of specific chemical hazards, this list is not comprehensive, but it will help PIs provide an appropriate safety plan for their laboratories. EHS is available for consultation on all safety and health-related issues.

1. General safety

    a. **Be alert to unsafe conditions and actions, calling attention to them so corrections can be made as soon as possible. Safety is a community responsibility.**

    b. Post warning signs and labels when unusual hazards such as radiation, lasers, flammable materials, infectious agents, or other special hazards exist.

    Caution/Emergency Information Signs (available from Safety Services) are to be posted on all entrances to the laboratory, clearly visible to personnel entering the lab. The Emergency Contact Information must be completed (listing two laboratory contacts) on each posted sign.

    c. Unauthorized minors and general population are prohibited in all laboratories.

    d. Visitors in laboratories must be accompanied by faculty, staff, or a graduate student. Visitors must wear the appropriate PPE in labs presenting a chemical or physical hazard.

e. No undergraduate laboratory class work shall be carried out in the absence of an instructor. Unauthorized experiments, as well as misconduct, are prohibited. Unapproved variations in experiments, including changing the quantities of reagents, may be dangerous and must be strictly guarded against in undergraduate laboratories.

f. DO NOT PERFORM HAZARDOUS PROCEDURES WHEN WORKING ALONE. This rule may be relaxed whenever there are other laboratory personnel in the area.

g. Eating, drinking, chewing gun, taking medications, applying cosmetics, and the use of certain hand lotions, as well as smoking, are prohibited in ALL laboratory areas.

h. According to OSHA Standard 29 CFR 1910.1030 (Occupational Exposure to Bloodborne Pathogens), hand lotion is not considered a cosmetic and is permitted. However, after this rule went into effect, it was brought to OSHA's attention that petroleum-based hand lotions affect the integrity of latex gloves. The following is a list of five recommended hand lotions that are non-petroleum based should:

- Johnson and Johnson Baby Lotion
- Cetaphil
- Jason Natural Cosmetics

Nexcare

- Keri Lotion

If you are concerned that the hand lotion you are using contains petroleum, contact Safety Services (368.2907).

2. Personal Protective Equipment (PPE)

a. The minimum PPE requirement for a laboratory is goggles/face shield, a buttoned laboratory coat, and appropriate chemically resistant gloves. **Laboratory coats, gloves, and other PPE shall not be worn outside the laboratory area.**

b. Clothing shall be appropriate to the laboratory – long pants and regular shoes, for example. Sandals or open-toed shoes, shorts, ties, or other dangling clothing can pose a safety threat in the laboratory.

c. Contact lenses are a risk when working with hazardous chemicals. Particulate matter, vapors, and liquids can lodge behind the contact lens, causing considerable eye damage before they can be washed with water from an eyewash station. In addition, solvent vapors can weld contact lenses to the eyes, requiring surgery to remove them.

d. Select appropriate gloves when working with toxic or corrosive materials. Call the glove manufacturer or consult Appendix C of this LSM for a discussion of glove compatibilities. Glove compatibilities can also be found under "Laboratory Safety" – "Glove Page" on the EHS website (http://case.edu/ehs) under "Chemical Safety."

e. Proper PPE must be worn at all times in the laboratory. Avoid direct contact with all chemicals. Keeping chemicals away from hands, face and clothing (including shoes) is especially important. Many substances are readily absorbed into the body through the skin, or may enter through the mouth because of contamination of the hands. In case of any accidental contact with chemicals, immediately wash the site of contact with soap and copious amounts of water, but take care not to abrade the skin.

f. A change of clothing should be available in the laboratory in case of an accident.

3. Housekeeping

   a. Aisles and hallways shall have proper egress.

   b. Keep drawers and cabinets closed while working.

   c. Avoid slippery floors by picking up any ice, glass beads, glass rods, or other small items. Mop up any spilled water.

   d. Keep the workplace uncluttered. Benches, floors, desks, and tables are work areas, not storage spaces. Keep the workplace free from extraneous chemicals and non-essential objects.

4. Safety with chemicals

    a. All heating of potentially hazardous chemicals must be performed in a chemical hood. Prior to heating a liquid, place boiling stones in vessels (other than test tubes). Use an alcohol thermometer (mercury thermometers are prohibited in laboratories) in a boiling liquid if there is the possibility of a dangerous exothermic decomposition, as in some distillations. Explosions are one of the most serious physical hazards in the laboratory.

    b. NEVER place your nose directly over a container to smell the contents.

    c. NEVER look down the opening of a vessel unless it is empty.

    d. Caution should be used when opening bottles which the lid or stopper is stuck. Wrap the bottle with a towel and place it in a container before applying additional force. The same precaution should be taken when opening ampoules.

    e. All containers with hazardous chemicals must be clearly labeled with the contents of the container. Use the complete chemical name, not the chemical formula or abbreviation (see *Chapter Four*).

    f. NEVER use any substance from an unlabeled or inadequately labeled container. Any unlabeled containers should be disposed of according to the University guidelines on waste disposal outlined in Chapter Four of this LSM.

    g. Flasks containing large volumes of toxic solutions, volatile solvents, boiling liquids and so forth, should be kept in pans large enough to contain the contents if the flask breaks. These should also be transported in appropriate transport containers.

    h. All chemicals or biological materials with an objectionable odor should be kept in the chemical hood or in an appropriately vented safety cabinet.

5. Waste disposal

    a. Hazards to the environment must be avoided by following the University guidelines on waste disposal outlined in Chapter Four of this LSM.

    b. Chemicals shall not be poured down the sanitary drains except for specific instances described in Chapter Four of this LSM.

Laboratory Practices for Specific Procedures

1. Flammable substances

    a. A chemical fume hood should be used for reactions in which flammable vapors are released (e.g. during the distillation of ether). If noxious or flammable gases are likely to be evolved in any process, the equipment must be confined to a chemical fume hood behind an explosion shield (see *Chapter Two* for a discussion of chemical fume hoods.)

    b. Ethers and other peroxide-forming chemicals should be dated when they are received and when they need to be disposed of. Ether should not be stored past the expiration date. Purchased ethers generally contain inhibitors to prevent the build-up of peroxides. Any distilled or processed ether no longer contains these inhibitors and should be used immediately or disposed of using the University guidelines on waste disposal for ethers described in Chapter Four of this LSM.

    c. Do not pour ether, petroleum, or other flammable water-immiscible liquids into the sanitary sink to be washed down with water. Fires and explosions have been caused in laboratories by vapors returning through the drainage system (e.g. during aspiration or rotary evaporation). See the University guidelines on waste disposal outlined in Chapter Four of this LSM.

    d. Dispose of glass in special waste receptacles designed and labeled for glass.

2. Reactive substances

    a. When conducting a reaction where there is a possibility of an explosion, use a face shield that is sufficiently large and strong enough to protect the face and neck, or use a standing shield. Goggles must be worn even when using a shield.

    b. When sodium, potassium, or lithium is used, the cuttings or residual pieces must be immediately disposed of by properly using the University guidelines on waste disposal described in Chapter Four of this LSM. Store these metals in oil, toluene, xylene, or other saturated hydrocarbon with a high boiling point.

    c. NEVER leave chemical reactions unattended that have not achieved kinetic equilibrium.

3. Corrosive substances

    a. Always pour acid into water. NEVER add water to acid as it can cause an exothermic reaction. For the same reason, pour concentrated solutions into water or less concentrated solutions while stirring.

    b. Always rinse the outside of acid bottles before opening them. Do not place a cap from an acid bottle on a surface where someone may rest a hand or arm. Keep acid bottles tightly closed. Rinse and dry them before storing them (do not store acids with bases). Make certain that no spills remain on tables, floor, or bottle.

    c. Bottles containing acids or other corrosive liquids shall be carried in the protective containers supplied for that purpose.

    d. Use the proper techniques for inserting and removing a glass tube from a stopper. Protect your hands. Shortcuts can lead to a severe puncture wound.

4. Electrical equipment

    a. All electrical connections should be grounded.

    b. Service cords for electrical equipment should be in good condition. Qualified personnel should repair frayed cords or exposed wires.

    c. Avoid overloading circuits. Do not use multiple outlet plugs for additional connections.

    d. Do not handle any electrical connections with wet hands or when standing in or near water.

    e. Do not use electric equipment, such as mixers or hot plates, around flammable chemicals.

    f. Do not try to repair equipment yourself unless you are qualified and fully understand the repairs required. Qualified personnel should do all repairs.

    g. NEVER try to bypass any safety device on a piece of electric equipment.

    h. In case of a fire on or near any electrical equipment, turn the equipment off if it can be done safely.

5. Apparatus

   a. Use pipetting devices. Do not mouth pipette chemicals.

   b. Know the location of the nearest safety shower, fire extinguisher, fire blanket, eyewash station, and spill kit to be used after a chemical has been spilled.

   c. Apparatus attached to a ring stand should be positioned so that the system’s center of gravity is over the base and not to one side. The lower the center of gravity, the better. Leave adequate room for removing burners or baths.

   d. Equipment with moving parts (gears, belts, and pulleys) must be equipped with protective guards.

   e. Make certain all personnel who operate centrifuges are well trained. Centrifuge tubes should be in good condition with no chips or other flaws. Tubes and rotor buckets must be balanced when in use. Inspect the rotors periodically and do not use them beyond their stated lifetime.

   f. Each water supply outlet within the laboratory must be equipped with either a vacuum breaker or a backflow prevention device. No auxiliary plumbing should be connected to a water distribution line unless adequate backflow prevention is provided.

   g. Secure all gas cylinders against walls or laboratory benches with safety straps or chains to prevent them from falling. Compressed gas cylinders in use should have pressure regulators attached to them and gas cylinders being in storage or empty gas cylinders should have valve protection caps secured on them. Store compressed gas cylinders by gas compatibility (no oxygen and hydrogen gas cylinders stored together). Store incompatible gas cylinders within at least 20 ft from each other.

   h. Use undamaged, clean glassware without chips or other flaws.

   i. Dewar flasks should be taped when in use or enclosed in metal mesh to protect personnel from shattered glass particles.

   j. Glass devices in vacuum systems should be epoxy-coated, taped, or shielded with wire mesh to protect personnel from fragmentation.

k. Sink traps and floor drains should be kept filled with water at all times to prevent escape of sewer gases into the laboratory. Such gases may be toxic or flammable and may be ignited, causing flash fires.

l. Do not use or place burners, hot plates, or non-explosion proof motors near experiments which may generate flammable gases.

m. Use beaker covers to prevent splattering when heating liquids on a hot plate. Keep a pair of tongs conveniently at hand. A specific tong for the dish crucible, beaker, casserole, or flask should be used.

n. In general, if the apparatus is likely to shatter either because of pressure or vacuum, surround it with mesh or cloth to limit the possibility of shards of shattered glass from becoming dangerous projectiles.

o. Glassware or any potential SHARPS (including chemical bottles and test tubes) should be set back from the front edge of the work bench to lessen the risk of injury if there is an accidental breakage of glass.

p. Adequate traps must be used in vacuum systems. When using a vacuum source, it is important to place a trap between the experimental apparatus and the vacuum source. The vacuum trap:

    i. Protects the pump and the piping from the potentially damaging effects of the material which could be infectious (if being used inside of bio-safety cabinet).

q. Protects maintenance workers who must work on the vacuum lines or system.

   Prevents vapors and related odors from being emitted back into the laboratory or system exhaust.

   Do not release the vacuum in any apparatus when the temperature is greater than 167ºF. The hot vapors may explode. To prevent contamination, all lines leading from experimental apparatus to the vacuum source should be equipped with filtration or other trapping as appropriate.

    i. For **particulates**, use filtration capable of efficiently trapping the particles in the size range being generated.

ii. For most **aqueous or non-volatile liquids**, a filter flask at room temperature is adequate to prevent liquids from getting to the vacuum lines and vacuum source.

iii. For **solvents** and other volatile liquids, use a cold trap of sufficient size and cold enough to condense vapors generated, followed by a filter flask capable of collecting fluid that could be aspirated out of the cold trap.

iv. For **highly reactive, corrosive or toxic gases**, use a sorbent canister or scrubbing device capable of trapping the gas.

v. Periodically disinfectant the chemical trap flasks. MAKE sure that disinfectant is compatible with chemicals collected in flask.

vi. Inline HEPA filters should be used as vacuum line filters; they should be inspected and replaced if clogged.

vii. Vacuum traps/flasks should be placed into secondary containers to prevent leakage in case of a broken flask.

r. Oven temperature regulators should be checked periodically to ensure the oven is functioning properly.

s. Bunsen burners should never be left burning when not in use. They should be turned off at the petcocks – do not depend upon the valve at the base of the burner.

t. Do not use natural gas in laminar flow or non-vented hoods.

u. Use laboratory approved heat guns in lieu of hairdryers. Switches and heating elements may cause a spark hazard.

PERSONAL PROTECTION: ADMINISTRATIVE CONTROLS, ENGINEERING CONTROLS, AND PPE

Introduction

Administrative controls, engineering controls, and PPE are designed to address and prevent hazards associated with the introduction of chemicals into the body. The major routes of entry into the body are inhalation, skin absorption, ingestion, injection, and subcutaneous entry. Engineering controls that ventilate gases, vapors, and small particulates are designed to eliminate the hazards associated with inhalation – the major route of entry. PPE is designed to eliminate exposure through all the above routes of entry and is to be used in conjunction with administrative and engineering controls.

Administrative Controls

Administrative controls are methodological procedures are those incorporated into activities in order to eliminate or minimize the potential for exposure to hazards. These include isolation of the operator or the process; hazards education; job rotation to limit time exposure to hazardous substances; substitution of less hazardous equipment or process (e.g. safety cans for glass bottles); and substitution of a less hazardous substance.

Engineering Controls

Engineering controls include tools or devices that reduce the hazard at the source. These include: Local and general ventilation (e.g. use of chemical fume hoods); use of biological safety cabinets or glove boxes; placing walls or increased distance between the operator and the hazard; and using appropriate disposal containers.

1. Laboratory ventilation

    a. Control of airflow in the laboratory – Safety in laboratory areas partially depends upon keeping infectious, toxic, and flammable airborne materials away from personnel. Controlling airflow helps accomplish this.

    b. Laboratory doors – In general, doors to laboratories should remain closed. When the airflow is correctly balanced, air pressure in the corridor is higher than in the laboratories and the air flows under the doors and through the door slots into the laboratory. This moving curtain of air keeps airborne substances generated in the work areas from entering the corridors.

2. Chemical hoods

    a. In general, chemical hoods offer two significant types of protection from atmospheric exposure to hazardous materials:

        i. Local ventilation to prevent toxic, offensive, or flammable vapors from entering the room.

        ii. A physical barrier between the researcher and the chemical reaction when that reaction is performed in a chemical fume hood, especially with the chemical fume hood sash closed. This barrier can protect the researcher from hazards such as chemical splashes or sprays, fires, and minor explosions.

    Chemical fume hoods should be considered primary safety devices that can contain and exhaust toxic, offensive, or flammable materials when the design of an experiment fails and particles or gases/vapors escape from the apparatus being used. Fume hoods should never be used as a means of disposing chemicals.

    Chemical fume hoods are tested at least annually by Safety Services, using two methods of testing:

        iii. Velocity testing is performed annually on each chemical fume hood with a smoke test to assure that the chemical fume hood has not deviated from the conditions under which the hood passed its ASHRAE 110 Tracer Gas test.

        iv. ASHRAE 110 Tracer Gas testing is performed on each chemical fume hood once in a five-year cycle. The fume hood is velocity tested during the other two years. The ASHRAE 110 Tracer Gas test utilizes SF_6 (sulfur hexafluoride) as a tracer gas that is released into the fume hood. A gas detector is used to measure leakage from the hood under varying conditions. If the fume hood does not spill more than an average of 100 ppb of SF_6 during the test, the fume hood passes this test.

    If you need assistance or more information about a chemical fume hood in one of your laboratories, or if your chemical fume hood is not posted with a label or sticker showing that it has been tested within the past year, contact Safety Services (368.2907).

NOTE: Use perchloric acid only in a specifically designated chemical fume hood. DO NOT use other chemicals in that chemical hood. Clearly mark that the chemical fume hood is for use only with perchloric acid.

b. Safe chemical fume hood work practices

   i. Keep work surfaces within the fume hood clear.

   ii. Make sure the exhaust blower is operating and air is entering the fume hood prior to starting an experiment.

   iii. If there is a problem with airflow, call Plant Services (368.2580). They will notify Safety Services, if necessary.

   iv. Do not disable flow measurement devices or alarms.

   v. Work with the sash at the proper operating level as indicated by Safety Services' sticker test arrows.

   vi. Do not place your face inside of a chemical fume hood. Keep hands out as much as possible.

   vii. Keep sources of emission at least six inches inside the fume hood.

   viii. Do not store chemicals in the fume hood. Immediately clean-up minor spills. Provide catch basins (secondary containers) for containers that could break or spill, to minimize the spread of spilled hazardous materials.

   ix. Avoid blocking the baffle exhaust slots in any manner. Keep large equipment two inches off the base of the chemical fume hood and at least two inches from the sides of the hood.

   x. Be aware of other room ventilation factors that may interfere with the chemical fume hood operation, such as open doors and windows, blocked exhaust ports, or heating and air conditioning vents.

   xi. Avoid cross drafts and disruptive air currents in front of the chemical fume hood.

        xii. Use the sash as a safety shield when boiling materials or conducting an experiment with reactive materials.

        xiii. Close the chemical fume hood sash when the hood is not in use.

3. Laminar airflow equipment

   Two types of laminar airflow equipment – the Biological Safety Cabinet (BSC) and the laminar flow clean bench – are discussed in this section. NOTE: Laminar flow hoods are not safety devices.

   a. *BSC* – If biological safety is an issue with your work, use a BSC with or without glove attachments as warranted by the experiment. BSC's include 100% exhaust laminar flow hoods and glove boxes with chemical traps or exhaust access to a chemical fume hood.

      Laminar flow equipment (including BSCs) will be leak tested, adjusted, or repaired by a certified contractor. Submit a request for repair or recertification, available on the EHS website (http://case.edu/ehs) under "Biological Safety."

   b. *Laminar flow clean bench* – Protects the product from airborne contamination but does not protect the operator. Because of the risk to personnel, working with hazardous materials on a laminar flow clean bench is not advisable. Use of clean benches should be limited to the preparation of sterile media, the assembly of sterile components into complete units (e.g. membrane filters), the examination of sterilized equipment and materials for possible contamination, and similar operations. **Work with pathogens is not permitted.**

      A large number of companies manufacture both vertical and horizontal laminar flow clean benches. Most of the commercially available equipment is adequate when:

      i. The High Efficiency Particulate Air (HEPA) filter has been tested and certified. To meet standards, this filter should be at least 99.97% efficient in removing particles 0.3 microns or larger by the Dioctylphthalate (DOP) test.

      ii. The HEPA filter housing has been properly sealed around the edges to prevent unfiltered air from bypassing the filter.

      iii. The airflow is adjusted to 80-100 linear feet per minute.

The pre-filter is periodically cleaned or replaced when the magnahelic gauge indicates it is full because of a pressure drop.

4. Biological Safety Cabinet

   The BSC protects both product and operator and may be used for organisms which exceed Biosafety Level 2. (See CDC/NIH publication "*Biosafety in Microbiological and Biomedical Laboratories*" for a list of organisms and applicable biosafety levels. Check the CDC/NIH website regularly for updated information: http://www.cdc.gov/ods/ohs.) Safety and desirability of using this equipment to contain infectious material should be determined on an individual basis, depending upon the agent, the proposed activity, and the need to prevent cross-contamination. This hood, however, cannot replace the standard gastight Class III BSC for extremely hazardous work.

   Do not use open flames in a BSC.

Personal Protective Equipment

Along with carefully planned work practices, administrative and engineering controls, PPE is the key element in minimizing the potential for worker exposure to hazardous chemicals. Proper use of PPE requires that the supervisor assess the hazard presented and attempt to apply administrative and/or engineering controls first. PPE is used when administrative and/or engineering controls will not be effective.

The performance of PPE as a barrier to chemicals is determined by the materials and quality of its construction. Three important factors to keep in mind when considering PPE are:

i. In general, there is no such thing as "impermeable" plastic or rubber clothing;

ii. No one clothing material will be a barrier to all chemicals; and

iii. For certain chemicals or combination of chemicals, there is no commercially available glove or clothing that will provide more than an hour's protection following contact. In this case, it is recommended that PPE be changed frequently or as soon as it comes into contact with chemicals or hazardous mixtures.

Of principal importance in the selection of PPE for protection from chemicals is: the rate at which chemicals permeate clothing materials, and the time elapsed between the contact with the chemical, and the appearance of the chemical on the inside of the PPE (called breakthrough time).

1. Respiratory Protection

   The basic purpose of any respirator is to protect the respiratory system from inhalation of hazardous atmospheres. Respirators provide protection either by removing contaminants from the air before it is inhaled or by supplying an independent source of respirable air.

   Safety Services has implemented a comprehensive Respiratory Protection Program. This training involves a physical examination at University Health Services, getting fit-tested with a respirator through Safety Services, and receiving proper training. Refer to the CWRU Respiratory Protection Program, which can be found on the EHS website (http://case.edu/ehs) under “Laboratory Safety – Forms and Manuals”. Annual retrain and fit-test are required for all respirator users. Respirator use, mandatory or voluntary, requires prior approval from Safety Services.

2. Dermal protection

   a. Gloves – Type of PPE that serves as hand protection and used to prevent cuts, abrasions, burns, and skin contact with chemicals that are capable of causing local or systemic effects following dermal exposure. Proper gloves must be used in the laboratory and should be selected on the basis of chemical compatibility (see *Appendix C*). In general, latex gloves do not provide adequate protection and are not recommended for any chemical operation. Reusable gloves that are readily available on campus include: Neoprene and nitrile-butadiene rubber. For the best gloves to use with your laboratory process, contact Safety Services (368.2907), or refer to the glove compatibility table listed in Appendix C of this LSM, or refer to the EHS website (http://case.edu/ehs) under “Laboratory Safety – Glove Page.”

   b. Laboratory coats – Should always be worn during active work in the laboratory and should be buttoned completely. Laboratory coats are loose-fitting by design so, in case of chemical contact, there is ample time to react before a chemical gets to the undergarments and ultimately to the skin. Laboratory coats shall not be taken home for any reason. They are not to be laundered in a public laundromat; instead, arrangements should be made in the laboratory group for laundry service.

      Refer to the EHS website (http://case.edu/ehs) under “Laboratory Safety – Forms and Manuals” for further laboratory coat laundering information.

3. Eye protection

   This LSM defines eye hazard areas where wearing eye protection equipment is mandatory. It also sets forth the supervisor's responsibilities, both in identifying locations where possible damage to the eyes could occur and in enforcing precautionary procedures in those areas.

   The Occupational Safety and Health Act of 1970 and good safety practices dictate that "protective eye and face equipment shall be required where there is a reasonable probability of injury that can be prevented by such equipment – suitable eye protectors shall be provided where machines or operations present the hazard of flying objects, glare, liquids, injurious radiation, or a combination of these factors."

   The type of eye protection required depends on the hazard. For most situations, safety glasses with side shields are not adequate. Where there is danger of splashing chemicals or hazardous gases/vapors, special non-ventilated sealed goggles are required. For more hazardous operations, a face shield or a combination face shield and safety goggles shall be used. **Failure to wear and to require the persons supervised to wear the prescribed eye protection equipment will present grounds for disciplinary action.** Safety Services can assist in the choice of suitable protective eye equipment.

   a. Special hazards – **Contact lenses shall not be worn by persons exposed to hazardous chemicals. It is the responsibility of supervisors to identify employees who wear contact lenses.** Contact lenses do not provide eye protection. The capillary space between the contact lenses and the cornea may trap material present on the surface of the eye. Chemicals trapped in this space cannot be washed off the surface of the cornea. If the material in the eye is painful or the contact lens is displaced, muscle spasms will make it very difficult to remove the lens.

      Supplies of caustic chemicals (e.g. ammonia solution, liquid phenol, acids, strong bases, etc.), should be stored no higher than countertop level to minimize the possibility of facial and upper body burns in the event of spills or breakage of containers. It is also a good practice to use the smallest size container compatible with the need.

   b. Eyewash facilities – Emergency eyewash facilities shall be available in the following areas, or other areas as deemed necessary, where:

      i. Chemicals are handled
      ii. Explosive materials are handled
      iii. Hollow glassware is under vacuum or pressure

    iv. Cryogenic materials are handled
    v. Airborne particles may be generated (grinders, mills, power saws, drill presses, lathes, etc.)
    vi. Molten metal is used or metal is melted (soldering, leading joints, etc.)
    vii. Gas or electric arc welding is performed
    viii. Processes can produce aerosols of infectious agents (e.g. removing lyophil vials from liquid nitrogen)

c. Supervisor's responsibilities – **Failure of the supervisor to enforce eye protection requirements will present grounds for disciplinary action.** The supervisor is responsible for:

    i. Determining that an eye hazard exists
    ii. Placarding the work area with proper signage
    iii. Determining the type of eye protection equipment needed
    iv. Obtaining necessary assistance from Safety Services
    v. Ensuring that the equipment is available to employees
    vi. Ensuring that the necessary PPE is worn by employees
    vii. Supplying all PPE as necessary

CHEMICAL STORAGE

General Rules

1. Keep minimum quantities of chemicals in the laboratory. Purchase only what is needed. Never acquire more than a year's supply of reactive or combustible chemicals.

2. Chemicals shall be stored in cabinets or on shelves. Long-term storage of chemicals on the floor, benches, or in chemical hoods is prohibited. Liquids should be stored below eye level.

3. Use spill trays under containers of strong reagents. Perchloric acid should be kept on glass or ceramic trays of sufficient capacity to hold all of the acid in case of breakage.

4. Do not store chemicals past their expiration date. Ethers, for example, generally contain inhibitors to prevent the build-up of peroxides. Any distilled or processed ether no longer contains any inhibitors and should be used immediately or disposed using the University guidelines on waste disposal described in Chapter Four of this LSM.

5. Store chemicals according to compatibility. Within compatible classes, chemicals may be stored alphabetically. See Appendix D for a table of

incompatible chemicals or consult an MSDS.

6. Label all containers (new bottles as well as temporary containers) properly with the following information: Your name, PI name, date, contents, purity location, hazards (if known).
7. Dispose of unwanted chemicals promptly using the University guidelines on waste disposal described in Chapter Four of this LSM.

Storage of Flammable Chemicals

The following guidelines establish policy and describes cabinets for storing flammable chemicals in the laboratory. In this guide, flammable chemicals are defined as liquid substances having a flash point below 140ºF and having a vapor pressure not exceeding 40 p.s.i.a. at 100ºF. All flammable chemical supplies exceeding a cumulative total of two gallons when kept in one laboratory room must be stored in National Fire Protection Association (NFPA) approved flammable chemical storage cabinets. Safety Services can advise on NFPA approved cabinets.

1. Several sizes of cabinets are manufactured to fit funds and available space. Many laboratories may require storage of only a few chemicals and the supervisors may wish to share cabinets with adjoining laboratories.
2. Commercially manufactured flammable storage cabinets are sold by several laboratory supply firms. These larger boxes hold either 30 or 45 one-gallon containers.
3. Laboratory supervisors should determine their storage needs and order appropriately sized and certified flammable storage cabinets.
4. 4. Flammable liquids should not be stored in the refrigerators unless it is UL approved for flammable liquid storage. Storage of flammable liquids in household grade refrigerators is a fire/explosion hazard. Household grade refrigerators should be labeled: "No food or flammable liquid storage".

Storage of Corrosive Chemicals

The following guidelines establish policy and provide information pertinent to the safe storage of corrosive chemicals (acids and bases).

1. Acids and bases shall not be stored together or kept in a flammable storage cabinet. An exception is glacial acetic acid which is also flammable, and it is suggested to store glacial acetic acid in the certified

flammable storage cabinet.

2. Different types of storage cabinets are sold by laboratory supply firms. Acids and bases shall be stored in separate storage cabinets manufactured specifically for corrosives, or one cabinet with two isolated sections. In both cases, there shall be no risk of acids and bases coming into contact with each other in case of a spill or accident.
3. Maintaining neutralizing agents for acid and base spills is recommended.
4. Acids and bases shall not be stored with active metals such as sodium, potassium, or magnesium. Contact Safety Services for more information.

Hazardous Waste Storage

The proper storage of hazardous chemical waste is no different than the proper storage of hazardous chemicals. Hazardous waste is still hazardous chemicals.

1. Segregate the hazardous chemical waste by chemical properties to avoid adverse reactions.
2. Store flammable liquid waste in a flammable liquids storage cabinet or in containers clearly marked “Hazardous Waste”.
3. Do not store chemical waste acids with waste bases.
4. Do not store chemical waste oxidizers with flammable liquids.
5. Segregate all hazardous waste toxic materials from acids, oxidizers, and flammable liquids.
6. Hazardous waste can be stored properly with chemicals still in use as long as care is taken to avoid incompatibilities.
7. All hazardous waste chemicals must be labeled with the words “Hazardous Waste,” AND the chemical contents of the waste container.

Chemical Compatibility Chart

Group 1-A	**Group 1-B**
Alkaline Liquids	Acid Liquids

Potential consequences: Heat generation, violent reaction

Group 2-A	Group 2-B
Aluminum	Wastes in Group 1-A or 1-B
Beryllium	
Calcium	
Magnesium	
Sodium	
Other reactive metals and metal hydrides	

Potential consequences: Fire or explosion generation of flammable hydrogen gas

Group 3-A	Group 3-B
Alcohols	Concentrated waste in Groups 1-A or 1-B
Water	Calcium
	Lithium
	Metal hydrides
	Potassium
	SO2Cl2, SOCl2, PCl3, CH3SiCl3
	Other water-reactive wastes

Potential consequences: Fire, explosion, or heat generation; generation of flammable or toxic gases.

Group 4-A	Group 4-B
Alcohols	Concentrated Group 1-A or 1-B wastes
Aldehydes	Group 2-A wastes
Halogenated hydrocarbons	
Nitrated hydrocarbons	
Unsaturated hydrocarbons	
Other reactive organic compounds and solvents	

Potential consequences: Fire, explosion, or violent reaction.

Group 5-A	Group 5-B
Spent cyanide and sulfide solutions	Group 1-B wastes

Potential consequences: Generation of toxic hydrogen cyanide or hydrogen sulfide gas

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Group 6-A
Chlorates
Chlorine
Chlorites
Chromic acid
Hypochlorites
Nitrates
Nitric acid, fuming
Perchlorates
Permanganates
Peroxides

Group 6-B
Acetic acid and other organic acids
Concentrated mineral acids
Group 2-A wastes
Group 4-A wastes
Other flammable and combustible wastes

Potential consequences: Fire, explosion, or violent reaction.

CWRU HAZARD WARNING SIGNS

In an effort to bring the system of signs used at CWRU into agreement – to warn of danger and to direct pedestrian traffic away from laboratory work areas – uniform hazard warning signs have been designed. This LSM describes these signs and sets forth the conditions under which the signs are to be posted. It is important that all employees and visitors comply with the policy for entering areas where these signs have been posted.

Description

Samples of commonly used warning signs are illustrated on the EHS website (http://case.edu/ehs – see “Labels and Warnings” under “Laboratory safety”). The signs inform employees and visitors that a hazard exists in an area. The degree of danger is indicated by the sign. In high-risk areas, admission is forbidden except to those assigned to that area. In low-risk areas, visitors must obtain permission from the PI to enter the laboratory.

Policy

The PI in charge of the laboratory is responsible for posting the signs in accordance with policy set forth in this LSM. Upon request, Safety Services will assist PIs in determining the need for posting warning signs.

The signs will be posted only while a hazard exists and must be taken down as soon as the source of danger is removed. Hazard signs will not be posted when no hazard exists simply to discourage pedestrian traffic through an area.

At the end of working hours, decontaminate laboratory work areas so that custodial personnel, plant personnel, firefighters, and other can safely enter the area. If this is not done, post a special “DANGER – DO NOT ENTER” sign. Hazard warning signs will show the name of the hazard, the PI and an alternate contact, and their home telephone or cell numbers. When appropriate, similar signs must be posted on both the laboratory and animal holding rooms.

The PI named on the hazard sign will determine when visitors are permitted in the laboratory. The PI is ultimately responsible for everyone’s including visitor’s safety while they are in the laboratory. Visits are restricted to those who have a need to observe laboratory procedures. Social visits by unauthorized individuals are prohibited in areas where biohazards are present.

Methods of Posting

Signs that are to be used permanently will be posted only in permanent frames. The PI in charge of the laboratory is responsible for requesting the installation of the frames. Signs that are to be used on a temporary basis (less than one month) will be posted in permanent frames if such frames have been installed. If frames have not been installed, these signs will be posted with masking tape on a glass surface or, if more appropriate, on refrigerators, freezers, doors, etc. Signs will not be posted with tacks, pins, or any adhesive material that would damage the doors, walls, or building when the signs are removed.

NFPA Signage

OSHA has adopted the National Fire Protection Association's (NFPA) standard 704 signage to indicate the hazards present in a given location. The NFPA diamond contains four sections. Each section contains a number from zero (for minimal hazard) to four (for the highest possible hazard). These signs shall be posted outside each laboratory and shall be filled in with the information on the highest possible hazard present in each laboratory. The color of the diamond indicates the type of hazard, while the number represents the degree of hazard.

Availability of Signs

The PI in charge of the laboratory is responsible for obtaining the appropriate signs and frames. These are available through most laboratory supply companies. Most commonly used signs are available from Safety Services.

Special signs for shared cold or warm rooms, and experiments in progress, are available from Safety Services. Experiments that are in progress after regular business hours (8:30 a.m. – 5:00 p.m.) or on weekends and holidays, must have an "Experiment in Progress" sign posted on the door. The signs and labels can be ordered from EHS by following instructions in the order form: (http://case.edu/ehs – see "Caution Sign and Label order form" on the bottom of the page under "Laboratory Safety" link).

HEALTH HAZARDS

TOXICOLOGY

General Definitions

1. "Toxicology" is the study of the nature, effects and detection of poisons and the treatment of poisoning.

2. "Toxicity" is the degree to which a substance can harm humans or animals, and the chemical's ability to produce injury once it reaches a susceptible site in or on the body.

3. "Toxicity hazard" is the probability that injury will occur considering the manner in which the substance is used.

Dose-Response Relationships

The potential toxicity inherent in a substance is manifest only when that substance comes into contact with a living biological system. A chemical normally thought of as harmless will evoke a toxic response if added in sufficient amount to a biological system. The toxic potency of a chemical is thus ultimately defined by the relationship between the dose (the amount) of the chemical and the response that is produced in a biological system.

Routes of Entry Into the Body

There are four main routes by which hazardous chemicals enter the body:

1. **Inhalation** through the respiratory tract is the most important in terms of severity and the most common route of exposure.

2. **Absorption** through the skin is the most frequent cause of occupational disease (such as dermatitis).

3. **Ingestion** through the digestive tract can occur through eating with contaminated hands or in contaminated work areas.

4. **Injection** into the skin by contaminated sharps such as a needle or broken glass.

Most exposure standards, Threshold Limit Values (TLVs), and Permissible Exposure Limits (PELs), are based on the inhalation route of exposure when airborne gases, fumes or particulates of the chemical enter the body via respiratory system. These limits are normally expressed in terms of either parts per million (ppm) or milligrams per cubic meter (mg/m^3) in air.
If a significant route of exposure for a hazardous substance is through skin absorption, its MSDS will have a “skin” notation. Examples include pesticides, carbon disulfide, carbon tetrachloride, dioxane, mercury, thallium compounds, xylene, hydrogen cyanide, and benzene.

Exposure Definitions

1. **Acute** poisoning is characterized by rapid absorption of the substance and the exposure is sudden and severe. Normally, a single large exposure is involved. Examples include carbon monoxide or cyanide poisoning.

2. **Chronic** poisoning is characterized by prolonged or repeated exposures of a duration measured in days, months, or years. Symptoms may not be immediately apparent. Examples include lead or mercury poisoning, and pesticide exposure.

3. **Local** refers to the site of action of an agent and means the action takes place at the point or area of contact. The site may be skin, mucous membranes, the respiratory tract, gastrointestinal system, eyes, etc. Absorption does not necessarily occur. Examples include strong acids or alkalis.

4. **Systemic** refers to a site of action other than the point of contact where presupposed absorption has taken place. Examples include an inhaled material that may act on the liver; arsenic affects on the blood, nervous system, liver, kidneys, and skin; benzene affects in bone marrow.

5. **Cumulative** poisons are characterized by materials that tend to build up in the body as a result of chronic exposure. The effects are not seen until a critical body burden is reached. Examples include heavy metals.

6. **Synergistic** or **potentiating** effects occur when two or more hazardous materials are present in combination. The resulting effect can be greater than the effect predicted based on the individual substances. Examples include transport or carrier substances, such as dimethylsulfoxide (DMSO), which is readily absorbed through the skin and can carry with it a more dangerous substance, which by itself is not easily absorbed.

Other Factors Affecting Toxicity

1. Rate of entry and route of exposure.
2. Concentration of chemical present in the air or amount of chemical absorbed into the body.
3. Age of affected individual, possibly affecting the capacity to repair tissue damage.
4. Previous exposure history, possibly leading to tolerance or increased sensitivity.
5. State of health, physical condition, and lifestyle. Pre-existing disease can result in increased sensitivity.
6. Environmental factors such as temperature and pressure.
7. Host factors including genetic predisposition and the sex of the exposed individual.

MATERIAL SAFETY DATA SHEETS

Definition and Policy

A chemical's MSDS provides the user with information on that particular chemical. The information is provided by the manufacturer or distributor of that chemical. OSHA requires that the MSDS for each chemical used in the laboratory be accessible to every employee of that lab. A compilation of MSDS' are available online through the EHS website (http://case.edu/ehs), under "MSDS." This MSDS system is available 24-hours a day through the EHS website. However, EHS recommends that laboratories download, in Adobe Acrobat format (.pdf), the MSDS for each chemical used in their laboratory in the event of a University power failure.

CLASSIFICATION OF TOXIC MATERIALS

Physical Classifications

1. A **gas** is a substance that exists in a state of single molecularity at room temperature and pressure, having the capability of indefinite expansion.
2. A **vapor** is the gaseous phase of a material which is ordinarily a solid or a liquid at room temperature and pressure.

When considering the toxicity of gases and vapors, the solubility of the substance is a key factor. Highly water-soluble materials, such as ammonia, irritate the upper respiratory tract. However, low water-soluble materials, such as nitrogen dioxide, penetrate deep into the lung. Fat-soluble materials, such as pesticides, tend to have longer residence times in the body.

3. A **liquid** is the state of matter between a solid and a gas. Liquids present skin and ingestion hazards. A liquid can evaporate to the gaseous state and present a respiratory hazard.

4. An **aerosol** (including smog, smoke, fumes, etc.) is composed of microscopic solid or liquid particles dispersed in a gaseous medium. The toxic potential of an aerosol is only partially described by its concentration in milligrams per cubic meter (mg/m^3). For a proper assessment of the toxic hazard, the size of the aerosol's particles is important. Particles above 5 µm tend to deposit in the upper respiratory tract. Particles below 5 µm enter the lungs. Very small particles (<0.2 µm) are generally not deposited but are instead absorbed like gases or vapors.

Physiological Classifications

1. Respiratory

    a. **Mucous membranes** (nose, mouth, throat, lungs) may become inflamed by contact with certain chemical irritants. Inflammation of tissue results from concentrations far below those needed to cause corrosion. Examples include ammonia, alkaline dust and mist, arsenic trichloride, diethyl/dimethyl sulfate, hydrogen chloride, hydrogen fluoride, halogens, nitrogen dioxide, ozone, phosgene, and phosphorus chlorides. Irritants can also cause changes in the mechanics of respiration and lung function. Examples include acetic acid, acrolein, formaldehyde, formic acid, iodine, sulfuric acid, and sulfur dioxide. Long-term exposure to irritants can result in increased mucous secretions and chronic bronchitis.

        i. A **primary** irritant exerts no systemic toxic action either because the products formed on the tissue of the respiratory tract are non-toxic or because the irritant action is far in excess of any systemic toxic action. An example includes hydrogen chloride.

        ii. A **secondary** irritant's effect on mucous membranes is overshadowed by the systemic effect resulting from absorption. Exposure to a secondary irritant can result in pulmonary edema, hemorrhage, and tissue necrosis.

Examples include hydrogen sulfide, and aromatic hydrocarbons.

b. **Central nervous system depressants**, such as anesthetics, affect the brain. Examples include chloroform, diethyl ether, hexane, and other nerve-depressing organic substances and alcohols. Many other chemicals also have deleterious effects on the central nervous system.

c. **Asphyxiants** have the ability to deprive tissue of oxygen. Simple asphyxiants are inert gases which displace oxygen. Examples include carbon dioxide, hydrogen, helium, nitrogen, and nitrous oxide. Chemical asphyxiants render the body incapable of utilizing an adequate oxygen supply. They can cause damage at very low concentrations. Examples include carbon monoxide, and hydrogen cyanide.

d. **Pulmonary agents** damage the lungs. Examples include asbestos, coal dust, cotton dust, silica, and wood dust. Dusts can cause a restrictive disease called pneumoconiosis ("black lung" disease). Other types of lung injuries include edema, which can be caused by hydrogen fluoride, nickel carbonyl, and perchlorethylene; and emphysema, which can be caused by ozone and oxides of nitrogen. Signs and symptoms include tightness in chest, and shortness of breath.

2. Skin and ingestion

   a. **Skin toxins** may result in anything from acute irritation to corrosion. Benzocaine, formaldehyde, and neomycin are common chemicals which cause contact allergies. A **sensitizer** causes a substantial proportion of exposed people to develop an allergic reaction in normal tissue after repeated exposure to the chemical. The reaction may be as mild as a rash (contact dermatitis) or as serious as anaphylactic shock. Examples include chlorinated hydrocarbons, chromium compounds, epoxies, nickel compounds, dicyclohexylcarbodiimide (DCC), and toluene diisocyanate. Signs and symptoms include defatting of the skin, rashes, and irritation.

   b. **Eye toxins** cause damage to the eye by direct contact, like any of the skin or mucous membrane toxins, or by systemic chemicals. The antimalarial drugs quinacrine and chloroquine have been shown to affect the cornea after oral administration. Signs and symptoms include conjunctivitis, and corneal damage.

3. Systemic

    a. **Hepatotoxic agents** cause damage to the liver. Examples include carbon tetrachloride, nitrosamines, and tetrachloroethane. Signs and symptoms include jaundice, and liver enlargement.

    b. **Nephrotoxic agents** damage the kidneys. Examples include halogenated hydrocarbons, and uranium compounds. Signs and symptoms include edema, and proteinurea.

    c. **Neurotoxic agents** damage the nervous system. The nervous system is especially sensitive to organo-metallic compounds and certain sulfide compounds. Examples include carbon disulfide, manganese, methyl mercury, organo-phosphate insecticides, tetraethyl lead, thallium, and triakyl tin compounds. Signs and symptoms include narcosis, behavioral changes, and decrease in motor function.

    d. **Hematotoxic agents** act on the blood, bone marrow, or hematopoietic system. Examples include aniline, benzene, nitrites, nitrobenzene, and toluidine. Benzene damages bone marrow which can lead to leukemia. Signs and symptoms include cyanosis (a bluish coloration to the skin) and loss of consciousness.

    e. **Carcinogenic agents** can initiate or speed the development of malignant or potentially malignant tumors or other malignant neoplastic proliferation of cells. Known human carcinogens are listed in Appendix B.

    f. **Reproductive toxins** cause damage to either the reproductive system directly or to the fetal tissue. 1,2-dibromo-3-chloropropane (DBCP) causes infertility (azoospermia) in males, while lead and ethylene oxide can cause infertility in males and females. **Teratogens** (embryotoxic or fetotoxic agents) interfere with normal embryonic development without damage to the mother or lethal effect on the fetus. Effects are not hereditary. Examples include lead, and DBCP (see *Appendix B* for a list of reproductive toxins). Signs and symptoms include sterility, and birth defects.

    g. **Immune system toxins**, specifically immunosuppression, can be caused by a wide variety of chemicals, including arsenic, benzene, cadmium, lead, methyl mercury, nitrous oxide, and polycyclic aromatic hydrocarbons (PAHs).

h. **Cardiotoxic agents** cause damage to the cardiovascular system. These chemicals may either cause damage to the heart directly (examples include aliphatic alcohols, aldehydes, and glycols) or they may also cause damage to the vascular system (examples include heavy metals such as lead, and cadmium).

WORKING SAFELY WITH HAZARDOUS CHEMICALS

It is the responsibility of the PI to determine the hazards associated with all of the chemicals used in his/her laboratory. There are many excellent compilations of the hazards associated with chemicals. The following references can be extremely useful and it is recommended that each laboratory have at least one of the following reference manuals available. All are available through the University libraries.

Suggested References on Hazardous Chemicals

Klaasen, C.D., Amdur, M., Doull, J., **Cassarett and Doull's Toxicology: The Basic Science of Poisons**, Third Edition, New York: Macmillan Publishing Company, 1986.

Lenga, R.A., **The Stigma-Aldrich Library of Chemical Safety Data**, Edition II, Volumes I and II, Sigma-Aldrich Corporation, 1988.

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National Research Council, **Prudent Practices for Handling Hazardous Chemicals in Laboratories**, Washington DC: National Academy Press, 1981.

Perrin, D.D., Armarega, W.L.F., Perrin, D.R., **Purification of Laboratory Chemicals**, 4th ed., New York: Pergamon Press, 1996.

Raffle, P.A.B., Lee, W.R., McCallum, R., Murray, R., **Hunter's Diseases of Occupations**, 8th ed., London, Boston: E. Arnold, 1994.

Richard J. Lewis Sr., **Hazardous Chemicals Desk Reference**, 6th Edition, Wiley, 2008
Pradyot Patnaik, A comprehensive guide to the hazardous properties of chemical substances, **3rd Edition**, **Wiley, 2007**

See the Select Bibliography for additional references.

Hazardous Chemicals

The following is a list of types of hazardous chemicals, divided into eight general classes based on the predominant effects of those general chemical types:

1. **Caustic** or **corrosive**: These are typically acids or bases which may burn or otherwise damage human tissue on contact. The corrosion of equipment should also be considered. Examples include chromic acid cleaning solutions; concentrated acids such as hydrochloric, sulfuric, and nitric; and acid-releasing substances such as thionyl chloride, and halogens (bromine, chlorine).

2. **Poisons**: The relative toxicity of this general class of chemicals is dependent on a large number of factors. This class would also include carcinogens. Examples include cyanide, and azide salts.

3. **Flammables liquids**: These are materials that will easily ignite, burn, and serve as a fuel for a fire. Examples include most common laboratory organic solvents such as acetone, tetrahydrofuran, diethylether, and petroleum distillates (pentanes, hexanes) as well as acetaldehyde, carbon disulfide, ether, methanol and glacial acetic acid.

4. **Explosives**: Chemicals in this class should be protected from shock, elevated temperatures, sparks, rapid temperature changes, and mixture with other reactive chemicals. Examples include nitroglycerin, nitrocellulose, and organic peroxides.

5. **Oxidizing** and **reducing agents**: The reactions of these agents can generate heat and are often explosive. Oxidizing agents include oxygen, perchloric acid, peroxyacids, peroxide forming compounds, and bleach (hypochlorite compounds).. Reducing agents include hydrogen, metallic hydrides, alkali metals, and active zinc and phosphorus.

6. **Water-reactive**: These chemicals react with water, steam, and moisture in the air to evolve heat and/or flammable or explosive gases. Isolate water sensitive substances from other reactive chemicals and store in a cool, dry area. Examples of chemicals that liberate heat only include strong acids and bases, acid anhydrides and sulfides. Examples of chemicals that liberate flammable gases include alkali metals, hydrides, nitrides, and anhydrous metallic salts.

7. **Acid-sensitive**: These chemicals react with acids to evolve heat, flammable and/or explosive gases and toxicants. Examples include alkali metals, cyanides, sulfides, carbonates, arsenic, and related elements.

8. **Pyrophoric**: These chemicals burn when exposed to air. In general, they require absolute protection from air. Examples include:
    a. Phosphorus (white or yellow)
    b. Alkali metals such as sodium and potassium
    c. Metal hydrides or nonmetal hydrides including germane, diborane, sodium hydride and lithium aluminum hydride
    d. Partially or fully alkylated derivatives of metal and non-metal hydrides like diethylaluminum hydride, trimethylaluminum, butyllithium and triethylboron
    e. Used hydrogenation catalysts such as Raney nickel
    f. Grignard reagents of the form RMgx
    g. Alkylated metal alkoxides or nonmetal halides such as diethylethoxyaluminum or dichloro(methyl)silane
    h. Metal carbonyls like pentacarbonyliron, octacarbonyldicobalt and nickel carbonyl
    i. Finely divided metals such as calcium and zirconium
    j. Methanetellurol (CH_3TeH)
    k. Pyrophoric gases include arsine, diborane, phosphine, and silane
    l. Pyrophoric liquids include hydrazine

Controlled Substances

Chemicals considered to be controlled substances are regulated by specific Federal and state regulations. In order to purchase and distribute controlled substances (such as opiates, barbiturates, or anesthetics), appropriate Federal and state licenses must be obtained. If use of these classes of chemicals is required, contact Safety Services for information at 216.368.2907.

Chemical Safety

The potential dangers that may be encountered when working with hazardous chemicals are very diverse and depend greatly upon the type of exposure. The dangers inherent in use of all chemicals in this LSM are not completely described.

It is the responsibility of the PI to be aware of hazards that exist when using the chemicals in his/her laboratory. MSDS' are available on the EHS website (http://case.edu/ehs) under "MSDS" and contain detailed information to inform workers of potential dangers of these materials.

WORKING SAFETY WITH EXTREMELY HAZARDOUS CHEMICALS

Select Carcinogens, Reproductive Hazards, and Chemicals with a High Degree of Acute Toxicity

When working with certain hazardous chemicals, the Laboratory Standard, 29 CFR 1910.1450, requires that you designate an area for such work. Chemicals for which special precautions are to be taken include carcinogens, reproductive toxins, and certain chemicals with a high degree of acute toxicity. A list of these substances is provided in Appendix B.

Creating a Designated Area

The designated area for use of extremely hazardous substances, as defined by the Laboratory Standard, may be a chemical fume hood or a portion of the laboratory, or the entire laboratory itself, depending on individual circumstances. The only requirements are that the area must be posted as to the nature of the hazard and that all employees who work in this area be informed as to the hazards involved. **"Employees" include maintenance personnel who may be exposed to the hazard while working in the area.**

In general, engineering controls such as chemical fume hoods or glove boxes are required to be used to contain select hazardous substances which may become volatile, result in the release of aerosols during manipulation, or may, through handling or reaction, result in the uncontrollable release of the substance. In addition, procedures for decontamination and the safe removal of contaminated material must be outlined. The PI is strongly urged to seek the advice of Safety Services prior to experimentation with these substances.

General Procedures

1. All guidelines for safe laboratory practice – such as use of proper eye protection, wearing proper protective clothing, following correct pipetting procedures, wearing the appropriate gloves, and not permitting smoking, eating, chewing gum, drinking, taking medications, or application of cosmetics in the laboratory – must be observed at all times in the laboratory, including when working with extremely hazardous chemicals.

2. Laboratory coats should be adequate to protect street clothing and should never be worn outside of the laboratory area.

3. Disposable gloves should be discarded after each use and immediately after overt contact with extremely hazardous chemicals. Gloves should never be worn outside of the laboratory area.

4. All personnel must wash their hands immediately after removing gloves and after the completion of any procedure using chemical hazards.

Operational Procedures

1. Work areas within a laboratory, where carcinogens or reproductive hazards are used, should be clearly marked with a warning sign which reads: “CAUTION – POTENTIAL CANCER HAZARD, AUTHORIZED PERSONNEL ONLY” or “CAUTION – POTENTIAL REPRODUCTIVE TOXIN, AUTHORIZED PERSONNEL ONLY.” Those areas used for storage of these chemicals should also be identified in a similar manner. Chemical-specific signs and labels are available from Safety Services.

2. Work areas where select hazards are being used should only be entered by authorized personnel. When extremely hazardous chemicals are being used in an area of a larger laboratory, the area should be clearly identified and should not be a high pedestrian traffic area in order to minimize exposure to uninvolved laboratory personnel with hazardous substances.

3. Work surfaces should be covered with impervious material such as dry absorbent plastic backed paper. The protective material should be decontaminated or disposed of as hazardous waste after the procedures are completed.

4. Adequate chemical traps must be used on all vacuum lines to prevent contamination of the vacuum systems. A separate vacuum pump should be used for extremely hazardous chemicals, and any service company should be informed of this use of the pump prior to servicing.

5. Procedures involving volatile chemicals, or those which may result in the generation of aerosols or dispersible particulates, should be conducted in a chemical fume hood. Work which may present a biological hazard should be conducted in a biological safety cabinet (BSC) or in a glove box. Precautions should also be taken to prevent exposure to aerosols that may be generated during such biological procedures. Equipment should be positioned so that any vapors or aerosols produced can be vented into a chemical fume hood. Aerosols can be generated from opening and closing vessels, transfer of chemicals (weighing chemicals), homogenization, open vessel centrifugation, and the application, injection, or incubation of extremely hazardous chemicals to experimental animals.

6. Minimum containment for tissue culture can be provided by a Class II, Type B BSC. The PI should refer to the CDC/NIH publication "*Biosafety in Microbiological and Biomedical Laboratories*," 5th Edition, USDHHS, 2007, for information concerning appropriate containment equipment and its usage (CDC website).
7. Stock and sample containers of regulated chemicals, as found in 29 CFR 1910 Subpart Z, should be stored in a designated area that is clearly marked with the warnings such as, "CAUTION – POTENTIAL CANCER HAZARD" or "CAUTION – POTENTIAL REPRODUCTIVE HAZARD." The PI must maintain an inventory of each carcinogen and other hazardous substances defined by OSHA as "regulated chemicals". This inventory should include the quantities and the date purchased. The storage vessel should also be marked with a label indicating the specific potential danger of the substance. Working quantities should be kept to a minimum and should also have the same label. Chemical-specific labels are available from Safety Services.

8. If it is necessary to transfer the chemicals from one site to another, the chemicals must be placed in durable secondary containment. Biologically contaminated materials should be placed in properly labeled biohazard bags to indicate the potential biohazard. Safety Services should be contacted for the proper disposal of hazardous chemical waste. Customer Services should be notified for disposal of biological waste. Organic liquid waste should also be disposed in containers per the University guidelines on waste disposal outlined in Chapter Four of this LSM. In all cases, prior to initiating any experiments with select chemical hazards, the PI should make plans for the handling of hazardous waste.

9. In order to ensure that the laboratory meets the standards for the use of a select chemical hazard (i.e. flow rate of the chemical fume hood), the PI should contact Safety Services prior to initiating experiments.

Working with Select Carcinogens

"Select carcinogens" are defined by the Laboratory Standard as being any substance which meets one of the following criteria:

1. It is regulated by OSHA as a carcinogen.

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).

3. It is listed under Group 1, "carcinogenic to humans," by the International Agency for Research on Cancer Monographs (IARC, latest edition).

4. It is listed in either Group 2A or 2B by IARC or under the category “reasonably anticipated to be carcinogens” by NTP. These chemicals cause 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 at dosages of less than 10 mg/m^3;

    b. After repeated skin application of less than 300 mg/kg of body weight per week (<20 g/week for an average adult);

    c. After oral dosages of less than 50 mg/kg of body weight per day (<3 g/day for an average adult).

The most recent list which fulfills the first three of these criteria is in Appendix B. Additional information on the use of chemical carcinogens can be obtained from the U.S. Department of Health and Human Services by requesting “*NIH Guidelines for the Laboratory Use of Chemical Carcinogens*” and from Chemsyn Science Laboratories which will supply “*Handling Chemical Carcinogens: A Safety Guide for the Laboratory Researcher*” by Mary K. Dornhoffer. Refer to the MSDS to determine whether a particular chemical falls into this category.

Working with Reproductive Hazards

“Reproductive hazards” is defined by the Laboratory Standard as “toxins (which) may manifest themselves in lethal effects on the fertilized egg, developing embryo or fetus or teratogenic (malformation) effects in the fetus. In addition, certain reproductive toxins may cause infertility in males and females.”

Reproductive hazards include chemicals which target developing embryos and fetuses. Ebryonic and fetal development is characterized by rapid growth and differentiation. In addition, maternal blood flow through the placenta increases and allows for fetal exposure to potential teratogens. Due to this unique sensitivity, any woman who believes she is pregnant should take special precautions to protect the developing fetus. If she chooses to declare her pregnancy, she should speak to her supervisor, informing him/her of her pregnancy, and they should then work together to develop ways to minimize her exposure to hazardous chemicals. Since disclosure of pregnancy is voluntary, the PI should protect his/her liability by warning all female laboratory employees of potential teratogenic or other reproductive hazards in the workplace. While no employee may be forced to resign from her job due to pregnancy, the PI should discuss any potential risks of exposure as soon as the fact of the pregnancy is known, and assist the employee in developing programs to minimize exposure.

The use of PPE or chemical fume hoods may substantially reduce exposures and they are of particular significance for a pregnant employee. Examples of reproductive toxins include benzene, mercury, ethylene dibromide, carbon monoxide, anesthetic gases (halothane), ionizing radiation, ethylene oxide, and glycidyl ethers. A more complete list of known reproductive hazards is presented in Appendix B. In addition, the MSDS may be consulted for information on additional chemicals with reproductive toxicity which may be in use in the laboratory. Safety Services is available for consultation on both hazards and means of reducing exposures.

Working with Substances with High Acute Toxicity

The Laboratory Standard requires that "**substances with high acute toxicity** such as hydrogen cyanide, hydrogen sulfide and nitrogen dioxide are included under the category of substances for which employers must consider the need for special precautions. Such substances may be fatal or cause damage to target organs as a result of a single exposure or exposures of short durations."

Experimentation with Animals

The use of extremely hazardous chemicals in experimental animals must be arranged with the personnel in the ARC. Call 368.3490 for information. Specific recommendations will be made by the Animal Research Committee on protocols to be used with chemical carcinogens.

ULTRAVIOLET RADIATION EXPOSURE

Effects of Exposure

The eyes and skin should not be exposed to direct or strongly reflected ultraviolet (UV) radiation. The effect of UV radiation overexposure is dependent on such factors as dosage, wavelength, portion of body exposed, and the sensitivity of the individual. Overexposure of the eyes will result in a painful inflammation of the conjunctiva, cornea, and iris. Symptoms will develop 3 to 12 hours following exposure. There is a very unpleasant foreign body sensation accompanied by watery eyes. The symptoms usually disappear in a day or two. Overexposure to the skin will produce erythema (reddening) 1 to 8 hours following exposure.

Protection Against Ultraviolet Radiation Exposure

Adequate eye and skin protection must be worn when working in a UV radiation area. Contact lenses do not offer protection against UV radiation. Safety glasses designed specifically for use with UV light and with side shields, or goggles with solid side pieces should be worn. The side pieces prevent the entrance of reflected UV radiation and direct radiation from a side source.

Skin protection is afforded by face shields, caps, gloves, gowns, etc. Overexposure to UV radiation should be reported to University Health Services.

For further information regarding UV radiation exposure, consult the EHS Physical Safety Manual available on the EHS website (http://case.edu/ehs) under "Plant Safety" link under "Forms and Manuals."

BIOLOGICAL HAZARDS

Any person working with infectious agents should be familiar with the CDC/NIH manual "*Biosafety in Microbiological and Biomedical Laboratories*." Safety Services recommends the CDC website for up-to-date information or to order a copy of the manual (http://www.cdc.gov/od/ohs).

For further information regarding bloodborne pathogens, consult "Working with Bloodborne Pathogens" in Chapter Five of this LSM.

Select Agent Program

All persons having access to select agents and toxins **MUST** complete forms and training which are available at Safety Services. The select agents and toxins are housed and used in special biological safety facilities and are specifically equipped for prion research.

CHAPTER FOUR

WASTE DISPOSAL AND WASTE REDUCTION

This chapter discusses the University procedures for all types of hazardous waste classifications, containment, labeling, and handling. These procedures are necessary for compliance with regulations of the United States and Ohio Environmental Protection Agencies (EPA & OhioEPA), the Nuclear Regulatory Commission (NRC), the Department of Transportation (DOT), the Occupational Health and Safety Administration (OSHA), and the Ohio Department of Health (ODH).

PIs and area supervisors must ensure that the appropriate personnel follow the procedures outlined in this LSM. Call Safety Services (368.2907) with specific hazardous waste disposal questions or problems. In the University Hospitals' area, contact UH Safety (844.1458) for hazardous waste disposal procedures. For disposal of SHARPS and biohazardous waste in CWRU buildings, contact Customer Services (368.2580) to schedule a pick-up. In University Hospitals' buildings, contact the Environmental Services Department (844.3071).

All researchers who handle potentially hazardous materials should recognize the hazards and be aware of procedures required to protect themselves and the environment from the effects of these materials.

The determination of whether a material is regulated as a hazardous waste is often a complex task. Generally, the physical state of a material (e.g. solid, liquid, gas) is not a determining factor. When in doubt, assume that the material is hazardous waste and manage the material accordingly until you receive instructions to the contrary from Safety Services.

DISPOSAL OF CHEMICAL WASTE

Disposal of Chemicals

Wastes regulated by the EPA as "hazardous wastes" are not permitted to be disposed in the sanitary sewer or in the normal trash. These waste chemicals must be retained by each laboratory in a separate container labeled with the hazardous waste tag provided by Safety Services.

Laboratories are permitted to accumulate and store waste under what is known as Satellite Accumulation. Bins and labels for Satellite Accumulation are available by contacting Safety Services (368.2907). A laboratory may not store more than 55 gallons of waste chemicals. Safety Services must be notified when storage capacity exceeds 55 gallons or 1 kilogram of acutely hazardous waste.

The following procedures should be performed to properly dispose of hazardous waste:

1. Segregate hazardous chemical waste by compatibility (see table below) and clearly label waste bottles with the hazardous waste tags provided by Safety Services. Plastic bottles are preferred over glass for storing hazardous waste, but first check the compatibility of the waste with the specific plastic. Compatibility charts are available from EHS

2. When containers have reached their capacity, or when laboratory safety requires disposal, complete a Hazardous Waste and Unwanted Chemical Disposal Listing Form and return it to Safety Services. Chemicals will be picked up for disposal at the earliest possible date after receipt of this form. In the University Hospitals' area, contact Environmental Services (844.3071). Chemical waste containers should be labeled with the following information and must be accompanied by a completed Hazardous Waste Information Form:

    a. Identity (full chemical name) and quantity of the waste
    b. Generation date of the waste
    c. Place of origin (department, room number)
    d. PIs name and telephone number
    e. Bottle number assigned on corresponding waste sheet

<u>Table of Incompatible Chemicals</u>

Chemicals may be sorted and stored in the following categories. Care should be taken since it is not unknown for two chemicals in the same group to be incompatible.

Acids	Bases
Oxidizers	Reducers
Flammable Liquids	Non-Flammable Liquids
Toxics/Poisons	Non-Hazardous Chemicals

The following general classes of chemicals are incompatible with one another:

General Classes of Incompatible Chemicals*	
Acids, oxidizing agents	**Bases, metals, reducing agents**
Chlorates Chromates Chromium trioxide Dichromates Halogens Halogenating agents Hydrogen peroxide Nitrates Nitric acid Perchlorates Peroxides Permanganates Persulfates	Ammonia, Anhydrous and aqueous Carbon Metals Metal hydrides Nitrites Organic compounds Phosphorus Silicon Sulfur

*These examples of oxidizing and reducing agents are illustrative of common laboratory chemicals; they are not intended to be exhaustive. See Appendix D for a table of specific chemical incompatibilities.

Hazardous Waste Labeling and Waste Procedures

All materials destined for disposal, that are regulated by the EPA under CFR 40 and may not be disposed to the environment, are considered hazardous wastes. Containers must be labeled “hazardous waste” and contain all the information previously listed above.

Laboratories must maintain “weekly leakage logs” for the storage containers used for chemical waste. The log must be in a bound composition book with date of inspection, name of inspector, and the status of the waste container at that time (“acceptable” or “leaking”). It is recommended that the PI choose a member of his/her staff to conduct the weekly (every seven days) inspections and to keep the log in the laboratory area for future Safety Service inspections.

1. Handling and storage instructions for hazardous wastes
    a. Ignitable liquids and organic solvents
        i. Keep halogenated solvent wastes separate from non-halogenated solvent wastes.
        ii. Separate organic solvents from aqueous solutions.
        iii. For larger waste volumes, use a covered 5-gallon metal can.

    iv. For smaller waste volumes, or for solvents that react with metal, use a covered 1-gallon glass (or, preferably, plastic) container (check compatibility).

b. Acids, bases, and aqueous solutions

    i. Collect concentrated acids or bases in 1-gallon glass bottles if possible; otherwise, use a covered 5-gallon container. **Exception:** hydrofluoric acid must be stored in plastic.

    ii. Do not mix strong acids or oxidizers with organic compounds.

    iii. Keep all perchloric acid wastes in exclusive-use containers.

c. Heavy metal solutions

    i. Keep solutions containing arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, or other heavy poisonous metals separate from other wastes.

d. Paint and paint thinners

    i. Keep water and water-based paint wastes separate from oil-based wastes. Rinsate from water-based paint clean-up is non-hazardous and can be disposed of in the sanitary sewer.

e. Used chromatographic adsorbent

    i. When possible, segregate chromatographic adsorbents from liquid wastes.

f. Indicate the chemical in the adsorbent material and its concentration of contaminants.

g. Animal waste contaminated with hazardous chemicals

    i. Procedure for handling animal wastes are implemented by the ARC (368.3490).

h. Mixed waste (radioactive waste combined with chemical waste or radioactive waste combined with bio-hazardous waste). Please contact Safety Services (368.2907) for detailed guidelines in proper disposal of mixed wastes.

i. Broken mercury thermometers

    i. Attach a hazardous waste tag to the container with broken mercury thermometer and label the material as “broken thermometer and elemental mercury.”

    ii. NOTE: Mercury volatilizes and can be a hazard. Even the mercury from one thermometer can create a potential health risk. Call Safety Services (368.2907) for disposal and pick-up. In the University Hospitals’ area, contact UH Protective Services (844.HELP) or UH Safety (844.1458).

    iii. For larger spills of mercury (>3 cc), evacuate the area and call Safety Services. They will respond, clean the spill, and monitor the room air to ensure the area is safe to re-enter. For a spill in a University Hospitals’ laboratory, operated by Case Western Reserve University employees, contact Protective Services at 368-3333. They will then call Safety Services.

2. Discarded hazardous substances

    a. Gas cylinders

        i. Promptly return discarded or empty gas cylinders and lecture bottles to the vendor to regain your deposit on the cylinder and minimize rental charges. Small lecture bottles must be disposed of as a hazardous chemical waste.

    b. Chemicals in original containers

        i. Label these containers with the same information as you would a hazardous waste.

Disposal of Chemicals in Sanitary Sewers (Drains)

Hazardous wastes are regulated by the EPA under the Resource Conservation and Recovery Act (RCRA). In general, these regulations do not permit any drain disposal, except for those items listed below. For questions, contact Safety Services (368.2907).

1. Inorganic acids and bases that have a pH between 5 and 10.

   These pH limits are imposed by regional sewer regulations. Sewer disposal is permitted provided no other regulated chemical is present. Neutralization is permitted to change the pH to within acceptable limits if it is written into the experiment's protocol.

2. Aqueous buffer solutions containing no regulated materials or biohazardous threat (e.g. common salt solutions or tissue culture media).

   Such solutions may contain millimolar concentrations of common biochemicals, buffers, serum by-products, or cell metabolites. When in solution, common salts (chlorides, bromides, bicarbonates, citrates, phosphates, sulfates, acetates) of sodium, potassium, magnesium, ammonium, and calcium may be disposed in the sanitary sewer.

3. Aqueous High Performance Liquid Chromatography (HPLC) solutions or other solutions containing less than 24% ethanol, propanol, or isopropanol (no other alcohols).

   The 24% limit is based on flammability of the alcohol. HPLC solutions containing any amount of acetonitrile or other organic solvents must be disposed through Safety Services. In University Hospitals, contact UH Safety (844.1458) to arrange for disposal of these chemicals.

4. Bacteriological and tissue culture media.

   All media containing live organisms must be sterilized by autoclaving or by another acceptable procedure and must not contain anything other than common biochemicals. Serum byproducts or cell metabolites containing azides or thioglycolate must be disposed by Safety Services or, in University Hospitals, by UH Safety.

5. Mixed waste handling must be taken care of properly, and all waste handling protocols must be included in the laboratories Chemical Hygiene and Exposure Control Plans. **SAFETY SERVICES and/or THE RADIATION SAFETY OFFICE MUST BE CONTACTED BEFORE ANY MIXED WASTE IS GENERATED FOR DISPOSAL.** Mixed wastes include:

a. Radioactive-Chemical mixed waste must be classified by chemical and level of radioactivity before drain disposal. Refer to the Radiation Safety Laboratory User Manual for disposal procedures and acceptable limits. The manual is available on the EHS website (http://case.edu/ehs) under "Forms/Manuals."

b. Radioactive-Biohazardous waste must either be disinfected, then disposed of as radioactive waste, or held until 10 half lives are reached, then be disposed of as biohazardous waste. **DO NOT GENERATE THIS MIXED WASTE WITHOUT FIRST CONSULTING EHS**

c. Radioactive-Biohazardous waste must either be disinfected, then disposed of as radioactive waste, or held until 10 half lives are reached, then be disposed of as biohazardous waste. This can be very tricky. **DO NOT GENERATE THIS MIXED WASTE WITHOUT FIRST CONSULTING EHS**

6. No more than unavoidable traces of highly toxic organic chemicals, such as those found on glassware surfaces, of either synthetic or biological in origin, should be allowed in the sanitary sewer.

NOTE: Hazardous waste cannot be diluted with a material which is not a waste (e.g. fresh water) in order to bring them to concentration suitable for drain disposal, unless this dilution is part of an experimental procedure.

DISPOSAL OF EXPLOSIVE OR EXTREMELY REACTIVE MATERIALS

1. Potentially explosive materials, such as dry picric acid or old ethers, will be picked up separately from other hazardous wastes. Contact Safety Services (368.2907) as soon as possible upon discovering potentially explosive materials.

2. In general, extremely reactive materials should be disposed in a compatible bottle. These should be taped if there is potential for explosion or implosion from developing pressure or vacuum.

3. Alert handling and disposal personnel to the hazardous nature of these items.

DISPOSAL OF SELECT AGENT

The "Destruction of Select Agent" form must be completed when a select agent and toxin is destroyed. The form can be downloaded from DOES web site under "Biological Safety" link in "Select Agents".

Before any destruction, please contact Safety Services (368.2907) to obtain permission and to verify the procedure. Destruction of select agents and toxins requires a 5-day notice to either APHIS or CDC. **Ignoring the notification procedure can result in fines and/or imprisonment.**

DISPOSAL OF OTHER LABORATORY WASTE

Classification of Waste and Disposal Procedures

Prior to disposal, non-chemical waste must be classified as one of the following: SHARPS, non-SHARPS, or uncontaminated laboratory waste.

Wastes which contain both chemical waste and another type of waste (e.g. animal parts stored in formalin) must be separated and disposed according to each pertinent waste policy. That is, the animal waste is disposed as biohazardous waste, and the formalin is disposed as chemical waste.

In addition, local landfills no longer permit the University to dispose of any biohazardous waste (whether or not autoclaved) or SHARPS in the regular trash. Therefore, it is essential to classify waste properly. Safety Services is available for consultation on a case-by-case basis. A summary of the following “bag” policies is described below. For University Hospitals, contact Environmental Services (844.3071) for information on disposal of biohazardous waste.

SHARPS

Definition: Examples include discarded hypodermic needles, syringes, and scalpel blades; cannulas, coverslips, microscope slides, all pipettes (glass or plastic) and pipette tips, test tubes, and glass Petri dishes; glassware, and any other item capable of causing puncture wounds or cuts.

Procedure: All SHARPS, contaminated or not, must be contained in puncture-resistant containers. Call Customer Service (368.2580) for disposal.

a. All needles, syringes, and scalpel blades; and any SHARP designed for use in biological, etiological, bacteriological, or tissue culture work must be placed in red rigid SHARPS containers. Call Purchasing (368.2560) for a list of vendors. **Hypodermic needles should not be recapped, clipped, broken, or disassembled.**

Under no circumstances are hypodermic needles, syringes, scalpel blades; or materials designed for use in biological, etiological, bacteriological, or tissue culture work permitted to be disposed of in any container other than the red rigid SHARPS container. All needles, syringes, scalpel blades and razor blades, whether contaminated with biologicals or not, must be disposed of in a properly marked and labeled rigid sharps container.

b. All other SHARPS (such as broken glassware) which are **NOT** contaminated may be discarded in red SHARPS containers or in a cardboard box labeled “SHARPS.” The box must be lined with a plastic bag to prevent leaking, and sealed with tape. The box must be clearly labeled “SHARPS” so that anyone inspecting the box will be aware of the nature of the hazard.

c. Empty glass chemical bottles must be marked “MT” or “EMPTY” with its label defaced or removed and, once decontaminated, be placed in a cardboard box marked “SHARPS” and sealed with tape. All bottle caps must be removed. A bottle is decontaminated after it is triple rinsed. The first rinsate is disposed of as hazardous chemical waste. The second and third rinsates can be disposed of in the drain. This same procedure is followed for disposal of plastic and metal containers except, once decontaminated, they are discarded in regular trash.

IMPORTANT: **NO** items that have been contaminated by chemotherapeutic drugs or anti-neoplastic agents (with the exception of trace amounts) can be disposed in SHARPS containers. Call Safety Services (368.2907) for disposal alternatives.

Radioactive SHARPS – Refer to the Radiation Safety Laboratory User Manual for the proper disposal of radioactive SHARPS. This manual is available on the EHS website (http://case.edu/ehs) under “Forms and Manuals.”

2. Non-SHARPS

Definition: All infectious plastic Petri plates and plastic tissue culture vessels containing media, cultures, and stocks of infectious agents; devices used to transfer, inoculate or mix such agents; and paper or cloth material contaminated with these agents.

Procedure: All of the above materials present a potential hazard to workers and must be treated prior to disposal. Treatment of this waste is the responsibility of each researcher.

Laboratories should maintain preventive maintenance and repair activity records for all instruments and equipment (including pH meters, analytical balances, incubators, refrigerators, autoclaves, and water baths). Steam sterilization for the appropriate amount of time and at the proper temperature is the simplest, most effective method. STEAM SHOULD BE CONDUCTED AS CLOSE TO THE POINT AND TIME OF WASTE GENERATION AS POSSIBLE.

All waste must be sterilized in red or orange biohazardous bags. All bags must be able to be autoclaved and conspicuously labeled with the international biohazard symbol. Biohazard bags can be ordered from scientific supply houses. After sterilization and cooling, these bags are to be denoted “sterilized” and tagged with the PI’s name and date of sterilization.

NO SHARPS (which includes glass, plastic pipettes and tips) are permitted to be placed in these autoclaved bags or any other bag. Such SHARPS are a hazard when handling these bags and cause contaminants to leak from bags in transit. They must be disposed if in a red rigid SHARPS container as biohazardous SHARPS.

After all autoclaved biohazardous waste has been appropriately tagged, Custodial Services will remove the waste in the evening for incineration. Arrangements for pick-up must be made by contacting Customer Service (368.2580) by 4:30 p.m. All biohazardous bags must remain in the laboratory for evening pick-up. Biohazardous waste must be disposed of expeditiously.

Liquid biomedical waste that has been treated to render it non-infectious can be poured in the sanitary drain, which should then be flushed with water.

EXCEPTIONS

a. Any liquid biomedical waste which contains radioactive materials. Contact Radiation Safety (368.2906) to receive disposal instructions for this exception or refer to the Radiation Safety Laboratory User Manual.

b. Any liquid biomedical waste which contains hazardous chemicals as set forth in the University Chemical Disposal Policy. Contact Safety Services (368.2907) to receive disposal instructions for this exception.

3. Uncontaminated laboratory waste

Definition: All laboratory waste which has not been contaminated by radioactive, chemical, or infectious agents, such as: Petri plates, plastic tissue culture vessels, paper cloths, gloves, tubing, non-sharp laboratory wastes, empty chemical containers, as well as “ordinary trash” such as computer paper, cardboard, packing materials, and the like.

Procedure: **Pick-up is provided by Custodial Services.**

DISPOSAL OF RADIOACTIVE WASTE

The RSOF provides radioactive waste pick-up and radiation disposal services for all University laboratories. Typically, individual laboratories collect radioactive waste in suitable containers, label the material with a yellow radioactive waste tag, and provide secondary packing, if necessary. A Disposal Listing for Radioactive Waste Form must be completed and faxed to the RSOF (fax: 368.2236). An RSOF specialist will call the laboratory to arrange a time and date for pick-up.

WASTE REDUCTION AND RECYCLING

Wastes regulated by the EPA are not permitted to be disposed of in the sanitary sewer or into a landfill, making them expensive to dispose of in an environmentally responsible manner. Reducing the amount of hazardous waste produced, both before the experimental procedure and after, and recycling whenever possible, provides a vital means of controlling the amount of hazardous waste generated.

Waste Reduction Procedures

1. Pre-experiment techniques

    a. Pre-weigh chemicals for undergraduate teaching laboratories. This will reduce spills and other wastes generated by students weighing their own materials.

    b. Substitute less hazardous chemicals in experiments to reduce the cost of the disposal of hazardous chemicals (i.e. use alcohol instead of benzene; sodium hypochlorite instead of sodium dichromate).

    c. Use alcohol or digital thermometers instead of mercury thermometers which are easily broken and extremely expensive to clean up and dispose of. (Mercury thermometers are prohibited in laboratories).
    d. Purchase only what is needed. Do not order larger quantities to take advantage of unit cost savings. Future

disposal for the unused portion of the chemical greatly exceeds the initial savings. The University's supplies store (Fisher Scientific stock room) sells chemicals in smaller quantities at bulk prices to facilitate waste minimization in laboratories.

2. Post-experiment techniques

    a. When cleaning with solvents, use spent solvent for the initial cleaning and use fresh solvent only for the final rinse.

    b. Destroy wastes as part of the last step of the experiment, if possible, provided the result is not a regulated material (call Safety Services to confirm). Such end-procedure neutralization techniques include oxidation-reduction, or precipitation and filtration of solids.

    c. Label all containers, new or temporary, with the proper information, even if the solutions they contain are innocuous. Disposing of an "unknown" waste, which is what materials in unlabeled containers often become, requires time-consuming and costly analysis. In addition, unknowns are dangerous in that they may explode or cause adverse reactions.

Recycling Procedures

Items currently managed by Safety Services for recycling as a hazardous waste are fluorescent and ultraviolet lamps, computers and computer monitors, batteries, lead, and paints.

Fluorescent lamps contain small amounts of mercury (0.6 mg), as well as lead found in the end caps. These items are currently managed as a recyclable material. Custodial Services will pick-up and remove fluorescent lamps provided they are properly boxed and marked. The laboratory may also treat fluorescent lamps as hazardous waste by labeling the boxed lamps with the hazardous waste tag, completing the Hazardous Waste Disposal Form, and submitting the form to Safety Services. This may be necessary with smaller laboratory scale lamps since they are considered laboratory materials.

E-Waste

Computers and computer monitors and other electronic devices contain large amounts of lead in the solder of the circuit boards. Monitors in the form of Cathode Ray Tubes (CRT) also contain barium. Both are highly regulated materials. If you wish to dispose of any electronic waste please complete the online e-Waste disposal request form which can be submitted via email by clicking the "SUBMIT" button at the bottom of the form. The form can be found on DOES web site under “Laboratory Safety” link: https://www.case.edu/ehs//LabSafety/equipment.html

CHAPTER FIVE

SPECIFIC LABORATORY PROCEDURES

CENTRIFUGE SAFETY

This LSM provides standards for the use of bench and floor centrifuges commonly used in clinical and biochemical laboratories, and procedures to be followed if a centrifuge accident occurs. Each employee using the centrifuge must become familiar with requirements for operation of the instrument. Assistance is available upon request from Safety Services (368.2907).

Each employee shall be instructed on proper operating procedures before being permitted to use the centrifuge. Instructions should include requirements for balancing loads, using the proper centrifuge head, and using accessory equipment. Conditions for loading and operating an ultra-centrifuge and preparative centrifuge vary considerably. Therefore, even experienced investigators should review procedures before operating an unfamiliar instrument.

Each employee who uses a centrifuge is responsible for the condition of the machine at the end of the procedure. This includes entering data in the log book, turning off the power, and cleaning spills, broken glass, etc. Detailed records of operation should be made for most high-speed centrifuges and rotors. The safe speed that rotors can be operated is determined by a rating formula which is based on numbers of starts and stops, rpm, and total “G” loads. Also, warranty coverage and service procedures for the machine are determined by hours of operation. These records should be kept in log books placed near each machine.

1. Safety precautions

    a. Laboratory area

        Rooms where live etiologic agents are centrifuged should be identified with a warning sign. Because of the hazards involved, continuous flow centrifugation of live etiologic agents may be done only in installations approved by Safety Services, including using batch type zonal rotors that require seal disconnection when in operation. This protocol must be included in the laboratory’s Exposure Control Plan.

b. Tubes

Reusable centrifuge tubes and centrifuge buckets should be carefully inspected prior to each ultra-centrifuge cycle. Only sound tubes and buckets should be used to process infectious material. Reusable tubes used in an ultra-centrifuge are subjected to great pressure, which sometimes causes them to break, especially after they have been through several cycles. Tubes likely to fail can often be identified by stress lines which appear in the area of junction of the sides and the bottom. Such tubes should be discarded.

Tubes to be used in angle-head centrifuges must never be filled to the point that liquid is in contact with the lip of the tube when it is placed in the rotor, even though the meniscus will be vertical during rotation. When the tube lip is wetted, high G forces drive the liquid past the cap seal and over the outside of the tube.

Nitrocellulose tubes should be used only when “fresh,” meaning, clear, without discoloration, and flexible. Small lots should be ordered several times a year instead of one large lot once a year. Storage at 4ºC extends shelf life. Used nitrocellulose tubes should be disinfected in a solution known to be effective against the agent being processed and discarded as solid waste.

c. Carrier rotors and cups

Rotor corrosion can create a hazardous condition, best prevented through cleanliness. Ultra-centrifuge heads in particular must be protected. After each use, the rotor should be rinsed in warm tap water and then with distilled water. If solid deposits persist, clean with a mild detergent solution and a stiff test tube brush. Do not scratch the surface of the tube wells in aluminum rotors. Rinse off the detergent with warm tap water and distilled water, and dry before use. Since caustic solutions are particularly damaging to rotors, clean them promptly after use.

When centrifuge tubes are used in dirty or rough cups, the tubes expand and seize against the walls of the cup, making it very difficult to remove the tubes. In some instances, tubes have had to be pulled with pliers and have been torn or broken in removal. To avoid this possibility, the inside of the cups may be sprayed with a silicon aerosol spray or similar product (see instructions that come with these ultra-centrifuges, as rotors require special care which may differ from instructions in this guide).

2. Post-accident procedures

    a. Major accident

       In case of a major centrifuge accident involving potential exposure to hazardous chemical or biological materials, immediately contact Safety Services (368.2907) for instructions.

    b. Spill response

       Clean-up and decontamination of laboratory equipment for reuse are the responsibilities of the user. Safety clearances for disposal of equipment contaminated with biohazardous or radioactive materials will be carried out by EHS If the spill involves pathogens or radioactive materials, EHS must be contacted immediately (Safety Services: 368.2907; Radiation Safety: 368.2906). In University Hospitals, contact UH Environmental Services (844.3071) for instructions on disposal of biohazards.

COMPRESSED GASES IN CYLINDERS

Users of compressed gases should be familiar with the pertinent equipment and the characteristics of the gases. Safety Services has information available on most of the gases likely to be used in CWRU laboratories. It has detailed information available on detecting leaks, selecting needle valves and regulators, toxicity, explosion hazards, chemical incompatibilities, etc. Use of flammable or explosive gases (i.e. hydrogen gas) requires notification of and prior approval by Safety Services.

General Standards

1. Rules for handling compressed gases

    a. Always use a cylinder hand truck for transport.

    b. Chain or otherwise secure cylinders in an upright position, away from chemical and mechanical damage. Only two cylinders may be chained together in a group. To store more than two cylinders in the same grouping, a cylinder rack must be installed.

    c. Do not drop cylinders or permit them to fall against each other.

    d. Leave valve caps on cylinders until secured and ready for use.

    e. Close all valves when not in use.

f. Use the proper regulator for the particular gas.

g. Always consider cylinders to be full and handle accordingly.

h. Cylinders should be considered empty when approximately 25 psi still remains, in order to prevent contaminated air from entering the tank.

i. See the table below for maximum size and quantity of cylinders permitted in any one laboratory unit.

	Flammable Gases and/or Oxygen Sprinklered Space	Flammable Gases and/or Oxygen Nonsprinklered Space	Liquified Flammable Gases Sprinklered Space	Liquified Flammable Gases Nonsprinklered Space	Gases with Health Hazard Rating of 3 or 4
Max. number of cylinders per 300 sq. ft. or less	6	3	3	2	3
Max. cylinder size (in.)	10 x 50	10 x 50	9 x 30	9 x 30	4 x 15
Approx. water volume (ft.)	2.0	2.0	0.6	0.6	0.1

j. Identify the contents of cylinders with decals, stencils, glued or wired-on tags, or other markings on the cylinders. Color codes alone or tags hung around the necks of the cylinders are not acceptable. Cylinders lacking proper identification must not be accepted from the vendors. A safe handling procedures sign should be posted above the cylinder storage area. The information about compressed gas cylinders safety can be found on EHS web site under “Chemical Safety”.

k. Employees must not attempt to repair cylinders or cylinder valves, or to apply force to stuck or frozen cylinder valves.

l. Empty cylinders must be marked “EMPTY” or “MT” with grease pencils. Generally, this marking should be on a large piece of adhesive or masking tape secured to the cylinder. Some cylinders have tags wired to the valve that identify their contents; in this case, the bottom half of this tag may be torn off to indicate an empty cylinder. In all cases, empty cylinders must be easily identifiable so as to not be confused or stored with full cylinders.

m. Cylinders not in use must have cylinder caps in place.

n. It is both prudent safety practice and cost effective to return cylinders to vendors as soon as they are empty.

2. Storing compressed gases

   a. Store cylinders in a cool, dry, and adequately ventilated area. If the cylinder contains a flammable compressed gas, it must be stored in a fire-resistant area.

   b. The storage area should not contain any sources of ignition.

   c. Storage area temperature should not exceed 100ºF.

   d. The floor should be level and designed to protect cylinders from dampness.

   e. Cylinders should be protected from weather extremes, direct sunlight, and other heat sources.

   f. Store oxygen-containing cylinders at least 25 feet from fuel gases, preferably in another storage area.

   g. Cylinders shall be stored in a well-protected, well-ventilated, dry location, at least 20 feet from highly combustible materials.

   h. Cylinders should be stored in definitively assigned places away from elevators, stairs, or gangways, or other areas where they might be knocked over or damaged by passing or falling objects, or subject to tampering.

   i. Empty cylinders shall have valves closed.

   j. Valve protection caps, where the cylinder is designed to accept a cap, shall always be in place, hand-tight, except when cylinders are in use or connected for use. The valve protection cap is designed to protect the valve in case the cylinder falls.

   k. Fuel-gas cylinder storage shall be limited to a total gas capacity of 2000 cubic feet or 300 pounds of liquefied petroleum gas.

   l. Acetylene cylinders shall be stored valve end up. If the cylinder is on its side, acetone may leak out and create a dangerous condition.

a. Oxygen cylinders in storage shall be separated from fuel-gas cylinders or combustible materials (especially oil or grease), a minimum distance of 20 feet or by a non-combustible barrier at least 5 feet high having a fire resistance rating of at least one-half hour.

2. Other tips for safe handling of compressed gases

    a. Oil should never be used with oxygen. Oxygen under pressure will rapidly oxidize oil or grease and result in an explosion. Only equipment cleaned for oxygen service must be used for oxygen application.

    b. Without a proper regulator, or when exposed to an ignition source, acetylene can explode. It can also form explosive compounds in contact with copper or brass. An automatic pressure regulator is the only type of control valve satisfactory for acetylene.

    c. Regulators can leak and build pressure within a closed gas delivery system. Insert pressure relief devices and include appropriate traps in outlet lines to prevent liquid from flowing back into the cylinder. If the liquid phase is being delivered from the cylinder, a trap will not prevent backflow, but a check valve will. Traps should be of sufficient capacity to hold all of the materials which could be drawn back into a cylinder during its operation.

    d. Open the cylinder valve only after connecting the regulator to the cylinder using a proper National Compressed Gas Association regulator.

    e. Do not pressurize glass equipment. A general rule is: Do not apply pressure greater than 10 inches of water if you are not wearing protective equipment.

    f. Never mix gases in a cylinder. Explosion, contamination, corrosion, and other hazards can result.

    g. To prevent corrosion, regulators, valves, and fittings used in compressed gas systems which conduct corrosive gases should be flushed with nitrogen or dry air after each use.

    h. The cap should be firmly in place when moving the cylinder.

i. Any system should be leak-tested before it is used. To check for leaks, use a leak detector or spread liquid soap or soapy water over all joints. The system is leaking if any bubbles appear.

j. The researcher is responsible for knowing the characteristics of the gases being used: toxicity, flammability, compatibility with materials and other gases.

m. Contact the cylinder manufacturer immediately if a leak or other malfunction is discovered. If a poison gas, such as chlorine, or a flammable gas, such as hydrogen, is found leaking, immediately contact Protective Services (368.3333) and Safety Services (368.2907). In University Hospitals, contact UH Protective Services (844.4357).

n. Do not purchase a concentrated gas (such as hydrogen) and mix to a lower concentration. Purchase gas at the needed working concentration to avoid the possibility of explosion.

Restricted Products

1. Some highly toxic gases may have regulations concerning their use. Ethylene oxide is one such gas. Therefore, consult and obtain written permission from Safety Services before purchase of any such product. Safety Services must be notified of intent prior to their proposed purchase to allow time for making necessary safety preparations. Large cylinders of toxic gases should not be purchased if it is possible to use small cylinders.

2. Laboratories using toxic gases should have respirators available that are effective against the agent. The supervisor is responsible for ensuring that employees are instructed in how to use respirators and other protective equipment. **Respirators can only be used after training by Safety Services.** Contact Safety Services (368.2907) for information on respirator selection and training requirements of the University's Respiratory Protection Program.

Purchase and use of the following gases are controlled and some require respirator training before use:

Ammonia
Arsine
Boron trifluoride
Chlorine
Dimethylamine
Ethylene oxide
Fluorine
Hydrogen bromide (hydrobromic acid)
Hydrogen chloride (hydrochloric acid)
Hydrogen fluoride (hydrofluoric acid)
Hydrogen sulfide
Iodine pentafluoride (liquid shipped in gas-type cylinder)
Methyl bromide (bromomethane)
Methyl chloride
Nitric oxide
Nitrogen dioxide (nitrogen tetroxide)
Nitrogen trioxide
Nitrosyl chloride (nitrogen oxychloride)
Phosgene
Silicon tetrafluoride (tetrafluorosilane)
Sulfur dioxide

3. Safety Services will notify PIs in charge of laboratories as soon as a EHS specialist determines that requirements for safe use of the gas have been fulfilled. PIs planning to use these gases are reminded that some of them are extremely toxic and may require both isolated laboratory space and equipment that is not immediately available. Additional training may also be required for some gases such as ethylene oxide or hydrogen. For these reasons, certification for use should be requested well in advance of the proposed use.

Flammable Gases

Because of the fire and explosion hazards that can result when these products are used in confined spaces, special care must be taken:

1. When reactive cylinders are kept inside a building, do not manifold two or more cylinders together. However, several instruments may be operated from one cylinder.

2. If more than one cylinder of highly flammable gas is to be placed in a laboratory, written permission must be obtained from Safety Services. Consideration for granting permission will include size and location of the room, airflow, other equipment in use, and ease of access to cylinders.

3. Standby cylinders of flammable gases (full reserve cylinders) or empty cylinders must not be stored in laboratories. Cylinders must be stored in restricted, shaded spaces outside and delivered to the laboratory on demand.

4. Limit cylinder size to 210 cubic feet.

5. Close valves on flammable gas cylinders before all employees leave the laboratory at the end of their work day, unless the cylinders are being used in a controlled experimental environment.

6. Tank adapters may be used only upon written permission from Safety Services. Only the approved regulator and valve units specified for use with a specific gas may be used.

7. Piping must be compatible with the gas (e.g. no copper piping for acetylene; no plastic tubing in any high-pressure portion of a system).

8. Only the appropriate regulator and valve unit specified for use with a specific gas may be used.

Accepting Cylinders from Vendors

1. The contents of cylinders must be identified with decals, stencils, glued or wired-on tags, or other markings on the cylinders. Color codes alone or tags hung around the necks of the cylinders must not be used. Cylinders lacking proper identification must not be accepted from a vendor.

2. Cylinders must not be accepted from a vendor unless the valve safety covers are in place and properly tightened.

3. Cylinder valves must conform to standards of the National Compressed Gas Association (i.e. they must be in serviceable condition and free of corrosion).

Pressure Regulators and Needle Valves

1. The valve fittings of cylinders used to store different families of gases are different and will only allow regulators or needle valves to be attached that are safe for use with those gases. Cylinders must not be purchased or accepted whose fittings do not conform to standards of the National Compressed Gas Association. Use of adapters to connect regulators to cylinder valves defeats this safeguard and must not be used without written permission from Safety Services. Only pressure regulators and needle valves approved for the specific gases may be used.

2. Threads and points of unions must be clean and should be inspected before they are connected. Personnel must not attempt to lubricate threads or fittings.

3. When attaching regulators or needle valves, personnel must firmly tighten the connections. Nonadjustable wrenches of the proper size should be used. Pliers or adjustable wrenches should not be used as they damage the nuts, most of which are brass and rather soft. Need for excessive force often indicates that the regulators or needle valves do not fit the cylinders. Leaks at the unions between the regulators and the cylinder valves are usually due to damage to the faces of the connections. Attempts to force a tight fit may damage the previously undamaged half of the connection. If the cylinder valve faces are damaged, the cylinders must be returned to the vendor. Employees must not attempt to repair cylinders in regulators. Damaged regulators must not be used until repaired.

4. After attaching the pressure regulator to the cylinder, personnel should turn out the delivery pressure adjusting screw of the regulator until it turns freely. The cylinder valve should be opened slowly. Laboratory personnel should avoid standing directly in front of the regulator at any time as the pressure of the cylinder may blow out the glass face of a faulty gauge. The cylinder valve handle should be left attached to the valve while the cylinder is in use. A cylinder valve that “sticks” and does not open when the usual amount of force is applied, may be damaged. Personnel must not attempt to force it open, but should return the cylinder to the vendor, stating on the cylinder that the valve is stuck.

5. Pressure in full cylinders should be indicated on the cylinders or labels. Lack of full pressure may indicate leaks at the connections between the cylinders and valve regulators, damaged regulators, or incompletely filled cylinders.

6. Connect delivery lines to the low-pressure outlet of the regulator valve or to the needle valve. Where low-pressure lines are used, their valves should be closed, and the line pressure adjusted, by turning the regulator delivery pressure-adjusting screw until the desire pressure is shown on the delivery pressure gauge.

7. If the gases are not to be used over a considerable length of time (24 hours), the cylinder valves should be closed, the lines bled, and the pressure-adjusting screws turned back until they turn freely. Damage to gauges and inaccurate readings may result if pressure is left on the gauges during extended periods of non-use.

Leak Testing

Compressed gas cylinders are tested for leaks when they are filled. However, leaks have been detected when cylinders were received in laboratories. Personnel should not attempt to repair cylinder leaks or leaks caused by loose valve stem packing.

1. Leak testing using a soap solution should be performed twice. The first test should be made before the regulator or needle valve is attached to determine if there are leaks at the union of the cylinder and the cylinder valve, and to determine if the valve is leaking. The second test should be made after the regulator is attached and the cylinder valve is opened to detect leaks around the valve stem packing, the connecting fittings, the regulator or needle valve, or the transfer lines to the instrument.

2. Cylinders leaking nontoxic, nonflammable gas may be taken to a loading dock or other place having suitable airflow for regular and scheduled vendor pick-up. Leaks from cylinders of toxic or flammable gases require immediate attention and should be reported to Safety Services or University Security.

3. Assistance with problems arising during use of gas products can be obtained from EHS Safety Services, local fire departments, or Protective Services of University Hospitals, depending on the location of the laboratory and the hazard involved.

ULTRAVIOLET LIGHTS – USE AND MAINTENANCE

Ultraviolet (UV) radiation includes that portion of the radiant energy spectrum between visible light and X-rays (approximately 3900 to 136 angstrom units). Under certain conditions, including radiation intensity and exposure time, UV radiation will kill many types of microorganisms – its greatest effectiveness being against vegetative forms of organisms. UV light is not a sterilizing agent, except in certain exceptional circumstances. Rather, it is used to substantially reduce the number of microorganisms on surfaces and in the air.

Guidelines

Low-pressure mercury vapor lamps, which emit 95% of their radiation in the 2537 angstrom unit region, are generally used for germicidal purposes. These lamps are used to reduce the number of microorganisms on exposed surfaces and in the air. Since such factors as lamp age and dust accumulation contribute to decreased efficiency of these lamps, and since care is required to maintain and use them properly and safely, the following guidelines have been developed:

1. Laboratories shall perform periodic intensity testing of all UV installations. UV lamps in constant use should be replaced every six months. NOTE: UV lights often continue to emit blue light after effective energy output has fallen well below a useful range. Periodic monitoring with an appropriate light energy meter is necessary to verify proper output of UV light sources. Contact Radiation Safety (368.2906) to perform UV light monitoring.

2. UV lamps in air locks and door barriers will be turned on continuously. Skin or eye protection is not usually required for persons walking through these areas. Protection is required, however, for persons exposed to the radiation for longer than a few seconds.

   UV lamps in BSCs will be turned on only when the cabinet is not in use. The lamps in the BSC lethal chamber above the filters are turned on automatically when the blower is turned on. Personnel must wear PPE (goggles, caps, gowns, and gloves) or turn off the lights before entering laboratories, animal rooms, or exposed spaces which have UV installations.

3. All UV lamps except those located in the BSC lethal chamber above filters must be cleaned at two-week intervals, or more often if located in an unusually dusty area. The lamps should be turned off and wiped with a soft cloth moistened with alcohol. Cleaning is the responsibility of the personnel in charge of the laboratory. Cleaning dates should be logged on a card and attached to the installation.

4. Special problems concerning use, cleaning, or installation of UV lamps should be referred to Radiation Safety (368.2906).

DECONTAMINATION OF LABORATORY SINK DRAINS TO REMOVE AZIDE SALTS

All laboratory sink traps and drains which have not been converted to polyvinyl chloride (PVC) are potentially contaminated with azides. Therefore, they must be chemically treated prior to any maintenance to remove the salts (usually lead azide). If you believe that azides were previously disposed in your laboratory’s drain and they have not been decontaminated, contact Safety Services (368.2907) for information or assistance in decontaminating prior to any maintenance work.

WORKING WITH BLOODBORNE PATHOGENS

The OSHA regulation known as The Bloodborne Pathogen Standard is intended to reduce occupational exposure to Hepatitis B (HBV), Human Immunodeficiency Virus (HIV), and other bloodborne pathogens. OSHA fully intends that, if necessary, your physical facility, work practices, and other areas will be modified to attain this goal, and that employees will be informed and educated so they can contribute to this reduction/elimination of exposure as well. These regulations affect all laboratories using the following materials:

1. Human pathogenic organisms found in blood, blood products, semen, vaginal secretions, cerebrospinal fluid, synovial fluid, pleural fluid, pericardial fluid, amniotic fluid, saliva in dental procedures, any body fluid that is visibly contaminated with blood, and all body fluids in situations where it is difficult or impossible to differentiate between body fluids.

2. Any unfixed tissue or organ (other than intact skin) from a human (living or deceased).

3. HIV-containing cell or tissue cultures, organ cultures, and HIV- or HBV-containing culture medium or other solutions; and blood organs, or other tissues from experimental animals infected with HIV or HBV. Any materials known to be contaminated with HIV or HBV.

4. Any perceived or contaminated “SHARPS” (see *Chapter Four* of this LSM for a complete definition).

5. All etiologic agents (CWRU also includes these as bloodborne pathogens).

Z-LIST OF TOXIC SUBSTANCES

The following table lists toxic chemicals which are regulated by OSHA and have restrictions concerning their use.

Source: OSHA Standard 29 CFR 1910.1000: Table Z-1. Limits for Air Contaminants.

Check the chemical’s MSDS for information on the following limits before beginning work:

1. **Permissible Exposure Limit (PEL)** – The term used by OSHA to indicate the maximum air concentration to which employees can be exposed during an 8-hour day on a regular basis. Exceeding these levels may result in additional duties, such as medical monitoring, or introduction of engineering controls to reduce air exposure levels.

2. **Threshold Limit Value (TLV)** – The term used by the American Conference of Governmental and Industrial Hygienists (ACGIH), an independent group, to indicate the time weighted average concentration (TLVTWA) for a normal 8-hour work day and a 40-hour work week, to which nearly all employees may be repeatedly exposed, day after day, without adverse exposure.

3. **Short-Term Exposure Limit (STEL or TLV-STEL)** – The concentration to which an employee can be exposed for no more than 15 minutes at a time, no more than 4 times a day. There must be at least 60 minutes between exposures at the STEL level.

4. **Ceiling (TLV-C)** – The highest concentration to which an employee can ever be exposed.

5. **SKIN** – This designation sometimes appears alongside a TLV or PEL. It refers to the possibility of absorption of the particular chemical through the skin and eyes. Thus, protection of large surface areas of skin through the use of chemical PPE, such as gloves, should be considered so that the TLV is not invalidated.

Acetaldehyde
Acetic acid
Acetic anhydride
Acetone
Acetonitrile
2-Acetylaminofluorene
Acetylene dichloride
Acetylene tetrabromide
Acrolein
Acrylamide
Acrylonitrile
Aldrin
Allyl alcohol
Allyl chloride
Allyl glycidyl ether
Allyl propyl disulfide
alpha-Alumina
Aluminum Metal
4-Aminodiphenyl
2-Aminoethanol
2-Aminopyridine
Ammonia
Ammonium sulfamate
n-Amyl acetate
sec-Amyl acetate
Aniline and homologs
Anisidine (o-,p-isomers)
Antimony and compounds (as Sb)
ANTU
Arsenic, organic and inorganic compounds
Arsine
Asbestos
Azinphos-methyl
Barium, soluble compounds (as Ba)
Barium sulfate
Benomyl
Benzene
Benzidine
p-Benzoquinone
Benzo(a)pyrene
Benzoyl peroxide
Benzyl chloride
Beryllium and beryllium compounds
Biphenyl
Bismuth telluride, undoped
Boron oxide
Boron trifluoride
Bromine
Bromoform
1,3-Butadiene
Butanethiol
2-Butanone
2-Butoxyethanol
n-Butyl-acetate
sec-Butyl acetate
tert-Butyl-acetate
n-Butyl alcohol
sec-Butyl alcohol
tert-Butyl alcohol
Butylamine
tert-Butyl chromate (as CrO3)
n-Butyl glycidyl ether
Butyl mercaptan
p-tert-Butyltoluene
Cadmium (as Cd)
Calcium carbonate
Calcium hydroxide
Calcium oxide
Calcium silicate
Calcium sulfate
Camphor, synthetic
Carbaryl (Sevin)
Carbon black
Carbon dioxide
Carbon disulfide
Carbon monoxide
Carbon tetrachloride
Cellulose
Chlordane
Chlorinated camphene
Chlorinated diphenyl oxide
Chlorine
Chlorine dioxide
Chlorine trifluoride
Chloroacetaldehyde
a-Chloroacetophenone
Chlorobenzene
o-Chlorobenzylidene malononitrile
Chlorobromomethane
2-Chloro-1,3-butadiene
Chlorodiphenyl (42% Chlorine)
Chlorodiphenyl (54% Chlorine)
1-Chloro-2,3-epoxypropane
2-Chloroethanol
Chloroethylene
Chloroform (Trichloromethane)
bis(Chloromethyl) ether
Chloromethyl methyl ether
1-Chloro-1-nitropropane
Chloropicrin
beta-Chloroprene
2-Chloro-6-trichloromethylpyridine
Chromic acid and chromates (as CrO3)
Chromium (II and III compounds as Cr)
Chromium metal and insoluble salts (as Cr)
Chrysene
Clopidol
Coal dust
Coal tar pitch volatiles (benzene soluble fraction)
Cobalt metal (dust and fume)
Coke oven emissions
Copper dusts and mists
Copper fume
Cotton dust
Crag herbicide (Sesone)
Cresol, all isomers
Crotonaldehyde
Cumene
Cyanides (as CN)
Cyclohexane
Cyclohexanol
Cyclohexanone
Cyclohexene
Cyclopentadiene 2,4-D
Decaborane
Demeton (Systox)
Diacetone alcohol
1,2-Diaminoethane
Diazomethane
Diborane
1,2-Dibromo-3-chloropropane (DBCP)
1,2-Dibromoethane
Dibutyl phosphate
Dibutyl phthalate
o-Dichlorobenzene
p-Dichlorobenzene
3,3'-Dichlorobenzidine
Dichlorodifluoromethane
1,3-Dichloro-5,5-dimethyl hydantoin
Dichlorodiphenyltrichloroethane (DDT)
1,1-Dichloroethane
1,2-Dichloroethane
1,2-Dichloroethylene
Dichloroethyl ether
Dichloromethane
Dichloromonofluoromethane
1,1-Dichloro-1- nitroethane
1,2-Dichloropropane
Dichlorotetrafluoroethane
Dichlorvos (DDVP)
Dicyclopentadienyl iron
Dieldrin
Diethylamine
2-Diethylaminoethanol
Diethyl ether
Difluorodibromomethane
Diglycidyl ether
Dihydroxybenzene
Diisobutyl ketone
Diisopropylamine
Dimethoxymethane
Dimethyl acetamide
Dimethylamine
4-Dimethylaminoazobenzene
Dimethylaminobenzene
Dimethylaniline
Dimethylbenzene

Dimethyl 1,2-dibromo-2,2 dichloroethyl phosphate
Dimethylformamide
2,6-Dimethylheptanone
1,1-Dimethylhydrazine
Dimethylphthalate
Dimethyl sulfate
Dinitrobenzene (all isomers)
Dinitro-o-cresol
Dinitrotoluene
Dioxane
Diphenyl
Diphenylmethane diisocyanate
Dipropylene glycol methyl ether
Di-sec-octyl phthalate
Emery
Endrin
Epichlorohydrin
EPN
1,2-Epoxypropane
2,3-Epoxy-1-propanol
Ethanethiol
Ethanolamine
2-Ethoxyethanol
2-Ethoxyethyl acetate
Ethyl acetate
Ethyl acrylate
Ethyl alcohol (Ethanol)
Ethylamine
Ethyl amyl ketone
Ethyl benzene
Ethyl bromide
Ethyl butyl ketone
Ethyl chloride
Ethyl ether
Ethyl formate
Ethyl mercaptan
Ethyl silicate
Ethylene chlorohydrin
Ethylenediamine
Ethylene dibromide
Ethylene dichloride
Ethylene glycol dinitrate
Ethylene glycol methyl acetate
Ethyleneimine
Ethylene oxide
Ethylidene chloride
N-Ethylmorpholine
Ferbam
Ferrovanadium dust
Fluorides (as F)
Fluorine
Fluorotrichloromethane
Formaldehyde
Formic acid
Furfural
Furfuryl alcohol
Glycerin
Glycidol
Glycol monoethyl ether
Grain dust (oat, wheat, barley)
Graphite (natural and synthetic)
Guthion
Gypsum
Hafnium
Heptachlor
n-Heptane
Hexachloroethane
Hexachloronaphthalene
n-Hexane
2-Hexanone
Hexone (Methyl isobutyl ketone)
sec-Hexyl acetate
Hydrazine
Hydrogen bromide
Hydrogen chloride
Hydrogen cyanide
Hydrogen fluoride
Hydrogen peroxide (90%)
Hydrogen selenide
Hydrogen sulfide
Hydroquinone
Iodine
Iron oxide fume
Isomyl acetate
Isomyl alcohol
Isobutyl acetate
Isobutyl alcohol
Isophorone
Isopropyl acetate
Isopropyl alcohol
Isopropylamine
Isopropyl ether
Isopropyl glycidyl ether
Kaolin
Ketene
Lead, inorganic (as Pb)
Limestone
Lindane
Lithium hydride
Liquified petroleum gas
Magnesite
Magnesium oxide fume
Malathion
Maleic anhydride
Manganese (compounds and fumes)
Marble
Mercury
Mesityl oxide
Methanethiol
Methoxychlor
2-Methoxyethanol
2-Methoxyethyl acetate
Methyl acetate
Methyl acetylene
Methyl acetylene propadiene mixture
Methyl acrylate
Methylal
Methyl alcohol
Methylamine
Methyl amyl alcohol
Methyl n-amyl ketone
Methyl bromide
Methyl butyl ketone
Methyl cellosolve
Methyl cellosolve acetate
Methyl chloride
Methyl chloroform
Methylcyclohexane
Methylcyclohexanol
o-Methylcyclohexanone
Methylene chloride
Methyl ethyl ketone
Methyl formate
Methyl hydrazine
Methyl iodide
Methyl isoamyl ketone
Methyl isobutyl carbinol
Methyl isobutyl ketone
Methyl isocyanate
Methyl mercaptan
Methyl methacrylate
Methyl propyl ketone
alpha-Methyl styrene
Methylene bisphenyl isocyanate
Mica
Molybdenum (soluble and insoluble compounds)
Monomethyl aniline
Monomethyl hydrazine
Morpholine
Naphtha
Naphthalene
alpha-Naphthylamine
beta-Naphthylamine
Nickel carbonyl
Nickel (metal and insoluble compounds as Ni)
Nickel (soluble compounds as Ni)
Nicotine
Nitric acid
Nitric oxide
p-Nitroaniline
Nitrobenzene
p-Nitrochlorobenzene
4-Nitrodiphenyl
Nitroethane
Nitrogen dioxide
Nitrogen trifluoride
Air Contaminants
Nitroglycerin
Nitromethane
1-Nitropropane
2-Nitropropane
N-Nitrosodimethylamine
Nitrotoluene
Nitrotrichloromethane
Octachloronaphthalene

Octane
Oil mist, mineral
Osmium tetroxide (as Os)
Oxalic acid
Oxygen difluoride
Ozone
Paraquat
Parathion
PCB
Pentaborane
Pentachloronaphthalene
Pentachlorophenol
Pentaerythritol
Pentane
2-Pentanone
Perchloroethylene
Perchloromethyl mercaptan
Perchloryl fluoride
Petroleum distillates (Naphtha)
Phenol
p-Phenylene diamine
Phenyl ether (vapor)
Phenyl ether-biphenyl mixture (vapor)
Phenylethylene
Phenyl glycidyl ether
Phenylhydrazine
Phosdrin (Mevinphos)
Phosgene
Phosphine
Phosphoric acid
Phosphorus (yellow)
Phosphorus pentachloride
Phosphorus pentasulfide
Phosphorus trichloride
Phthalic anhydride
Picloram
Picric acid
Pindone
Plaster of paris
Platinum (soluble salts as Pt)
Portland cement
Propane
beta-Propriolactone
n-Propyl acetate
n-Propyl alcohol
n-Propyl nitrate
Propylene dichloride
Propylene imine
Propylene oxide
Propyne
Pyrethrum
Pyridine
Quinone
RDX
Rhodium (metal fume and insoluble compounds as Rh)
Rhodium (soluble compounds as Rh)
Ronnel
Rotenone
Rouge
Selenium compounds (as Se)
Selenium hexafluoride
Silica, amorphous precipitated and gel
Silica, amorphous, diatomaceous earth, containing less than 1% crystalline silica
Silica, crystalline cristobalite
Silica, crystalline quartz
Silica, crystalline tridymite
Silicates (less than 1% crystalline silica)
Silicon
Silicon carbide
Silver
Soapstone
Sodium fluoroacetate
Sodium hydroxide
Starch
Stibine
Stoddard solvent
Strychnine
Styrene
Sucrose
Sulfur dioxide
Sulfur hexafluoride
Sulfur monochloride
Sulfur pentafluoride
Sulfuric acid
Sulfuryl fluoride
Systox
2,4,5-T
Talc
Tantalum (metal and oxide dust)
TEDP
Tellurium and compounds (as Te)
Tellurium hexafluoride (as Te)
Temephos
TEPP
Terphenylis
1,1,1,2-Tetrachloro-2,2-difluoroethane
1,1,2,2-Tetrachloro-1,2-difluoroethane
1,1,2,2-Tetrachloroethane
Tetrachoroethylene
Tetrachloromethane
Tetrachloronaphthalene
Tetraethyl lead (as Pb)
Tetrahydrofuran
Tetramethyl lead (as Pb)
Tetramethyl succinonitrile
Tetranitromethane
Tetryl
Thallium (soluble compounds as Tl)
4,4'-Thiobis(6-tert, Butyl-mcresol)
Thiram
Tin, inorganic compounds (except oxides)
Tin, organic compounds
Titanium dioxide
Toluene
Toluene-2,4-diisocyanate
o-Toluidine
Toxaphene
Tremolite
Tributyl phosphate
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Trichloroethylene
Trichloromethane
Trichloronaphthalene
1,2,3-Trichloropropane
1,1,2-Trichloro-1,2,2-trifluoroethane
Triethylamine
Trifluorobromomethane
2,4,6-Trinitrophenol
2,4,6-Trinitrophenylmethyl nitramine
Trinitrotoluene (TNT)
Triorthocresyl phosphate
Triphenyl phosphate
Turpentine
Uranium (soluble and insoluble compounds as U)
Vanadium (as V2O5 dust and fume)
Vegetable oil mist
Vinyl benzene
Vinyl chloride
Vinyl cyanide
Vinyl toluene
Warfarin
Xylenes
Xylidine
Yttrium
Zinc chloride fume
Zinc oxide fume
Zinc oxide
Zinc stearate
Zirconium compounds (as Zr)

LIST OF EXTREMELY HAZARDOUS CHEMICALS

APPENDIX B

The chemicals listed in the following three categories are considered extremely hazardous chemicals, and the handling of them must be completed only in a designated area. The three categories are: select carcinogens, reproductive toxins, and chemicals with a high degree of acute toxicity.

Carcinogens

The following is a list of chemicals which OSHA considers confirmed human carcinogens:

2-Acetylaminofluorene
Benzidine
3,3'-Dichlorobenzidine (and its salts)
Ethyleneimine
Alpha-Naphthylamine
Beta-Propiolactone
4-Aminodiphenyl
bis-Chloromethyl ether
4-Dimethylaminoazobenzene
Methyl chloromethyl ether
beta-Naphthylamine
4-Nitrobiphenyl
N-Nitrosodimethylamine

“Select carcinogens” are defined by the Laboratory standard 29 CFR 1910.1450 as being any substance which meets one of the following criteria:

1. It is regulated by OSHA as a carcinogen.

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).

3. It is listed under Group 1, “carcinogenic to humans,” by the International Agency for Research on Cancer Monographs (IARC, latest edition).

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/m^3.

    b. After repeated skin application of less than 300 mg/kg of body weight per week.

    c. After oral dosages of less than 50 mg/kg of body weight per day.

Though many of these chemicals are in common use, they have been listed by the corresponding agency as being carcinogenic. The following is a list of chemicals which fulfill the above criteria with an indication of the agency or group which has so classified that chemical.   This compilation, though at present complete, is a guide only. Regulating agencies add chemicals to their lists on a regular basis. For the most current information on a chemical's carcinogenic status, refer to Section 3 of its MSDS, "Hazards Identification."

Substance	**Source**
acetaldehyde	NTP, IARC
acetamide	IARC
2-acetylaminofluorene	OSHA, NTP
acrylamide	NTP, IARC
acrylonitrile	OSHA, NTP, IARC
adriamycin	NTP, IARC
aflatoxins	NTP, IARC
2-amino 9H-pyrido[2,3-b]indole	IARC
2-aminoanthraquinone	NTP
para-aminoazobenzene	IARC
o-aminoazotoluene	NTP, IARC
4-aminobiphenyl	OSHA, IARC, NTP
1-amino-2-methylanthraquinone	NTP
2-amino-5-(5-nitro-2-furyl)-1,3,4-thiadiazole	IARC
amitrole	NTP, IARC
androgenic (anabolic) steroids	IARC
o-anisidine	IARC
o-anisidine hydrochloride	NTP
antimony trioxide	IARC
aramite	IARC
arsenic (and certain arsenic compounds)	OSHA, IARC, NTP
asbestos	OSHA, IARC, NTP
atrazine	IARC
auramine	IARC
azaserine	IARC
azacitidine	IARC
azathioprine	IARC, NTP
benzene	OSHA, IARC, NTP

Substance	Source
benzidine	OSHA, IARC, NTP
benz[a]anthracene	IARC
benzidine-based dyes	IARC
benzo[a]pyrene	IARC
benzo[b]fluoranthene	IARC
benzo[j]fluoranthene	IARC
benzo[k]fluoranthene	IARC
benzofuran	IARC
benzotrichloride	NTP
benzyl violet 4B	IARC
beryllium and Be compounds	NTP, IARC
N,N-Bis(chloroethyl)-2-naphthylamine (Chlornaphazine)	IARC
bis(chloromethyl) ether and chloromethyl methyl ether(technical grade)	OSHA, IARC, NTP
bischloroethyl nitrosourea	NTP, IARC
bleomycins	IARC
bracken fern	IARC
bromodichloromethane	NTP, IARC
1,3-butadiene	IARC, NTP
1,4-butanediol dimethanesulfonate (myleran)	IARC, NTP
butylated hydroxyanisole	IARC, NTP
b-butyrolactone	IARC
cadmium and Cd compounds	NTP, IARC
caffeic acid	IARC
captafol	IARC
carbon black	IARC
carbon tetrachloride	NTP, IARC
ceramic fibers (respirable size)	NTP, IARC
chlorambucil	NTP, IARC
chloramphenicol	IARC
chlordane	IARC
chlordecone (kepone)	IARC
chlorendic acid	NTP, IARC
chlorinated paraffins (C12, 60% chlorine)	NTP
chlorinated toluenes	IARC
p-chloroaniline	IARC
1-(2-chloroethyl)-3-cyclohexyl-1-nitrosourea(CCNU)	NTP, IARC
1-(2-chloroethyl)-3-(4-methylcyclohexyl)-1-nitrosourea (methyl CCNU)	NTP, IARC
chloroform	NTP, IARC
3-chloro-2-methylpropene	NTP
1-chloro-2-methylpropene	IARC
chlorophenols	IARC
chlorophenoxy herbicides	IARC
4-chloro-o-phenylenediamine	NTP, IARC
p-chloro-o-toluidine	IARC
chlorozoticin	IARC
chromium and certain chromium compounds	IARC, NTP
CI Acid Red 114	IARC
CI Basic Red 9 monohydrochloride	NTP, IARC
CI Direct Blue 15	IARC
ciclosporin	IARC
cisplatin	NTP, IARC
citrus red no. 2	IARC
clonorchis sinesis (infection with)	IARC
cobalt and cobalt compounds	IARC
cotton dust	OSHA
p-cresidine	NTP, IARC
cupferron	NTP
cycasin	IARC
cyclophosphamide	NTP, IARC

Substance	Source
dacarbazine	NTP, IARC
dantron	IARC
daunomycin	IARC
DDT	NTP, IARC
N,N'-diacetylbenzidine	IARC
2,4-diaminoanisole	IARC
2,4-diaminoanisole sulfate	NTP
4,4'-diaminodiphenyl ether	IARC
2,4-diaminotoluene	NTP, IARC
dibenz[a,h]acridine	IARC
dibenz[a,j]acridine	IARC
dibenz[a,h]anthracene	IARC
7H-dibenzo[a,h]carbazole	IARC
dibenzo[a,e]pyrene	IARC
dibenzo[a,h]pyrene	IARC
dibenzo[a,i]pyrene	IARC
dibenzo[a,l]pyrene	IARC
1,2-dibromo-3-chloropropane	OSHA, NTP, IARC
1,2-dibromoethane (ethylene dibromide)	NTP
1,4-dichlorobenzene	NTP, IARC
3,3-dichlorobenzidine	NTP, IARC
3,3-dichlorobenzidine and its salts	OSHA
3,3'-dichloro-4,4'-diaminodiphenyl ether	IARC
1,2-dichloroethane	NTP, IARC
dichloromethane (methylene chloride)	NTP, IARC
1,3-dichloropropene (technical grade)	NTP, IARC
dichlorvos	IARC
diepoxybutane	NTP, IARC
di(2-ethylhexyl)phthalate	NTP, IARC
diethylstilbestrol	NTP, IARC
diethyl sulfate	NTP, IARC
1,2'-diethylhydrazine	IARC
diglycidyl resorcinol ether	NTP, IARC
dihydrosafrole	IARC
diisopropyl sulfate	IARC
3,3-dimethoxybenzidine	NTP, IARC
3,3-dimethoxybenzidine 2HCl	NTP
4-dimethylaminoazobenzene	OSHA, NTP, IARC
trans-2-[(dimethylamino)methylimino]-5-[2-(5-nitro-2-furyl)vinyl]-1,3,4-oxadiazole	IARC
2,6-dimethylaniline	IARC
3,3-dimethylbenzidine	NTP, IARC
dimethylcarbamoyl chloride	NTP, IARC
dimethylformamide	IARC
1,1-dimethylhydrazine	NTP, IARC
1,2-dimethylhydrazine	IARC
dimethyl sulfate	NTP, IARC
dimethyl vinyl chloride	NTP
3,7-dinitrofluoranthene	IARC
3,9-dinitrofluoranthene	IARC
1,6-dinitrofluoranthene	IARC
1,8-dinitrofluoranthene	IARC
2,4-dinitrofluoranthene	IARC
2,6-dinitrofluoranthene	IARC
1,4-dioxane	NTP, IARC
direct Blue 6	NTP
direct Black 38	NTP
disperse blue 1	IARC
epichlorohydrin	NTP, IARC
Epstein-Barr virus	IARC

Substance	Source
erionite	NTP, IARC
estrogens (conjugated)	NTP
estradiol 17 beta	
estrone	
ethinyl estradiol	
mestranol	
estrogen replacement therapy	IARC
estrogens (steroidal and non-steroidal)	IARC
ethyl acrylate	NTP, IARC
ethylene dibromide	IARC
ethyleneimine	OSHA
ethylene oxide	OSHA, IARC, NTP
ethylene thiourea	NTP, IARC
ethyl methanesulfonate	NTP, IARC
N-ethyl-N-nitrosourea	IARC
formaldehyde	OSHA, NTP, IARC
2-(2-formylhydrazino)-4-(5-nitro-2-furyl)thiazole	IARC
furan	IARC
glass wool (respirable size)	NTP, IARC
glu-P-1 (2-amino-6-methyldipyrido[1,2-a:3'2'-d] imidazole	IARC
glu-P-2 (2-aminodipyrido[1,2-a:3'2'-d] imidazole	IARC
glycidaldehyde	IARC
glycidol	NTP
griseofulvin	IARC
HC blue No. 1	IARC
heliobacter pylori (infection with)	IARC
hepatitis B and C viruses (chronic infection with)	IARC
heptachlor	IARC
hexachlorobenzene	NTP, IARC
hexachloroethane	NTP
hexachlorocyclohexanes	IARC
hexamethylphosphoramide	NTP, IARC
human immunodeficiency viruses 1 and 2 (infection with)	IARC
human papillomavirus types 16, 18, 31, 33	IARC
human papillomaviruses: other types	IARC
human T-cell lymphotropic virus	IARC
hydrazine and hydrazine sulfates	NTP, IARC
hydrazobenzene	NTP
indeno[1,2,3-cd]pyrene	IARC
IQ (2-amino-3-methylimidazo[4,5-f]quinoline	IARC
iron dextran complex	NTP, IARC
isoprene	IARC
Kaposi's sarcoma herpesvirus/human herpesvirus 8	IARC
kepone (chlordecone)	NTP
lasiocarpine	IARC
lead acetate and lead phosphate	NTP
lindane and other hexachlorocyclohexane isomers	NTP
magenta (containing CI basic red 9)	IARC
meA-a-C-((2-amino-3-methyl-9H -pyrido[2,3-b]indole	IARC
medroxyprogesterone acetate	IARC
meIQ (2-amino-3,4-dimethylimidazo[4,5-f]quinoline)	IARC
meIQx (2-amino-3,8-dimethylimidazo[4,5-f]quinoline)	IARC
melphalan	NTP, IARC
merphalan	IARC
5-methoxypsoralen	IARC
8-methoxypsoralen(methoxsalen) with Ultraviolet A therapy (PUVA)	NTP, IARC
2-methylaziridine (propyleneimine)	NTP, IARC
methylazoxymethanol acetate	IARC
methyl chloromethyl ether	OSHA
methylchrysene	IARC

Substance	Source
4,4-methylenebis(2-chloroaniline)(MBOCA)	NTP, IARC
4,4-methylenebis(2-methylaniline)	IARC
4,4-methylenebis(N,N-dimethyl)benzenamide (Michler's base)	NTP
methylene chloride	OSHA, NTP, IARC
4,4-methylenedianiline and its dihydrochloride	NTP, IARC
methylmercury and its compounds	IARC
methyl methanesulfonate	NTP, IARC
2-methyl-1-nitroanthraquinone (uncertain purity)	IARC
N-methyl-N'-nitro-N-nitrosoguanidine	NTP, IARC
N-methyl-N-nitrosourea	IARC
N-methyl-N-nitrosourethane	IARC
methylthiouracil	IARC
metronidazole	NTP, IARC
Michler's ketone	NTP
mineral oils, untreated and mildly treated	IARC
mirex	NTP, IARC
mitomycin	IARC
monocrotaline	IARC
5-(morpholinomethyl)-3-[(5-nitrofurfurylidene)amino]-2-oxazolidinone	IARC
MOPP and other combined chemotherapy including alkylating agents	IARC
mustard gas (sulfur mustard)	NTP, IARC
nafenopin	IARC
2-naphthylamine	NTP, IARC
alpha-naphthylamine	OSHA
beta-naphthylamine	OSHA
nickel and Ni compounds	NTP, IARC
niridazole	IARC
4-nitrobiphenyl	OSHA
nitrilotriacetic acid (and its salts)	NTP, IARC
5-nitroacenaphthene	IARC
2-nitroanisole	IARC
nitrobenzene	IARC
6-nitrochrysene	IARC
nitrofen	NTP, IARC
2-nitrofluorene	IARC
1-[(5-nitrofurfurylidene)amino]-2-imidazolidinone	IARC
N-[4-(5-nitro-2-furyl)-2-thiazolyl]acetamide	IARC
nitrogen mustard	IARC
nitrogen mustard hydrochloride	NTP
nitrogen mustard N-oxide	IARC
2-nitropropane	NTP, IARC
1-nitropyrene	IARC
4-nitropyrene	IARC
N-nitrosodi-n-butylamine	NTP, IARC
N-nitrosodiethanolamine	NTP, IARC
N-nitrosodiethylamine	NTP, IARC
N-nitrosodimethylamine	OSHA, NTP, IARC
N-nitrosodi-n-propylamine	NTP
3-(N-nitrosomethylamino)propionitrile	IARC
N-nitroso-N-ethylurea	NTP
4-(N-nitrosomethylamino)-1(3-pyridyl)-1-butanone	IARC
N-nitrosomethylethylamine	IARC
N-nitroso-N-methylurea	NTP
N-nitrosomethylvinylamine	NTP, IARC
N-nitrosomorpholine	NTP, IARC
N-nitrosonornicotine	NTP, IARC
N-nitrosopiperidine	NTP, IARC
N-nitrosopyrrolidine	NTP, IARC
N-nitrososarcosine	NTP, IARC
norethisterone	NTP

Substance	**Source**
ochratoxin A	NTP, IARC
oil orange SS	IARC
opisthorchis viverrini (infection with)	IARC
oral contraceptives, combined and sequential	IARC
oxazepam	IARC
4,4-oxydianiline	NTP
oxymetholone	NTP
palygorskite (attapulgite)	IARC
panfuran S (containing dihydroxymethylfuratrizine)	IARC
pentachlorophenol	IARC
phenacetin (analgesic mixtures containing)	NTP, IARC
phenazopyridine hydrochloride	NTP, IARC
phenobarbital	IARC
phenoxybenzamine hydrochloride	NTP, IARC
phenyl glycidyl ether	IARC
phenytoin	NTP, IARC
PhIP (2-amino-1-methyl-6-phenylimidazo[4,5-b]pyridine	IARC
polybrominated biphenyls(PBB)	NTP
polychlorinated biphenyls(PCB)	NTP
polycyclic aromatic hydrocarbons(PAHs)	NTP
benz(a)anthracene	
benzo(b)fluoranthene	
benzo(j)fluoranthene	
benzo(k)fluoranthene	
benzo(a)pyrene	
dibenz(a,h)acridine	
dibenz(a,j)acridine	
dibenz(a,h)anthracene	
7H-dibenzo(c,g)carbazole	
dibenzo(a,e)pyrene	
dibenzo(a,h)pyrene	
dibenzo(a,i)pyrene	
dibenzo(a,l)pyrene	
indeno(1,2,3-cd)pyrene	
5-methylchrysene	
ponceau MX	IARC
ponceau 3R	IARC
potassium bromate	IARC
procarbazine hydrochloride	NTP, IARC
progesterone	NTP, IARC
1,3-propane sultone	NTP, IARC
beta-propiolactone	OSHA, NTP, IARC
propylene oxide	NTP, IARC
propylthiouracil	NTP, IARC
radon	NTP, IARC
reserpine	NTP
rockwool	IARC
saccharine	NTP, IARC
safrole	NTP, IARC
schistosoma haematobium (infection with)	IARC
schistosoma japonicum (infection with)	IARC
selenium sulfide	NTP
silica	NTP, IARC
slagwool	IARC
sodium *ortho*-phenylphenate	IARC
solar radiation	IARC
sterigmatocysin	IARC
streptozotocin	NTP, IARC
styrene	IARC
styrene-7,8-oxide	IARC

Substance	Source
sulfallate	NTP, IARC
talc containing asbestos fibers	IARC
tamoxifen	IARC
2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)	NTP, IARC
thiotepa	IARC
tetrachloroethylene (perchloroethylene)	NTP, IARC
trichloroethylene	IARC
tetranitromethane	NTP, IARC
1,2,3-trichloropropane	IARC
thioacetamide	NTP, IARC
1,4’-thiodianiline	IARC
thiourea	NTP, IARC
thorium dioxide	NTP
toluene diisocyanates	NTP, IARC
o-toluidine and o-toluidine hydrochloride	NTP, IARC
toxaphene	NTP
treosulfan	IARC
trichlormethine (trimustine hydrochloride)	IARC
2,4,6-trichlorophenol	NTP
tris(1-aziridinyl)phosphine sulfide	NTP
tris(2,3-dibromopropyl)phosphate	NTP, IARC
trp-P-1 (3-amino-1,4-dimethyl-5H-pyrido[4,3-b] indole	IARC
trp-P-2 (3-amino-1-methyl-5H-pyrido[4,3-b] indole	IARC
trypan blue	IARC
uracil mustard	IARC
urethane	NTP, IARC
ultraviolet radiation A, B, and C	IARC
vinyl acetate	IARC
vinyl bromide	IARC
vinyl chloride	OSHA, NTP, IARC
4-vinylcyclohexane	IARC
4-vinylcyclohexane diepoxide	NTP, IARC
vinyl fluoride	IARC

In addition, IARC has listed the following **mixtures** and **exposure circumstances** as carcinogenic:

Mixtures:

alcoholic beverages
betel quid with tobacco
bitumens
carrageenan
chlorinated paraffins of average carbon chain length
coal-tars and coal-tar pitches
coffee (urinary bladder)
creosotes
diesel engine exhaust
diesel fuel, marine
engine exhaust, gasoline
fuel oils, residual (heavy)
gasoline
hot mate
mineral oils, untreated and mildly treated
non-arsenical insecticides (occupational exposures in spraying and application)
pickled vegetables (traditional in Asia)
polychlorinated biphenyls
polybrominated biphenyls
salted fish (Chinese-style)
shale-oils
soots
tobacco products, smokeless
tobacco smoke
toxaphene
toxins derived from *fusarium moniliforme*
welding fumes

Exposure Circumstances:

aluminum production
art glass, glass containers and pressed ware (manufacture of)
auramine, manufacture of
boot and shoe manufacture and repair
carpentry and joinery
coal gasification
coke production
dry cleaning (occupational exposures in)
furniture and cabinet making
hematite mining (underground) with exposure to radon
hairdresser or barber (occupational exposure as a)
iron and steel founding
isopropanol manufacture (strong-acid process)
magenta, manufacture of
painter (occupational exposure as a)
petroleum refining (occupational exposures in)
printing processes (occupational exposures in)
rubber industry
strong-inorganic-acid mists containing sulfuric acid
sunlamps and sunbeds (use of)
textile manufacturing industry (work in)

Reproductive Hazards

Reproductive toxins are chemicals or other hazards which may manifest themselves in lethal effects on the fertilized egg, developing embryo, or fetus, or have teratogenic effects in the fetus. In addition, certain reproductive toxins may cause infertility in males and females. The following is a list of chemicals which have been found to have at least one of the above effects. *Source*: Zenz C, Dickerson OB, Horvath EP. Reproductive toxicology and occupational exposure. Occupational Medicine St Louis: Mosby, 1994 .

Substance	**Effect**
acrylamide	decreased fertility
anesthetic gases (halogenated gases)	fetal effects
benzene, toluene, xylene	decreased fertility
boron	decreased fertility
cadmium	decreased fertility, fetal effects
carbaryl	decreased fertility
carbon disulfide	decreased fertility, increased menstrual bleeding
carbon monoxide	decreased fertility, fetal effects
chlordane and heptachlor	decreased fertility
chlordecone (kepone)	decreased fertility
1,2-dibromo-3-chloropropane (DBCP)	decreased fertility
dioxin	decreased fertility, fetal effects
epichlorohydrin	decreased fertility
ethylene dibromide (EDB)	decreased fertility, fetal effects
ethylene oxide	fetal effects
glycol ethers	decreased fertility, fetal effects
hexachlorobenzene (HCB)	fetal effects
ionizing radiation (x-rays and gamma rays)	decreased fertility, fetal effects
lead	decreased fertility, fetal effects
mercury	fetal effects
polycyclic aromatic hydrocarbons	decreased fertility, fetal effects
styrene	fetal effects
tetrachloroethylene (perchloroethylene)	decreased fertility, menstrual disorders
vinyl chloride	decreased fertility, fetal effects

“Fetal effects” may include spontaneous abortion, low birth weight, still-births, neonatal deaths, congenital anomalies, and behavioral or developmental disabilities.

“Decreased fertility” may include both male and female fertility disorders.

Chemicals with a High Degree of Acute Toxicity

Chemicals with a high degree of acute toxicity are so classified because they may be fatal or cause damage to target organs as a result of a single exposure, or exposures of short duration. Examples include hydrogen cyanide, hydrogen sulfide, and nitrogen dioxide.

GLOVE COMPATIBILITY CHART

The following list contains brief guidelines for glove use with common chemicals. Refer to the glove manufacturer for additional details or if the chemical with which you are working is not on this list.

Latex gloves are not recommended for any laboratory procedure involving chemicals, as they do not provide adequate protection.
Source: Adapted from the National Research Council, 1981.

GLOVE COMPATIBILITY CHART KEY:

E = Excellent protection
G = Good protection
F = Fair protection
P = Poor protection
-- = no available data

[a] Aromatic and halogenated hydrocarbons will attack all types of natural and synthetic glove materials. Should the gloves swell, the user should change to fresh gloves and allow the swollen gloves to dry and return to their normal state.

[b] No data is available on the resistance to dimethyl sulfoxide of neoprene, nitrile, or vinyl materials. The manufacturer recommends using butyl rubber gloves.

Chemical	Neoprene	Nitrile	Vinyl
Acetaldehyde	G	E	G
Acetic Acid	E	E	E
Acetone	G	G	F
Acrylonitrile	G	--	F
Ammonium hydroxide	E	E	E
Aniline	G	E	G
Benzaldehyde	F	E	G
Benzenea	F	G	F
Benzyl Chloride[a]	P	G	P
Bromine	G	--	G
Butane	E	--	P
Butyraldehyde	G	--	G
Calcium hypochlorite	G	G	G
Carbon disulfide	P	G	F
Carbon tetrachloride	F	G	F
Chlorine	G	--	G
Chloroacetone	E	--	P
Chloroform[a]	F	G	P
Chromic acid	F	F	E
Cyclohexane	E	--	P
Dibenzyl ether	G	--	P
Dibutyl phthalate	G	--	P
Diethanolamine	E	--	E
Diethyl ether	G	E	P
Dimethyl sulfoxide[b]	--	--	--
Ethyl acetate	G	G	F
Ethylene dichloride[a]	F	G	P
Ethyl glycol	G	E	E
Ethylene trichloride[a]	P	--	P
Fluorine	G	--	G
Formaldehyde	E	E	E
Formic acid	E	E	E
Glycerol	G	E	E
Hexane	E	--	P
Hydrobromic acid (40%)	E	--	E
Hydrochloric acid (conc)	G	G	E
Hydrofluoric acid	G	G	E
Hydrogen peroxide	G	G	E
Iodine	G	--	G
Methylamine	G	E	E
Methyl cellosolve	E	--	P
Methyl chloride	E	--	P
Methyl ethyl ketone	G	G	P
Methylene chloride	F	G	F
Monoethanolamine	E	--	E
Morpholine	E	--	E
Naphthalene	G	E	G
Nitric acid (conc)	P	P	G
Perchloric acid	G	F	E
Phenol	E	--	E
Phosphoric acid	E	--	E
Potassium hydroxide (sat)	G	G	E
Propylene dichloride[a]	F	--	P
Sodium hydroxide	G	G	E
Sodium hypochlorite	P	F	G
Sulfuric acid (conc)	G	F	G
Toluene[a]	F	G	F
Trichloroethylene[a]	F	G	F
Tricresyl phosphate	F	--	F
Triethanolamine	E	E	E

TABLE OF CHEMICAL INCOMPATIBILITIES

APPENDIX D

The following list illustrates common laboratory chemical incompatibilities. Chemicals in both columns A and B should be kept separate from each other. This list is not intended to be exhaustive. *Source*: Adapted from the National Research Council, 1981.

*NOTE: Oxidizing agents include the types of compounds listed in the entry for alkali and alkaline earth metals, etc.

Column A	Column B
Acetylene and mono-substituted acetylenes	Groups IB and IIB metals and their salts; Halogens
Acids	Bases
Alkali and alkaline earth metals (including carbides, hydrides, hydroxides, oxides, and peroxides)	Water; Acids; Halogenated organic compounds; Oxidizing agents* (including chromates, dichromates, halogens, halogenating agents, hydrogen peroxide and peroxides, nitric acid, nitrates, perchlorates and chlorates, permanganates, and persulfates)
Ammonia, anhydrous and aqueous	Halogens; Halogenating agents; Silver; Mercury
Inorganic azides	Acids; Heavy metals and their salts; Oxidizing agents*
Inorganic cyanides	Acids; Strong bases
Inorganic nitrates	Acids; Metals; Nitrites; Sulfur
Inorganic nitrites	Acids; Oxidizing agents*
Inorganic sulfides	Acids
Mercury and its amalgams	Acetylene; Ammonia (anhydrous and aqueous); Nitric acid; Sodium azide
Nitric acid	Chromic acid and chromates; Metals; Nitrites; Reducing agents; Permanganates; Sulfides; Sulfuric acid
Organic compounds	Oxidizing agents*
Organic acyl halides	Bases; Organic hydroxy compounds
Organic anhydrides	Bases; Organic hydroxy compounds
Organic halogen compounds	Aluminum metal
Organic nitro compounds	Strong bases
Oxalic acid	Mercury and its salts; Silver and its salts
Phosphorus (yellow)	Oxygen; Oxidizing agents*; Strong bases
Phosphorus pentoxide	Halogenating agents; Water
Powdered metals	Acids; Oxidizing agents*
Sulfuric acid	Metals; Chlorates; Perchlorates; Permanganates; Nitric acid

SMALL SPILL CLEAN-UP GUIDELINES

Spills of many innocuous laboratory chemicals can be handled by laboratory personnel with appropriate procedures outlined below. If laboratory personnel have knowledge of the chemical(s) involved and can discern that the spill does not pose any hazards, clean-up may begin without the presence of Safety Services. If at any time there is doubt as to the nature or extent of the hazard, call Safety Services (368.2907). In University Hospitals, call UH Protective Services for assistance (844.4357). UH Protective Services will then notify EHS Safety Services.

Contaminated clothing must be removed immediately and the skin washed with soap and water. Clothing must be laundered before reuse and, in some cases, may have to be disposed of.

Proper disposal of chemical waste is outlined in Chapter Four of this LSM. For University Hospitals' chemical waste disposal, call Protective Services (844.4357) or UH Safety (844.1458).

1. **Acid** – Use an absorbent material which will neutralize the acid. Commercially marketed acid neutralizers and sodium bicarbonate powder are recommended. Dry sand can be used but is much less effective. After neutralization has occurred, scoop the mixture into a plastic bag and dispose of properly.

2. **Flammable Solvents** – Turn off all spark-producing equipment. Use an absorbent noted above that will retard the vaporization of the solvent; sand is ineffective. Pour the absorbent around the perimeter of the spill area and proceed with the clean-up toward the center. Scoop the mixture into a plastic bag and dispose of properly.

3. **Mercury** – Mercury is one of the most insidious hazards, capable of adhering to surfaces (including vertical surfaces) and lodging into very small openings. When mercury is spilled, no matter the quantity, evacuate the immediate area. This includes the mercury which is released upon breakage of mercury thermometers (see *Chapter Four* of this LSM on disposal procedures for broken thermometers).

4. **Bromine** – Spilled bromine should be reacted with sodium thiosulfate solution (5%-10%). Under no circumstance should ammonium hydroxide be used, as an explosion may result upon mixing any of the halogens with ammonia. An appropriate respirator must be worn during clean-up.

5. **Acid Chloride** – Use calcined absorbent products, such as Oil-Dry, Zorb-All, or dry sand. Scoop the mixture into a plastic bag and dispose of properly.

6. **Hydrazines** – Avoid using anything contaminated with organic materials as an absorbent. Flush contaminated area with copious amounts of water.

7. **Alkali Metal** – The spilled metal should be smothered by using Met-L-X Yellow Extinguisher and removed to a safe location where it can be disposed of by reaction with a dry secondary alcohol (such as isopropanol) or by outdoor burning. Any metal particles splattered on the skin should be quickly removed, and the skin should then be flushed with water.

Arrange a follow-up survey with Safety Services to ensure the area is completely decontaminated. Safety Services will provide for proper waste disposal of any spilled or contaminated materials.

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GLOSSARY OF TERMS

Acute	Severe, often dangerous conditions in which relatively rapid changes occur.
Acute Exposure	An intense exposure over a relatively short period of time.
Asphyxiant	A chemical (gas or vapor) that can cause death or unconsciousness by suffocation. Simple asphyxiants, such as nitrogen, either use up or displace oxygen in the air. They become especially dangerous in confined or enclosed spaces. Chemical asphyxiants, such as carbon monoxide and hydrogen sulfide, interfere with the body's ability to absorb or transport oxygen to the tissues.
Boiling Point	The temperature at which the vapor pressure of a liquid equals atmospheric pressure or at which the liquid changes to a vapor. The boiling point is usually expressed in degrees Fahrenheit (ºF). If a flammable material has a low boiling point, it indicates a special fire hazard.
"C" or Ceiling	A description usually seen in connection with a published exposure limit. It refers to the concentration that should not be exceeded, even for an instant. It may be written at TLV-C or Threshold Limit Value Ceiling (see also *Threshold Limit Value*).
Carcinogen	A substance or physical agent that may cause cancer in animals or humans.
C.A.S. Number	Identifies a particular chemical by the Chemical Abstracts Service, a service of the American Chemical Society that indexes and compiles abstracts of worldwide chemical literature called "Chemical Abstracts."

Chemical	As broadly applied to the chemical industry, an element or a compound produced by chemical reactions on a large scale of either direct industrial and consumer use or for reaction with other chemicals.
Chemical Reaction	A change in the arrangement of atoms or molecules to yield substances of different composition and properties (see also *Reactivity*).
Chronic	Persistent, prolonged, or repeated conditions.
Chronic Exposure	A prolonged exposure occurring over a period of days, weeks, or years.
Combustible Liquid	According to DOT and NFPA, combustible liquids are those having a flash point at or above 100ºF, or liquids that will burn. They do not ignite as easily as flammable liquids. However, combustible liquids can be ignited under certain circumstances and must be handled with caution.
Concentration	The relative amount of a material in combination with another material. For example, 5 parts (of acetone) per million (parts of air).
Corrosive	A substance that, according to DOT, causes visible destruction or permanent changes in human skin tissue at the site of contact, or is highly corrosive to steel.
Cubic Meter (m^3)	A measure of volume in the International System (SI) of Units.
Cutaneous	Pertaining to, or affecting the skin.
Decomposition	The breakdown of a chemical or a substance into different parts of simpler compounds. Decomposition can occur due to wear, chemical reaction, decay, etc.
Dermatitis	An inflammation of the skin.
Designated Area	An area which may be used for work with select carcinogens, reproductive toxins, or substances with a high degree of acute toxicity (see *Appendix B*). A designated area may be the entire lab or a section of it, such as a chemical hood.

Dilution Ventilation	See *General Ventilation*.
Dyspnea	Shortness of breath; difficult or labored breathing.
Employee	An individual employed in a laboratory workplace who may be exposed to hazardous chemicals in the course of his/her assignments.
Epidemiology	The study of disease in (human) population.
Erythema	A reddening of the skin.
Evaporation Rate	The rate at which a material is converted to vapor (evaporates) at a given temperature and pressure when compared to the evaporation rate of a given substance.
Explosive	A chemical that causes a sudden, almost instantaneous release of pressure, gas, or heat when subjected to sudden shock, pressure, or high temperature.
Eye Hazard	A chemical which affects the eye or visual capacity. Signs and symptoms include conjunctivitis, corneal damage. Chemicals include organic solvents, acids.
Flammable Aerosol	An aerosol that, when tested by the method described in 16 CFR 1500.45, yields a flame projection exceeding 18 inches at full valve opening or a flashback (a flame extending back to the valve) at any degree of opening.
Flammable Gas	a) a gas that, at ambient temperature and pressure, forms a flammable mixture with air as a concentration of 13% by volume or less; or b) a gas that, at ambient temperature and pressure, forms a range of flammable mixtures with air wider than 12% by volume, regardless of flash point below 100ºF, except any mixture having components with flash points of 100ºF or higher, the total of which make up 99% or more of the total volume of the mixture.

Flammable Liquid	According to DOT and NFPA, a liquid which has a flash point below 100ºF (see *Flash Point*).
Flammable Solid	A solid, other than a blasting agent or explosive as defined in 16 CFR 1910.109(s), that is liable to cause fire through friction, absorption or moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or which can be ignited readily and when ignited, burns so vigorously and persistently as to create a serious hazard. A chemical shall be considered to be a flammable solid if, when tested by the method described in 16 CFR 1500.45, it ignites and burns with a self-sustained flame at a rate greater than one-tenth of an inch per second along its major axis.
Flash Point	The lowest temperature at which liquid gives off enough vapor to form an ignitable mixture and burn when a source of ignition (spark, open flame, cigarette, etc.) is present. Two tests are used to determine flash point: Open cup and close cup. The appropriate test method is indicated on the MSDS.
General Ventilation	Also known as general exhaust ventilation. This is a system of ventilation consisting of either natural or mechanically induced fresh air movements to mix with and dilute contaminants in the workroom air. This is not the recommended type of ventilation to control contaminants that are highly toxic, when there may be corrosion problems from the contaminant being generated, and where fire or explosion hazards are generated close to sources of ignition (see also *Local Exhaust Ventilation*).
Hazardous Material	Any substance of compound that has the capability of producing adverse effects on the health and safety of humans.
Hematopoietic	Agents which act on the blood or the hematopoietic system. They decrease hemoglobin function and deprive the body tissues of oxygen. Signs and symptoms include cyanosis, loss of consciousness. Chemicals include carbon monoxide, cyanides.

Hepatoxins	Chemicals which produce liver damage. Signs and symptoms include jaundice, liver enlargement. Chemicals include carbon tetrachloride, nitrosamines.
Highly Toxic	a) A chemical that has a median lethal dose of 50 mg (LD50) or less per kg of body weight when administered orally to albino rats weighing between 200 g and 300 g each. b) A chemical that has an LD50 of 200 mg or less per kg of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between 2 kg and 3 kg each. c) A chemical that has a median lethal concentration (LC50) in air of 200 ppm by volume or less or gas or vapor, or 2 mg/L or less of mist, fume, or dust when administered by continuous inhalations for one hour (or less if death occurs within one hour) to albino rats weighing between 200 g and 300 g each.
Ignitable	A solid, liquid, or compressed gas waste that has a flash point of less than 140ºF. Ignitable material may also be regulated by the EPA as a hazardous waste.
Incompatible	The term applied to two substances to indicate that one material cannot be mixed with the other without the possibility of a dangerous reaction (see *Appendix D: Table of Incompatible Chemicals*).
Ingestion	Taking a substance into the body through the mouth, as in food, drink, medicine, cigarettes, or unknowingly as on contaminated hands, etc.
Inhalation	The breathing in of an airborne substance that may be in the form of gases, fumes, mists, vapors, dusts, or aerosols.
Inhibitor	A substance that is added to another to prevent or slow down an unwanted reaction or change.
Irritant	A substance that produces an irritating effect when it contacts skin, eyes, nose, or respiratory system.

Kilogram (kg)	A unit of weight in the International System (SI) of Units equal to 2.2 U.S. pounds.
Lethal Concentration 50 (LC50)	The concentration of a material in air that will kill 50% of the test subjects when administered as a single exposure (typically 1 or 4 hours).
Lethal Dose 50 (LD50)	The dose of a substance or chemical that will kill 50% of the test animals in a group during a single exposure.
Local Exhaust Ventilation	Also known as exhaust ventilation. A ventilation system that captures and removes the contaminants at the point they are being produced before they escape into the workroom air. The system consists of hoods, ductwork, a fan, and possibly an air-cleaning device. It works by removing the contaminant, not just diluting it, making it more economical over the long-term. However, the system must be properly designed with correctly shaped hoods, and correctly sized fans and ductwork.
Lower Explosive Limit (LEL) *Also known as:* Lower Flammable Limit (LFL)	The lowest concentration of a substance that will produce a fire or flash when an ignition source is present. It is expressed in the percent of vapor or gas in the air by volume. Below the LEL or LFL, the air/contaminant mixture is theoretically too “lean” to burn (see also *UEL*).
Lung Hazards	Chemicals which damage the lungs. Signs and symptoms include cough, tightness in chest, shortness of breath. Chemicals include silica, asbestos.
Melting Point	The temperature at which a solid changes to a liquid. A melting range may be given for mixtures.
MPPCF	Millions of particles of particulate per cubic foot of air.
Material Safety Data Sheet (MSDS)	Safety information about a chemical provided by the manufacturer or distributor. OSHA regulations require that an MSDS for each chemical used in a laboratory be accessible to every employee of that laboratory.

Mutagen	Anything that can cause a change (or mutation) in the genetic material of a living cell.
Narcosis	Stupor or unconsciousness caused by chemical exposure.
Nephrotoxins	Chemicals which produce kidney damage. Signs and symptoms include edma, proteinuria. Chemicals include halogenated hydrocarbons, uranium.
Odor Threshold	The minimum concentration of a substance at which a majority of test subjects can detect and identify the substance’s characteristic odor.
Oxidation	The process of combining oxygen with some other substances of a chemical change in which an atom loses electrons.
Oxidizer	A substance that initiates or promotes combustion in other materials, thereby causing fire either of itself or through the release of oxygen or other gases.
Oxygen Deficiency	An atmosphere having less than the normal percentage of oxygen (20%) found in normal air.
Permissible Exposure Limit (PEL)	The term used by OSHA to indicate the maximum air concentration to which employees can be exposed. PEL may be given as an 8-hour time-weighted average (TWA) exposure limit, a 15-minute short-term exposure limit (STEL), or a ceiling (C).
Personal Protective Equipment (PPE)	Any device or clothing worn by the worker to protect against hazards in the laboratory. Examples include respirators, gloves, lab coats, and splash goggles.
PPM	Parts (of vapor or gas) per million (parts of air) by volume.
Polymerization	A chemical reaction during which two or more small molecules combine to form larger molecules that contain repeating structural units of the original molecules. A hazardous polymerization is the above reaction with an uncontrolled release of energy.

Pyrophoric	A chemical that will ignite spontaneously in air at a temperature of 130ºF or below.
Reactivity	A substance’s susceptibility to undergoing a chemical reaction or change that may result in dangerous side effects, such as explosions, burning, and corrosive or toxic emissions. The conditions that cause the reaction, such as heat, other chemicals, or dropping, will usually be specified as “Conditions to Avoid” when a chemical’s reactivity is discussed on an MSDS.
Reproductive Toxins	Chemicals which affect the reproductive capabilities, including chromosomal damage (mutations), and effects on fetuses (teratogenesis). Signs and symptoms include birth defects, sterility. Chemicals include lead, 1,2-dibromo-3-chloropropane (DBCP).
Risk Assessment	Evaluation of existing hazards concerned with a procedure or process in the work environment.
Select Carcinogen	See *Appendix B* for full definition.
Short-Term Exposure Limit (STEL or TLV-STEL)	The maximum concentration to which an employee can be exposed for no more than 15 minutes at a time, no more than 4 times a day. There must be at least 60 minutes between exposures at the STEL level. The Time Weighted Average (TLV-TWA) must also not be exceeded.
SKIN	This designation sometimes appears on an MSDS alongside a TLV or PEL. It refers to the possibility of absorption of the particular chemical through the skin and eyes. Thus, protection of large surface areas of skin should be considered so that the Threshold Value Limit (TLV) is not invalidated.
Skin Hazards	Chemicals which affect the dermal layer of the body. Signs and symptoms include depletion of fats of the skin, rashes, irritation. Chemicals include ketones, chlorinated compounds.
Systemic	Spread throughout the body, affecting many or all body systems or organs not located in one spot or area.

Teratogen	An agent or substance that may cause physical defects in the developing embryo or fetus.
Threshold Limit Value (TLV)	Airborne concentrations of substances devised by the ACGIH that represent conditions under which it is believed that nearly all employees may be repeatedly exposed, day after day, without adverse effects. TLVs are advisory guidelines, not legal standards, that are based on evidence from industrial experience, animal studies, or human studies when they exist. TLVs include: Time Weighted Average (TLV-TWA), Short-Term Exposure Limit (TLV-STEL), and Ceiling (TLV-C) (see also *PEL*).
Time Weighted Average (TLV-TWA)	The average time over a given work period (e.g., an 8-hour work day) of a person's exposure to a chemical or agent. The average is determined by sampling for the contaminant throughout the work period.
Upper Explosive Limit (UEL) *Also known as:* Upper Flammable Limit (UFL)	The highest concentration of a substance that will burn or explode when an ignition source is present. It is expressed in the percent of vapor or gas in the air by volume. Above the UEL, or UFL, the air/contaminant mixture is theoretically too "rich" to support combustion. The difference between the LEL and the UEL constitutes the flammable range or explosive range of a substance. That is, if the LEL is 1 ppm and the UEL is 5 ppm, then the explosive range of the chemical is 1 ppm to 5 ppm (see also *LEL*).
Unstable	A chemical which in the pure state, or as produced or transported, will vigorously polymerize, decompose, condense, or wil become self-reactive under conditions of shock, pressure, or temperature.
Vapor	The gaseous form of substances which are normally in the liquid or solid state (at normal room temperature and pressure). Vapors evaporate into the air from liquids, such as solvents. Solvents with low boiling points will readily evaporate.
Water-Reactive	A chemical that reacts with water to release a gas that is either flammable or presents a health hazard.

GLOSSARY OF ORGANIZATIONS

APPENDIX H

ACGIH	The American Conference of Governmental Industrial Hygienists is a voluntary membership organization of professional industrial hygiene personnel in governmental or educational institutions. The ACGIH develops and publishes recommended occupational exposure limits each year called Threshold Limit Values (TLVs) for hundreds of chemicals, physical agents, and biological exposure indices.
ANSI	The American National Standards Institute is a voluntary membership organization (operating with private funding) that develops consensus standards nationally for a wide variety of devices and procedures.
DOT	The Department of Transportation is the Federal Agency that regulates the labeling and transportation of hazardous materials.
EPA	The Environmental Protection Agency is the Federal Agency responsible for administration of laws to control and/or reduce pollution of water, air, and land systems.
IARC	The International Agency for Research on Cancer, among other duties, publishes authoritative independent assessments (called the IARC Monographs series) by international experts of the carcinogenic risks posed to humans by a variety of agents, mixtures, and exposures.
NFPA	The National Fire Protection Association is a voluntary membership organization whose aims are to promote and improve fire protection and prevention. The NFPA has published 16 volumes of codes known as the National Fire Codes. Within these codes is Standard No. 704, "*Identification of the Fire Hazards of Materials*." This system rates the hazards of a material during a fire. These hazards are divided into health, flammability, and reactivity hazards and appear in a color-coded diamond system using numbers 0 (no special hazard) through 4 (severe hazard) indicating the severity of the hazard.

NIOSH	The National Institute for Occupational Safety and Health (NIOSH) is the federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness.
NIH	The National Institutes of Health is a biomedical research center comprised of 27 separate institutes and centers. The goal of the NIH research is to acquire new knowledge to help prevent, detect, diagnose, and treat disease and disability.
OSHA	The Occupational Safety and Health Administration is a Federal Agency under the Department of Labor which publishes and enforces safety and health regulations for most businesses and industries within the United States.