Section 3 - Chemical Hygiene Plan

Background and Introduction

Purpose

The University of California Agriculture and Natural Resources (UC ANR) Chemical Hygiene Plan (CHP) establishes a formal written program for protecting laboratory personnel against adverse health and safety hazards associated with exposure to potentially hazardous chemicals and must be made available to all employees working with hazardous chemicals. The CHP describes the proper use and handling practices and procedures to be followed by faculty, staff, students, visiting scholars, and all other personnel working with potentially hazardous chemicals in laboratory settings. This plan is based on best practices identified in, among others sources, "Prudent Practices for Handling Hazardous Chemicals in Laboratories," published by the National Research Council, and the American Chemical Society's "Safety in Academic Chemistry Laboratories" (www.acs.org).

UC ANR has developed and is implementing this Chemical Hygiene Plan. Each principal investigator is responsible for modifying this plan by adding SOPs and documentation to address lab-specific hazards. Each principal investigator is responsible for working with lab users, location safety coordinators, and EH&S specialist as needed to assure implementation, oversight, and annual review of this CHP

Scope

The CHP applies to laboratories that use, store, or handle potentially hazardous chemicals and all personnel who work in these facilities. This document is be part of the Injury Illness and Prevention Plan (IIPP) for each ANR location where employees handle hazardous chemicals in laboratory settings. The CHP does not apply to research involving exclusively radiological materials, radiation producing machines, lasers, or biological materials, as these safety procedures and regulatory requirements are outlined in the UC Davis Radiation Safety Manual, Hydroprobe Safety Manual, Laser Safety Manual, and project-specific Biosafety Plan or Biological Use Authorization (BUA) respectively. Research involving more than one type of hazard must comply with all applicable regulatory requirements and follow guidance outlined in the relevant safety manuals. Laboratory personnel in compliance with the Chemical Hygiene Plan are not required to comply with the Hazard Communication component of the IIPP.

The information presented in the CHP represents best practices and provides a broad overview of the information necessary for the safe operation of laboratories that utilize potentially hazardous chemicals. It is not intended to be all inclusive. Departments, divisions or other work units engaged in work with potentially hazardous chemicals that have unusual characteristics, or are otherwise not sufficiently covered in the written CHP, must customize the document by adding additional SOPs addressing the hazards and how to mitigate their risks, as appropriate. SOPs that are added to the CHP must receive prior approval from the PI and/or the UC ANR Office of Environmental Health and Safety (EH&S). For information on specific chemical safety topics not covered in the CHP, please contact the EH&S department via email ehs@ucanr.edu or phone (530) 530-1264.

Identification & Classification of Hazardous Chemicals

Chemical hazard communication

Subsequent to the passage of the Federal Occupational Safety and Health Act in 1971, the California Hazard Communication Standard 8CCR5194, was established in December of 1981. UC ANR has an established Hazard Communication Program that complies with the Cal/OSHA Hazard Communication Standard (http://safety.ucanr.edu/files/2858.pdf). The purpose of UC ANR's Hazard Communication Program is to ensure that all employees and, upon request, their personal physicians, have the right to receive information regarding the hazardous substances to which they may have been exposed at work. The requirements of the hazard communication program apply to those locations and activities specifically excluded from the Cal/OSHA laboratory standard environments such as greenhouse facilities, shops, pesticide storage facilities, and some technical work rooms.

Following adoption of the Hazard Communication Standard in California, the laboratory community successfully campaigned for a more performance-based standard. In March 1991, after federal adoption of a similar standard, California adopted the laboratory standard (8CCR5191) which sets requirements for chemical safety in laboratories, including the establishment of a Chemical Hygiene Plan to guide chemical safety in lab settings. The lab standard (and requirement for a chemical hygiene plan) applies in laboratory work areas.

The Cal/OSHA lab standard definitions:

Laboratory. A facility where the "laboratory use of hazardous chemicals" occurs. It is a workplace where relatively small quantities of hazardous chemicals are used on a non-production basis.

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

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

Laboratory scale. Work with substances in which the containers used for reactions, transfers, and other handling of substances are designed to be easily and safety manipulated by one person.

Many projects span both lab and non-lab areas. Due to the above definitions, it is also possible for some operations with what would otherwise seem like a lab, to be required to comply with the Hazard Communication Standard. In both cases, UC ANR is responsible for providing information about the hazardous substances in our workplace, the associated hazards, and the control of these hazards, through a comprehensive hazard communication program. Proper hazard communication involves the active participation of the PI, the Location or Laboratory Safety Representative, and Environmental Health and Safety, who are each responsible for providing consultation and safety information to employees working with hazardous chemicals.

Chemical inventory (list of hazardous substances)

All labs and work sites are required to maintain a current and accurate chemical inventory that includes each hazardous substance on their possession, specific information on any associated health or safety hazards must be made readily available to all laboratory personnel, typically though Safety Data Sheets.

Hazard determination

Principal investigators are responsible for verifying if any items on their chemical inventory are health hazards or hazardous substances.

The term "hazardous substance" refers to any chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed individuals. Hazardous substances may include, but are not limited to, those chemicals listed in the following:

1. "The Hazardous Substance List", prepared by the Cal/OSHA Director 8CCR339 (www.dir.ca.gov/title8/339.html);
2. "Toxic and Hazardous Substances, Air Contaminants", 8CCR5155 (www.dir.ca.gov/title8/5155.html)
3. "Threshold Limit Values for Chemical Substances in the Work Environment", ACGIH, 2004;
4. Most Recent "Annual Report on Carcinogens", NTP http://ntp.niehs.nih.gov/ntp/roc/twelfth/roc12.pdf
5. "Monographs", IARC, WHO (www.iarc.fr/en/publications/list/monographs)
6. SDSs for reproductive toxins and cancer causing substances (www.ehs.ucr.edu/services/msds.html).

Safety Data Sheets (SDS)

An SDS must be available for each hazardous substance in a laboratory's chemical inventory. SDSs are available from the UC online SDS library, available through: www.ehs.ucr.edu/services/msds.html

New chemical substances synthesized or produced in a laboratory, and used or shared for commercial purposes outside of the lab where it is created, require the preparation of an SDS for each synthesized substance. The UC-system wide SDS library has the capability of developing new SDSs based on the known chemical and physical properties of that substance. SDS for a proprietary or experimental chemical which is not yet commercially available should be provided by the chemical manufacturer. If such documentation is not available, the primary exposure hazards of the chemical must verified and documented in some form. For assistance, contact UC ANR EH&S (ehs@ucanr.edu; 530-750-1264)

Labels, signs and other forms of warning

Labeling requirements for all hazardous substances are summarized as follows:

- Labels on incoming containers of hazardous chemicals shall not be removed or defaced until the container is completely empty.
- All containers of hazardous materials must be labeled with the identity of the hazardous substance and all applicable hazard warning statements. If abbreviations are used, each room should have a posting listing the abbreviations used, along with the full chemical names an example of such an abbreviation list can be found at www.ehs.ucr.edu/laboratory/Chemical%20Abbreviation%20Example.pdf.

- Newly synthesized compounds and experimental/proprietary chemicals must be labeled with the appropriate hazard warnings based on the knowledge of the chemical and physical properties of that substance.
- Labels must be legible, in English, and clearly displayed; Lewis structures alone are inadequate.
- Non-original (secondary) containers (e.g., smaller or temporary containers into which a material is transferred for use) must be labeled with the identity of the substance and appropriate hazard warnings. Containers which are typically used for food and drink or which could be mistaken for food or drink containers should never be used to store hazardous chemicals.
- Symbols and/or other languages may be provided for non-English speaking employees.
- Use the symbols in the Globally Harmonized System of classification and labeling of chemicals (www.osha.gov/dsg/hazcom/ghs.html – see section 1 signage and postings)

Classes of Hazardous Chemicals

Chemicals can be divided into several different hazard classes. The hazard class will determine how these materials should be stored and handled and what special equipment and procedures are needed to use them safely. Each chemical container, whether supplied by a vendor or produced in the laboratory, must include labels that clearly identify the hazards associated with that chemical. In addition to specific chemical labels, hazard information for specific chemicals can be found by referencing the Safety Data Sheet (SDS) for that chemical.

Flammability hazards

Flammable substances are in common use in UC ANR laboratories. Flammable liquids include those chemicals that have a flashpoint of less than 100 degrees Fahrenheit (37.78 degrees Celsius). No more than 10 gallons in aggregate of flammable liquids shall be stored outside of an approved and labeled storage cabinet. No more than 60 gallons of flammable liquids may be stored inside of an approved flammable liquid storage cabinet. Flame-resistant laboratory coats must be worn when working with large quantities (4 liters or more) of flammable materials and/or with procedures where a significant fire risk is present (e.g., when working with open flame or near ignition sources). These materials can constitute a significant immediate threat and should be treated with particular care, even though the use of these materials is fairly common in the laboratory setting. Particular attention should be given to preventing static electricity and sparks when handling flammable liquids by using electrical grounding and bonding techniques whenever possible.

Reactivity hazards

Reactive and explosive substances are materials that decompose under conditions of mechanical shock, elevated temperature, or chemical action, and release large volumes of gases and heat. Some materials, such as peroxide formers, may not be explosive, but may form explosive substances over time. These substances pose an immediate potential hazard and procedures for their use must be carefully reviewed. These materials must also be stored in a separate storage cabinet or in a separate laboratory grade refrigerator or freezer that is designed for flammable/reactive chemicals. Pyrophoric chemicals are a special classification of reactive materials that spontaneously combust when in contact with air and require laboratory-specific training. Flame-resistant laboratory coats or other appropriate flame resistant protection must always be worn when working with pyrophoric chemicals.

Health hazards

Cal/OSHA uses the following definition for health hazards:

The term 'health hazard' includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic systems, and agents which damage the lungs, skin, eyes, or mucous membranes.

The major classes of "hazardous" and "particularly hazardous substances" and their related health and safety risks are detailed below:

Corrosive substances

As a health hazard, corrosive substances cause destruction of, or alterations in, living tissue by chemical action at the site of contact.

Major classes of corrosive substances include:

- Strong acids – e.g., sulfuric, nitric, hydrochloric acids
- Strong bases – e.g., sodium hydroxide, potassium hydroxide and ammonium hydroxide
- Dehydrating agents – e.g., sulfuric acid, sodium hydroxide, phosphorus pentoxide and calcium oxide
- Oxidizing agents – e.g., hydrogen peroxide, chlorine and bromine.

Symptoms of exposure for inhalation include a burning sensation, coughing, wheezing, laryngitis, shortness of breath, nausea, and vomiting. For eyes, symptoms include pain, blood shot eyes, tearing, and blurring of vision. For skin, symptoms may include reddening, pain, inflammation, bleeding, blistering and burns. As a physical hazard, corrosive substances may corrode materials they come in contact with and may be highly reactive with other substances. It is important to review information regarding the materials they may corrode, and their reactivity with other substances, as well as information on health effects. In most cases, these materials should be segregated from other chemicals and require secondary containment when in storage.

Irritants

Irritants are defined as non-corrosive chemicals that cause reversible inflammatory effects on living tissue by chemical action at the site of contact. A wide variety of organic and inorganic compounds, including many chemicals that are in a powder or crystalline form, are irritants. The most common example of an irritant may be ordinary smoke which can irritate the nasal passages and respiratory system. Consequently, eye and skin contact with all laboratory chemicals should always be avoided. Symptoms of exposure can include reddening or discomfort of the skin and irritation to respiratory systems.

Sensitizers

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

Hazardous substances with toxic effects on specific organs

Substances included in this category include:

- Hepatotoxins – i.e., substances that produce liver damage, such as nitrosamines and carbon tetrachloride;
- Nephrotoxins – i.e., agents causing damage to the kidneys, such as certain halogenated hydrocarbons;
- Neurotoxins – i.e., substances which produce their primary toxic effects on the nervous system, such as mercury, acrylamide and carbon disulfide;

- Ototoxic chemicals – i.e., substances which can cause or worsen hearing loss when coupled with noise exposures, such as toluene, styrene, trichloroethylene, acetonitrile, and metal fumes;
- Agents which act on the hematopoietic (blood cell production) system – e.g., carbon monoxide and cyanides which decrease hemoglobin function and deprive the body tissues of oxygen;
- Agents which damage lung tissue – e.g., asbestos and silica.

Symptoms of exposure to these materials vary. People working with these materials should review the SDS for the specific material being used, take special note of the associated symptoms of exposure and contact EH&S for assistance in selection of PPE.

Particularly hazardous substances

OSHA recognizes that some classes of chemical substances pose a greater health and safety risk than others. To differentiate this different risk characteristic, OSHA identifies two categories of hazardous chemicals: Hazardous Chemicals and Particularly Hazardous Substances.

Substances that pose such significant threats to human health are classified as "particularly hazardous substances" (PHSs). The OSHA laboratory standard and Cal/OSHA regulations require that special provisions be established to prevent the harmful exposure of researchers to PHSs, including:

1. Establishment of a designated area;
2. Use of containment devices such as fume hoods or glove boxes;
3. Procedures for safe removal of contaminated waste; and
4. Decontamination procedures.

In addition to the above requirements, a chemical-specific or procedure-specific SOP should be created for each PHS in regular use in a laboratory. Refer to the appendices in this section for more information on SOPs.

Particularly hazardous substances are divided into three primary types:

1. Acute Toxins;
2. Reproductive Toxins; and
3. Carcinogens.

A list can be found through www.ehs.ucr.edu/hazardousmaterials/AppendixAList+PHS.xlsx

Acute toxins

Substances that have a high degree of acute toxicity are interpreted by OSHA as being substances that "may be fatal or cause damage to target organs as the result of a single exposure or exposures of short duration." These chemicals, associated chemical waste, and storage containers must be handled with care to prevent cross contamination of work areas and unexpected contact. These chemicals must be labeled as "Toxic." Empty containers of these substances must be packaged and disposed of as hazardous waste without rinsing trace amounts into the sanitary sewer system.

Reproductive toxins

Reproductive toxins (http://web.princeton.edu/sites/ehs/labsafetymanual/appa.htm) include any chemical that may affect the reproductive capabilities, including chromosomal damage (mutations) and effects on fetuses (teratogenesis).

Reproductive toxins can affect the reproductive health of both men and women if proper procedures and controls are not used. For women, exposure to reproductive toxins during pregnancy can cause adverse effects on the fetus; these effects include embryolethality (death of the fertilized egg, embryo or fetus), malformations (teratogenic effects), and postnatal functional defects. For men, exposure can lead to sterility.

Examples of embryotoxins include thalidomide and certain antibiotics such as tetracycline. Women of childbearing potential should note that embryotoxins have the greatest impact during the first trimester of pregnancy. Because a woman often does not know that she is pregnant during this period of high susceptibility, special caution is advised when working with all chemicals, especially those rapidly absorbed through the skin (e.g., formamide). Pregnant women and women intending to become pregnant should consult with occupational health professional or EH&S before working with substances that are suspected to be reproductive toxins.

Carcinogens

Carcinogens are chemical or physical agents that cause cancer. Generally they are chronically toxic substances; that is, they cause damage after repeated or long-duration exposure, and their effects may only become evident after a long latency period. It is also important to recognize that some substances involved in research laboratories are new compounds and have not been subjected to testing for carcinogenicity.

Chronic toxins are particularly insidious because they may have no immediately apparent harmful effects. These materials are separated into two classes: Select Carcinogens and Regulated Carcinogens.

Select Carcinogens are materials which have met certain criteria established by the National Toxicology Program or the International Agency for Research on Cancer regarding the risk of cancer via certain exposure routes. (See definition of Select Carcinogen).

The following references (links provided) are used to determine which substances are select carcinogens by Cal/OSHA's classification:

U.S. OSHA carcinogen list (http://web.princeton.edu/sites/ehs/labsafetymanual/sec7j.htm):

- Annual Report on Carcinogens published by the National Toxicology Program (NTP), including all of the substances listed as "known to be carcinogens" and some substances listed as "reasonably anticipated to be carcinogens" http://ntp.niehs.nih.gov/index.cfm?objectid=32BA9724-F1F6-975E7FCE50709CB4C932
- International Agency for Research on Cancer (IARC), including all of Group 1 "carcinogen to humans" by the International Agency for Research on Cancer Monographs (IARC) (Volumes 1-48 and Supplements 1-8); and some in Group 2A or 2B, "reasonably anticipated to be carcinogens" by the National Toxicology Program (NTP), and causes statistically significant tumor incidence in

experimental animals in accordance with any of the following criteria: (i) after inhalation exposure of 6-7 hours per day, 5 days per week, for a significant portion of a lifetime to dosages of less than 10 mg/m3; (ii) after repeated skin application of less than 300 mg/kg of body weight per week; or (iii) after oral dosages of less than 50 mg/kg of body weight per day http://monographs.iarc.fr/ENG/Classification/crthgr01.php

Regulated carcinogens fall into a higher hazard class and have extensive additional requirements associated with them. The use of these agents may require personal exposure sampling based on usage. When working with regulated carcinogens, it is particularly important to review and effectively apply engineering and administrative safety controls as the regulatory requirements for use of these chemicals are very extensive.

How to Reduce Exposures to Hazardous Chemicals

Hazardous chemicals require a carefully considered, multi-tiered approach to ensure safety. There are four primary routes of exposure for chemicals which have associated health hazards:

- Inhalation;
- Absorption (through the skin or eyes);
- Ingestion; and
- Injection (skin being punctured by a contaminated sharp object or uptake through an existing open wound).

Of these, the most likely route of exposure in the laboratory is by inhalation. Many hazardous chemicals may affect people through more than one of these exposure modes, so it is critical that protective measures are in place for each of these uptake mechanisms.

Safety controls

Safety controls are divided into three main classifications:

- Engineering Controls;
- Administrative Controls; and
- Personal Protective Equipment.

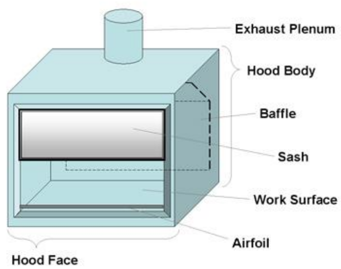
Elements of these three classes are used in a layered approach to create a safe working environment. The principles of each of these elements are detailed below.

Engineering controls

Engineering controls include all "built in" safety systems. These controls offer the first line of protection and are highly effective in that they generally require minimal special procedures or actions on the part of the user except in emergency situations. A fundamental and very common example is the laboratory fume hood which is very effective at containing chemical hazards and protecting users from inhalation hazards. Other examples of engineering controls include general room ventilation, flammable material storage units, and secondary containment.

General laboratory ventilation

All laboratory rooms in which hazardous materials are used must have fresh air ventilation with 100% of the exhaust venting to the outside; laboratory rooms should not be part of recycled air systems. In cases where this is not feasible, a formal hazard evaluation will be made by EH&S to determine what work can be done in the space and under what special conditions or limitations. Laboratory rooms should be kept at negative pressure compared to public areas to prevent the spread of hazardous vapors. See Appendix 3a for guidelines on laboratory ventilation.



Fume hoods

Fume hoods are the most commonly used local exhaust system in laboratories. Other methods include vented enclosures for large pieces of equipment or chemical storage, and portable exhaust systems for capturing contaminants near the point of release. Some systems are equipped with air cleaning devices (HEPA filters or carbon absorbers). Exhaust from fume hoods are designed to terminate at least ten feet above the roof deck or two feet above the top of any parapet wall, whichever is higher.

It is advisable to use a fume hood when working with all hazardous substances. In addition, a fume hood or other suitable containment device must be used for all work with "particularly hazardous substances." A properly operating and correctly used hood can reduce or eliminate volatile liquids, dusts, and mists. Fume hoods must be evaluated for operation and certified by EH&S or other qualified facilities staff on an annual basis. These annual evaluations check the fume hood air flow patterns and velocity to ensure that the unit will contain hazardous vapors. Data on annual fume hood monitoring is maintained by EH&S.

Each fume hood should have a current calibration sticker and a marker indicating the highest sash height to be used when working with hazardous materials. Contact EH&S for a fume hood evaluation if these labels are missing.

Each fume hood must be equipped with at least one type of continuous quantitative monitoring device designed to provide the user with current information on the operational status of the hood. When hazardous materials are in a fume hood, but it is not under active use (e.g., during an unattended reaction or experiment), the sash should be closed. Fume hoods are not designed for long term storage of hazardous materials.

Routine maintenance and repairs of fume hoods must be conducted by qualified service contractor or equivalently-qualified ANR staff. Great care must be taken with fume hoods and associated ducting as many hoods include some amount of asbestos-containing materials which must not be handled or disturbed without proper safety controls in place. EH&S or the user may initiate maintenance as well as coordinate with location safety coordinator to ensure that any repair or maintenance work is completed safely. EH&S or other qualified HVAC professional must re-inspect the fume hood following maintenance or repairs.

General rules for fume hood use

The following general rules should be followed when using fume hoods:

1. Fume hoods should not be used for work involving hazardous substances unless they have a certification label that confirms certification has occurred within the past year.
2. Always keep hazardous chemicals >6 inches behind the plane of the sash.
3. **Never** put your head inside a fume hood containing hazardous materials. The plane of the sash is the barrier between contaminated and uncontaminated air.
4. Work with the hood sash in the **lowest practical position.** The sash acts as a physical barrier in the event of an accident. Keep the sash closed when not conducting work in the hood.
5. Do not clutter your hood with unnecessary bottles or equipment. Keep it clean and clear. Only materials actively in use should be in the hood.
6. Do not make any modifications to hoods, duct work, or the exhaust system without first contacting EH&S.
7. Do not use large equipment in laboratory hoods unless the hood is dedicated for this purpose, as large obstructions can change the airflow patterns and render the hood unsafe.
8. Shut your sash! For energy efficiency, make sure to shut your sash when the hood is not in use.
9. Shut the sash if the fire alarm sounds.

Laboratory fume hoods are one of the most important pieces of equipment used to protect laboratory and other workers from exposure to hazardous chemicals. Chemical fume hoods should be inspected upon installation, renovation, when a deficiency is reported, or a when change has been made to the operating characteristics of the hood. Since fume hoods used for regulated carcinogens have additional requirements, such as increased face velocity, contact the EH&S if the intended use changes.

Glove boxes and ventilation devices

In addition to fume hoods, some laboratories use contained glove box units for working with reactive chemicals under an inert environment, working with very toxic substances in a completely closed system, or for creating a stable, breeze free, system for weighing hazardous or reactive materials. These units can be very effective because they offer complete containment. Another type of ventilation device is the elephant trunk, or snorkel, which is connected to the exhaust system. This device is effective for capturing discharges from instruments such as gas chromatographs. The intake of the snorkel must be placed very close to the source to be effective. There are newer designs that are mounted on articulating arms, which make the systems more convenient to use.

Other engineering controls

In addition to the elements listed above, consideration must be given to providing sufficient engineering controls for the storage and handling of hazardous materials.

No more than 10 gallons of flammable chemicals may be stored outside of an approved flammable storage cabinet. For refrigerated or frozen storage, flammable and explosive materials must be kept in refrigeration units specifically designed for storing these materials. Generally these units do not have internal lights or electronic systems that could spark and trigger an ignition; additionally, the cooling elements are external to the unit. These units should be labeled with a rating from Underwriters Laboratory or other certifying organization.

Secondary containment must be provided for corrosive and reactive chemicals and is recommended for all other hazardous chemicals. Secondary containment should be made of chemically resistant materials and should be sufficient to hold at least 110% the volume of at least the largest single bottle stored in the container.

Laboratories where hazardous materials are in use must contain a sink, kept clear for hand washing to remove any final residual contamination. Hand washing is required whenever a staff member who has been working with hazardous materials plans to exit the laboratory or work on a project that does not involve hazardous materials.

Administrative controls

The next layer of safety controls are Administrative Controls. These controls consist of policies and procedures; they are not generally as reliable as engineering controls in that the user has to carefully follow the appropriate procedures and must be fully trained and aware in order to do so.

Laboratory groups should also review their operations to minimize the amounts of hazardous substances in use or to replace them with less hazardous alternatives. Attention must also be paid to the appropriate segregation of incompatible materials.

Standard operating procedures (SOPs)

Standard operating procedures that are relevant to safety and health considerations must be developed and followed when laboratory work involves the use of hazardous chemicals (CCR, Title 8, Section 5191 (e)(3)(A)), especially for "particularly hazardous substances" (PHS). SOPs are written instructions that detail the steps that will be performed during a given experimental procedure and include information about potential hazards and how these hazards will be mitigated. SOPs should be written by laboratory personnel who are most knowledgeable and involved with the experimental process. The development and implementation of SOPs is a core component of promoting a strong safety culture in the laboratory and helps ensure a safe work environment.

While general guidance regarding laboratory work with chemicals is contained in this plan, PIs are required to develop and implement laboratory-specific SOPs for certain hazardous chemicals and PHS that are used in their laboratories. These SOPs must be submitted and reviewed by the location safety committee and/or lab safety coordinator prior to implementation. For certain hazardous chemicals, PHS, or specialized practices, consideration must be given to whether additional consultation with EH&S is warranted or required.

Circumstances requiring prior approval from the PI must also be addressed in laboratory specific SOPs. These circumstances are based on the inherent hazards of the material being used, the hazards associated with the experimental process, the experience level of the worker, and the scale of the experiment. Some examples of circumstances that may require prior approval include working alone in a laboratory, unattended or overnight operations, the use of highly toxic gas of any amount, the use of large quantities of toxic or corrosive gases, the use of extremely reactive chemicals (e.g., pyrophorics, water reactive chemicals), or the use of carcinogens.

UC Davis and UC Riverside EH&S websites have downloadable templates for SOPs.

UC Davis Chemical SOPs templates:

file:///C:/Users/malendia/Downloads/UC%20Davis%20Safety%20Services%20-%20Standard%20Operating%20Procedure%20(SOP)%20Templates%20-%202017-05-10.pdf

UC Riverside Chemical SOP templates: http://ehs.ucr.edu/laboratory/SOP/library.html

UC Davis and UC Riverside EH&S departments maintain websites with tools and resources that may be referenced while developing SOPs, including fact sheets for the use of certain hazardous chemicals, online safety videos and an SOP Library. UC ANR EH&S is also available to assist with the development of SOPs. SOPs must be developed prior to initiating any experiments with hazardous chemicals or particularly hazardous substances and are to be filed and maintained in the Laboratory and Research Safety Manual where they are available to all laboratory personnel.

When drafting an SOP, consider the type and quantity of the chemical being used, along with the frequency of use. The Safety Data Sheet (SDS) for each hazardous chemical or particularly hazardous substance that will be addressed in the SOP should be referenced during SOP development. The SDS lists important information that will need to be considered, such as exposure limits, type of toxicity, warning properties, and symptoms of exposure. If a new chemical will be produced during the experiment, an SDS will not necessarily be available. In these cases, the toxicity is unknown and it must be assumed that the substance is particularly hazardous, as a mixture of chemicals will generally be more toxic than its most toxic component.

Chemical safety training resources

Employee training on specific workplace hazards must be provided at the time of initial assignment, whenever a new hazard is introduced into the workplace, and whenever employees may be exposed to hazards in other work areas.

Safety Note #48 Hazard Communication Awareness is available on the UC ANR EH&S website (http://safety.ucanr.edu/files/1441.pdf) and can be used for employee training.

UC Davis has published a helpful training handout (http://safetyservices.ucdavis.edu/sites/default/files/documents/Training_Course_Handout.pdf). UC Davis and UC Riverside have also made training available online.

Links to UC campus hazard communication training online:
UC Davis: http://safetyservices.ucdavis.edu/training/hazard-communication
UC Riverside: http://www.ehs.ucr.edu/training/online/hazardcommunication/indexlms.html

Additional Resources

- “Occupational Exposure to Hazardous Chemicals in Laboratories.” California Code of Regulations Title 8, Section 5191 8CCR5191
- Standard Operating Procedures (SOPs) for handling toxic chemicals (Laboratory Specific)
- General information on the signs and symptoms associated with exposure to hazardous substances used in the laboratory or facility (Laboratory-specific SOPs or SDS)
- Identity labels, showing contents of containers and associated hazards
- Warnings at areas or equipment where special or unusual hazards exist
- Procedures to follow in case of an emergency:
    - Emergency telephone numbers of emergency personnel/facilities, supervisors, and laboratory workers;
    - Location signs for safety showers, eyewash stations, other safety and first aid equipment, exits and areas where food and beverage consumption and storage are permitted; and
    - Information for designated medical providers where employees may go for emergency care.

Personal protective equipment

Personal protective equipment (PPE) serves as a researcher’s last line of defense against chemical exposures and is required fir everyone entering a laboratory containing hazardous chemicals.

The UC PPE policy outlines the basic PPE requirements, which include but are not limited to:

- Full length pants and close-toed shoes, or equivalent.
- Protective gloves, laboratory coats, & eye protection when working with, or adjacent to, hazardous chemicals.
- Flame resistant laboratory coats for high hazard materials, pyrophorics, and ≥4 liters of flammables.

The primary goal of basic PPE is to mitigate, at a minimum, the hazard associated with exposure to hazardous substances. In some cases, additional, or more protective, equipment must be used. If a project involves a chemical splash hazard, chemical goggles are required; face shields may also be required when working with chemicals that may cause immediate skin damage. Safety goggles differ from safety glasses in that they form a seal with the face, which completely isolates the eyes from the hazard. If a significant splash hazard exists, heavy gloves, protective aprons and sleeves may also be needed. Gloves should only be used under the specific condition for which they are designed, as no glove is impervious to all chemicals. It is also important to note that gloves degrade over time, so they should be replaced as necessary to ensure adequate protection. The UC Riverside EH&S website (http://ehs.ucr.edu/safety/ppeselection.html) provides PPE Selection Guide to assist in selecting the appropriate glove type for the type of potential hazard.

EH&S requires each laboratory to complete and document a hazard assessment prior to beginning work and to provide annual updates thereafter. PPE can be selected based on this hazard assessment.

UC laboratory hazard assessment tool (LHAT)

The UC Laboratory Hazard Assessment Tool (LHAT) was developed to broadly identify activities involving chemical and other types of hazards and is an effective method of hazard communication. The online Hazard Assessment Tool can be accessed at: https://ehs.ucop.edu/lhat/

The UC LHAT captures information on the specific type of hazard, the location of the hazards, the name of the Faculty or other Supervisor who oversees the facility and provides guidance for the proper exposure controls (Engineering, Administrative and Personal Protective Equipment (PPE), that should be used by the people working with and around the hazards to protect themselves. Once the PPE selection is made, the laboratory is required to conduct and document training for laboratory personnel on the use of PPE.

If completion of the online tool is not feasible, an equivalent paper form is available for download on the UC ANR EH&S website (http://safety.ucanr.edu/files/274338.pdf) and included as an Appendix 1b. The paper form or a printed copy of the current hazard assessment and training record should be retained with other lab safety documentation.

How to use and maintain PPE

Personal protective equipment should be kept clean and stored in an area where it will not become contaminated. Personal protective equipment should be inspected prior to use to ensure it is in good condition. It should fit properly and be worn properly. If it becomes contaminated or damaged, it should be cleaned or repaired when possible, or discarded and replaced.

Contaminated clothing/PPE

In cases where spills or splashes of hazardous chemicals on clothing or PPE occur, the clothing/PPE should immediately be removed and placed in a closed container that prevents release of the chemical. Heavily contaminated clothing/PPE resulting from an accidental spill should be disposed of as hazardous waste. Lightly contaminated laboratory coats should be cleaned and properly laundered, as appropriate. Laboratory personnel should never take contaminated items home for cleaning or laundering. Persons or companies hired to clean contaminated items should be provided with hazard communication and personal protective equipment.

Respiratory protection

Typically, respiratory protection is not needed in a laboratory. Under most circumstances, safe work practices, small scale usage, and engineering controls (fume hoods, biosafety cabinets, and general ventilation) adequately protect laboratory workers from chemical and biological hazards. Under certain circumstances, however, respiratory protection may be needed. These can include:

- An accidental spill such as:
  - a chemical spill outside the fume hood
  - a spill of bio-hazardous material outside a biosafety cabinet
- Performance of an unusual operation that cannot be conducted under the fume hood or biosafety cabinet.

- When weighing powdered chemicals or microbiological media outside a glove box or other protective enclosure. Disposable filtering face-piece respirators are generally recommended for nuisance dusts. If the chemicals are toxic, contact EH&S for additional evaluation.
- When exposure monitoring indicates that exposures exist that cannot be controlled by engineering or administrative controls.
- As required by a specific laboratory protocol or as defined by applicable regulations.

Because there are numerous types of respirators available, and each has specific limitations and applications, respirator selection and use requires pre-approval by EH&S. For either required or voluntary use of a respirator, the employee must contact UC ANR EH&S to request consultation with an Industrial Hygienist, who will contact the employee to evaluate the potential exposure.

The Industrial Hygiene review will include an evaluation of the work area and activities for the following:

- Provision of additional ventilation controls or enclosure of the airborne hazard;
- Substitution with a less hazardous substance;
- Qualitative or quantitative exposure assessment; and
- Respirator usage.

Processes with potential airborne hazards that cannot be eliminated by engineering or administrative controls will not be authorized by EH&S until affected employees can be incorporated into UC ANR's Respiratory Protection Program.

Because wearing respiratory equipment places a physical burden on the user, laboratory workers must be medically evaluated prior to wearing respiratory equipment. Certain individuals (e.g., persons with severe asthma, heart conditions, or claustrophobia) may not be medically qualified to wear a respirator. Upon enrollment in Respirator Training and Fit Testing, the employee will be sent the appropriate medical questionnaire. The completed medical questionnaire will be evaluated before the employee proceeds with the training. NOTE: This medical questionnaire is confidential. The employee will be provided additional information on who to contact for follow up questions.

After successful completion of the medical evaluation, the employee will be trained and fit tested by EH&S. Training topics include:

- Why the respirator is necessary and how improper fit, usage, or maintenance can compromise the protective effect of the respirator;
- What the limitations and capabilities of the respirator are;
- How to use the respirator effectively in emergency situations, including situations in which the respirator malfunctions;
- How to inspect, put on and remove, use, and check the seals of the respirator;
- What the procedures are for maintenance and storage of the respirator;
- How to recognize medical signs and symptoms that may limit or prevent the effective use of respirators; and
- The general requirements of the respiratory program.

Finally, a qualitative or quantitative fit test is conducted by EH&S for each respirator user. The fit test ensures a proper face to face piece seal for each individual and his/her mask. Fit testing is done in accordance with Cal/OSHA regulations (8CCR5144) (http://www.dir.ca.gov/title8/5144.html).

An annual refresher is required for the medical evaluation, respirator training, and fit testing. In addition to the annual training refresher, a more frequent re-training, fit testing or medical evaluation must be performed when any of the following occur:

- Changes in the workplace or the type of respirator render previous training obsolete;
- Inadequacies in the employee's knowledge or use of the respirator indicate that the employee has not retained the requisite understanding or skill;
- Any other situation arises in which reevaluation appears necessary to ensure safe respirator use;
- Facial scarring, dental changes, cosmetic surgery, or an obvious change in body weight; or
- An employee reports medical signs or symptoms related to their ability to use a respirator.

Laboratory safety and emergency response equipment

New personnel must be instructed in the location of fire extinguishers, safety showers, and other safety equipment before they begin work in the laboratory. This training is considered part of the laboratory specific training that all staff members must attend.

Fire extinguishers

All laboratories working with combustible chemicals, flammable chemicals, or other potential ignition sources (e.g. lasers) must be outfitted with appropriate fire extinguishers. All extinguishers should be mounted on a wall in an area free of clutter or stored in a fire extinguisher cabinet. Research personnel should be familiar with the location, use, and classification of the extinguishers in their laboratory.

Laboratory personnel are not required to extinguish fires that occur in their work areas and should not attempt to do so unless:

- It is a small fire (i.e., small trash can sized fire); and
- Appropriate training has been received; and
- It is safe to do so.

Any time a fire extinguisher is used, no matter for how brief a period, the PI, or most senior laboratory personnel present at the time of the incident, must immediately report the incident to the EH&S (ehs@ucanr.edu; 530-750-1264).

The UC ANR EH&S website contains a Fire Extinguisher training video which provides information on fire extinguisher use (http://safety.ucanr.edu/Training/Fire_Extinguisher_Video/).

Safety Showers and Eyewash Stations

All laboratories using hazardous chemicals must have immediate access to safety showers with eye wash stations. Access must be available in an unlocked location within 10 seconds or less for a potentially injured individual and access routes must be kept clear. This requirement applies to all areas where, during routine operations or emergencies, the eyes or body of an employee may come in contact with a substance that could cause corrosion, severe irritation, permanent tissue damage, or is toxic by absorption. Safety showers must have a minimum clearance of 16 inches from the centerline of the spray pattern in all directions at all times; this means that no objects should be stored or left within this distance of the safety shower.

In the event of an emergency, individuals using the safety shower should be assisted by an uninjured person to aid in decontamination and should be encouraged to stay in the safety shower for 15 minutes to remove all hazardous material.

Principal investigators are responsible for assuring that safety shower/eyewash stations are tested on a monthly basis. Tests may be performed by the location safety coordinator or physical plant staff. If an eyewash or safety shower needs repair, the location safety coordinator must be notified immediately and unit must be repaired before work with hazardous chemicals commences in the area served by the shower. Safety Notes #34 outlines requirements for safety eyewash and shower stations at UC ANR (http://safety.ucanr.edu/files/1426.pdf). Any questions regarding requirements for safety eyewashes or showers should be directed to UC ANR EH&S (ehs@ucanr.edu, 530-750-1264).

Fire doors

Many areas of research buildings may contain critical fire doors as part of the building design. These doors are an important element of the fire containment system and should remain closed unless they are on a magnetic self-closing or other automated self-closing system.

Safe laboratory habits

As detailed above, a safety program must include layers of policies and protective equipment to allow for a safe working environment, but to ensure effectiveness of the program, a number of fundamental elements must become basic working habits for the research community. Some of these elements are detailed below:

Personal protective equipment:

- Wear closed-toe shoes and full length pants, or equivalent, at all times when in the laboratory.
- Utilize appropriate PPE while in the laboratory and while performing procedures that involve the use of hazardous chemicals or materials.
- Confine long hair and loose clothing.
- Remove laboratory coats or gloves immediately on significant contamination, as well as before leaving the laboratory.
- Avoid use of contact lenses in the laboratory unless necessary. If they are used, inform supervisor so special precautions can be taken.
- Use any other protective and emergency apparel and equipment as appropriate. Be aware of the locations of first aid kits and emergency eyewash and shower station.

Chemical handling:

- Properly label and store all chemicals. Use secondary containment when required or advised.
- Deposit chemical waste in appropriately labeled receptacles and follow all other waste disposal procedures of the Chemical Hygiene Plan.
- Do not smell or taste chemicals.
- Never use mouth suction for pipetting or starting a siphon.
- Do not dispose of any hazardous chemicals through the sewer system.
- Be prepared for an accident or spill and refer to the emergency response procedures for the specific material. Procedures should be readily available to all personnel. For general guidance, the following situations should be addressed:
    - Eye Contact: Promptly flush eyes with water for a prolonged period (15 minutes) and seek medical attention.
    - Skin Contact: Promptly flush the affected area with water and remove any contaminated clothing. If symptoms persist after washing, seek medical attention.

Equipment storage and handling:

- Store laboratory glassware with care to avoid damage. Use extra care with Dewar flasks and other evacuated glass apparatus; shield or wrap them to contain chemicals and fragments should implosion occur.
- Use certified fume hoods, glove boxes, or other ventilation devices for operations which might result in release of toxic chemical vapors or dust. Preventing the escape of these types of materials into the working atmosphere is one of the best ways to prevent exposure.
- Keep fume hood sash closed when you are not working in the hood.
- Do not use damaged glassware or other equipment.
- Do not use uncertified fume hoods or glove boxes for hazardous chemical handling.
- Avoid storing materials in hoods.
- Do not allow the vents or air flow to be blocked.

Laboratory operations:

- Keep the work area clean and uncluttered.
- Seek information and advice about hazards, plan appropriate protective procedures, and plan positioning of equipment before beginning any new operation.
- If unattended operations are unavoidable, and have been approved by the PI, place an appropriate sign on the door, leave lights on, and provide for containment of toxic substances in the event of failure of a utility service (such as cooling water).
- Be alert to unsafe conditions and ensure that they are corrected when detected.
- Research staff and students should never work alone on procedures involving hazardous chemicals, biological agents, or other physical hazards.
- Do not engage in distracting behavior such as practical jokes in the laboratory. This type of conduct may confuse, startle, or distract another worker.

Food/Drink:

- Do not eat, drink, smoke, chew gum, or apply cosmetics in areas where laboratory chemicals are present; wash hands before conducting these activities.
- Do not store, handle, or consume food or beverages in storage areas, refrigerators, glassware or utensils which are also used for laboratory operations.
- Wash areas of exposed skin well before leaving the laboratory.

Chemical Inventory, Labeling, Storage, and Transportation

Chemical inventories

Principal investigators must maintain a current, accurate and complete chemical inventory that includes the hazardous materials, solids, liquids gases and gels used and the locations to which they are assigned or allowed to be used. The information maintained in the inventory includes the name of the chemical, the concentration, the chemical abstracts number, the size of the container, the number of identical containers, the amount on hand, the physical state, the type of the container, whether it is pure or a mixture and both the storage pressure and temperature. Chemical inventories are used to provide the required information to the fire department, to ensure compliance with fire code storage limits, and to comply with homeland security reporting thresholds. The chemical inventory can also be used in an emergency to identify potential hazards for emergency response operations and more.

The chemical inventory list should be reviewed prior to ordering new chemicals and only the minimum quantities of chemicals necessary for the research should be purchased. As new chemicals are added to the inventory, each laboratory group can confirm that they have access to the Safety Data Sheet (SDS) for that chemical through www.ehs.ucr.edu/services/msds.html. Where practical, each chemical should be dated so that expired chemicals can be easily identified for disposal. Each Pi or their delegate must review the inventory of chemicals in the laboratory at least annually for accuracy and completeness. Items that should be replaced, have deteriorated, or show container deterioration should be flagged for action or disposal. This will assure that chemical storage areas are not overcrowded with materials that are no longer useful. The Department of Homeland Security (DHS) requires a report to be submitted within 60 days of specific chemicals that exceed set threshold aggregate amounts. As a result, everyone who has chemicals at UC ANR must update their chemical inventory for each of the Department of Homeland Security (DHS) “chemicals of interest” within 60 days of when they are received or consumed/disposed. A list of these chemicals is included as an appendix to this chemical hygiene plan and also published online (https://www.dhs.gov/sites/default/files/publications/appendix-a-to-part-27-508.pdf). Unneeded items should be transferred to a colleague who has a legitimate business use for the chemical or they should be discarded as chemical waste through an authorized chemical waste vendor.

Attributes that may indicate the materials need to be disposed are: cloudiness in liquids, a change in color, evidence of liquids in solids, or solids in liquids, “puddling" of material around outside of containers, pressure build-up within containers and obvious deterioration of containers in addition to exceeding a manufacturer’s expiration date.

Access to hazardous chemicals, including toxic and corrosive substances, should be restricted at all times. These materials must be stored in laboratories or storerooms that are kept locked when laboratory personnel are not present. Locked storage cabinets or other precautions are always recommended, and may be required in the case of unusually toxic or hazardous chemicals. Unusually toxic chemicals may include those that are immediately dangerous to life or health (IDLH). For guidance on storage requirements, please contact EH&S at 530-750-1264.

On termination or transfer of laboratory personnel, all related hazardous materials should be properly disposed of, or transferred to the PI or a designee.

Chemical labeling

All containers (including those with abbreviations) of hazardous materials must be labeled with the identity of the hazardous substance and all applicable hazard warning statements or abbreviations. If abbreviations are used, a list of the abbreviations used, the full chemical names and the hazards warning statement associated with each, must be prominently displayed in each room. An example of such an abbreviation list can be found at www.ehs.ucr.edu/laboratory/Chemical%20Abbreviation%20Example.pdf. In either case, all containers not actively being used in transfer or a reaction must be labeled.

New synthesized compounds must be labeled with the appropriate hazard warnings based on the knowledge of the chemical and physical properties of that substance.

Labels must be legible, in English, and clearly displayed; Lewis structures alone are inadequate.

Secondary containers (such as spray bottles) must be labeled with the identity of the substance and appropriate hazard warnings. Symbols and/or other languages may be provided for non-English speaking employees. Use the hazard symbols in the Globally Harmonized System of Classification and Labeling of Chemicals (www.osha.gov/dsg/hazcom/ghs.html).

Peroxide-forming chemicals (e.g., ethers) must be labeled with a date of receipt and the date when the bottle is first opened. For the containers without a manufacturer supplied expiration date, these chemicals are only allowed a one year shelf life and must be disposed of as waste within one year of receipt or six months of opening. These chemicals can degrade to form shock sensitive, highly reactive compounds and should be stored and labeled very carefully.

Particularly Hazardous Substances such as Regulated Carcinogens (https://www.dir.ca.gov/title8/sb7g16a110.html), highly hazardous chemicals (https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=9761&p_table=standards), and highly toxic chemicals should be segregated from less hazardous chemicals to help with proper access control and hazard identification.

Chemical storage & segregation

Establish and follow safe chemical storage & segregation procedures for your laboratory.

Storage guidelines are included for materials that are flammable, oxidizers, corrosive, and water reactive, explosive and highly toxic. The specific Safety Data Sheet (SDS) should always be consulted when doubts arise concerning chemical properties and associated hazards. All procedures employed must comply with Cal/OSHA, Fire Code and building code regulations. Always wear appropriate personal protective equipment (e.g., laboratory coat, safety glasses, gloves, safety goggles, apron) when handling hazardous chemicals. Be aware of the locations of the safety showers and emergency eyewash stations. Each laboratory is required to provide appropriate laboratory-specific training on how to use this equipment prior to working with hazardous chemicals.

Safe chemical storage priorities

Keep in mind that most chemicals have multiple hazards and a decision must be made as to which storage area would be most appropriate for each specific chemical. First you have to determine your priorities:

1. Flammability. When establishing a storage scheme, the number one consideration should be the flammability characteristics of the material. If the material is flammable, it should be stored in a flammable cabinet.
2. Isolate. If the material will contribute significantly to a fire (e.g., oxidizers), it should be isolated from the flammables. If there were a fire in the laboratory and response to the fire with water would exaggerate the situation, isolate the water reactive material away from contact with water.
3. Corrosivity. Next look at the corrosivity of the material, and store accordingly. Acids and bases should be segregated and contained to prevent mixture of materials in case of spill.
4. Toxicity. Finally, consider the toxicity of the material, with particular attention paid to regulated materials. In some cases, this may mean that certain chemicals will be isolated within a storage area. For example, a material that is an extreme poison but is also flammable, should be locked away in the flammable storage cabinet to protect it against accidental release.
5. There will always be some chemicals that will not fit neatly in one category or another, but with careful consideration of the hazards involved, most of these cases can be handled in a reasonable fashion.

General recommendations for safe storage of chemicals

Each chemical in the laboratory should be stored in a specific location and returned there after each use. Acceptable chemical storage locations may include corrosive cabinets, flammable cabinets, laboratory shelves, or appropriate refrigerators or freezers. Fume hoods should not be used as general storage areas for chemicals, as this may seriously impair the ventilating capacity of the hood.

The image to the right depicts improper fume hood storage. Chemicals should not be routinely stored on bench tops or stored on the floor. Additionally, bulk quantities of chemicals (i.e., larger than one-gallon) should be stored in a separate storage area, such as a stockroom or supply room.

Laboratory shelves should have a raised lip along the outer edge to prevent containers from falling. Hazardous liquids, toxic or corrosive chemicals should not be stored on shelves above eye-level and chemicals which are highly toxic or corrosive should be in unbreakable secondary containers.

Chemicals must be stored at an appropriate temperature and humidity level and should never be stored in direct sunlight or near heat sources, such as laboratory ovens. Incompatible materials should be stored in separate cabinets, whenever possible. If these chemicals must be stored in one cabinet, due to space limitations, adequate segregation and secondary containment must be ensured to prevent adverse reactions. All stored containers and research samples must be appropriately labeled and tightly capped to prevent vapor interactions and to alleviate nuisance odors. Flasks with only septa, cork, rubber or glass stoppers should be avoided because of the potential for leaking.

Laboratory refrigerators and freezers must be labeled appropriately with "No Food/Drink" and must never be used for the storage of food or drinks intended for human consumption. Freezers should be defrosted periodically so that chemicals do not become trapped in ice formations. Never store peroxide formers (e.g., ether) in a refrigerator not specifically designed for storage of flammable liquids.

Flammable and combustible liquids

Large quantities of flammable or combustible materials should be stored in locations outside of most laboratories. The actual fire code limits on the specific volume of flammable materials or other classes of hazardous chemicals depends on the original design and construction of the facility and can vary from building to building at ANR facilities. In most B occupancy labs the maximum total quantity of class 1A, 1B and 1C flammable liquids is limited to no more than 60 gallons which must all be stored in a flammable storage cabinet.

Hazard classification for flammable liquids			
Class	**Flash point**	**Boiling point**	**Examples**
I-A	below 73°F (23°C)	below 100°F (38°C)	diethyl ether, pentane, ligroin, petroleum ether
I-B	below 73°F (23°C)	at or above 100°F (38°C)	acetone, benzene, cyclohexane, ethanol
I-C	73-100°F (24-38°C)	----	p-xylene
Hazard classification for combustible liquids			
II	101-140°F (39-60°C)	----	diesel fuel, motor oil, kerosene, cleaning solvents
III-A	141-199°F (61-93°C)	----	paints (oil base), linseed oil, mineral oil
III-B	200°F (93°C) or above	----	paints (oil base), neatsfoot oil

Storage Volume: No more than 10 gallons in total of flammable liquids shall be stored outside of an approved and labeled storage cabinet. Class 1A solvents, such as ethyl ether, should be purchased only in one gallon (4 liter) or smaller containers. Because of the extreme flammability of the Class 1 liquids, only quantities needed for immediate use should be stored. Examples of equipment that can be used for storage include: flammable storage cabinets, flammable storage refrigerators or freezers that are designed and UL approved for the storage of flammable substances, or approved safety cans or drums that are grounded. Always segregate flammable or combustible liquids from oxidizing acids and oxidizers. Flammable materials must never be stored in domestic-type refrigerators/freezers and should not be stored in a refrigerator/freezer if the chemical has a flash point below the temperature of the equipment. Flammable or combustible liquids must not be stored on the floor or in any exit access.

Handle flammable and combustible substances only in areas free of ignition sources and use the chemical in a fume hood whenever practical. Only the amount of material required for the experiment or procedure should be stored in the work area. Always transfer flammable and combustible chemicals from glass containers to glassware or from glass container/glassware to plastic. Transferring these types of chemicals between plastic containers may lead to a fire hazard due to static electricity. The transfer of flammable liquid from 5 gallon or larger metal containers should not be done in the laboratory.

Pyrophoric & water reactive substances

Because pyrophoric substances can spontaneously ignite on contact with air and/or water, they must be handled under an inert atmosphere and in such a way that rigorously excludes air and moisture. Some pyrophoric materials are also toxic and many are dissolved or immersed in a flammable solvent. Other common hazards include corrosivity, teratogenicity, or peroxide formation.

Only minimal amounts of reactive chemicals should be used in experiments or stored in the laboratory. These chemicals must be stored as recommended in the SDS. Reactive materials containers must be clearly labeled with the correct chemical name, in English, along with a hazard warning.

Suitable storage locations may include inert gas-filled desiccators or glove boxes; however, some pyrophoric materials must be stored in a flammable substance approved freezer. If pyrophoric or water reactive reagents are received in a specially designed shipping, storage or dispensing container (such as the Aldrich Sure/Seal packaging system), ensure that the integrity of that container is maintained. Ensure that sufficient protective solvent, oil, kerosene, or inert gas remains in the container while pyrophoric materials are stored. Never store reactive chemicals with flammable materials or in a flammable liquids storage cabinet.

Storage of pyrophoric gases is described in the California Fire Code, Chapter 41. Gas cabinets, with remote sensors and fire suppression equipment, are required. Gas flow, purge and exhaust systems should have redundant controls to prevent pyrophoric gas from igniting or exploding. Emergency back-up power should be provided for all electrical controls, alarms and safeguards associated with the pyrophoric gas storage and process systems.

Never return excess reactive chemical to the original container. Small amounts of impurities introduced into the container may cause a fire or explosion. For storage of excess chemical, prepare a storage vessel in the following manner:

- Dry any new empty containers thoroughly;
- Insert the septum into the neck in a way that prevents atmosphere from entering the clean dry (or reagent filled) flask;
- Insert a needle to vent the flask and quickly inject inert gas through a second needle to maintain a blanket of dry inert gas above the reagent;
- Once the vessel is fully purged with inert gas, remove the vent needle then the gas line. To introduce the excess chemical, use the procedure described in the handling section of the SOP;

- For long-term storage, the septum should be secured with a copper wire or hose clamp
- For extra protection a second same-sized septa (sans holes) can be placed over the first; and
- Use "Parafilm M®" or equivalent around the outer septa and remove the Parafilm M® and outer septum before accessing the reagent through the primary septum.

Pyrophoric Liquid Safety SOPs and videos for the safe handling of pyrophoric chemicals and can be viewed through www.ehs.ucr.edu/resources/SOPs/standard_operating_procedures_list.html.

Oxidizers

Oxidizers (e.g., oxygen, ozone, hydrogen peroxide, and other inorganic peroxides; fluorine, chlorine, and other halogens; nitric acid and nitrate compounds; persulfuric acids; chlorite, chlorate, perchlorate, and other analogous halogen compounds; hypochlorite and other hypohalite compounds, including household bleach; hexavalent chromium compounds such as chromic and dichromic acids and chromium trioxide, pyridinium chlorochromate, and chromate/dichromate compounds; permanganate compounds; sodium perborate; nitrous oxide; silver oxide; osmium tetroxide; Tollens' reagent; 2,2'-dipyridyldisulfide) should be stored in a cool, dry place and kept away from flammable and combustible materials, such as wood, paper, Styrofoam™, most plastics, flammable organic chemicals, and away from reducing agents, such as zinc, alkaline metals, and formic acid.

Peroxide-forming chemicals

Peroxide forming chemicals (e.g., acetaldehyde diethyl acetal (acetal); cumene (isopropyl benzene); cyclohexene ; cyclopentene; decalin (decahydronaphthalene); diacetylene (butadiene); diethyl ether (ether); diethylene glycol dimethyl ether (diglyme); diisopropyl ether (isopropyl ether); dioxane; divinylacetylene (DVA); ethylene glycol dimethyl ether (glyme); ethylene glycol ether acetates; ethylene glycol monoethers (cellosolves); furan; inylidene chloride (1, 1-di-chloroethylene); methylacetylene; methylcyclopentane; potassium amide; potassium metal ; sodium amide (sodamide); tetrahydrofuran (THF); tetralin (tetrahydronapthalene); vinyl ethers) should be stored in airtight containers in a dark, cool, and dry place and must be segregated from other classes of chemicals that could create a serious hazard to life or property should an accident occur (e.g., acids, bases, oxidizers). The containers should be labeled with the date received and the date opened. This information, along with the chemical identity should face forward to minimize container handling during inspection. These chemicals must also be tested and documented for the presence of peroxides periodically. Minimize the quantity of peroxide forming chemicals stored in the laboratory and dispose of peroxide forming chemicals before peroxide formation.

Carefully review all cautionary material supplied by the manufacturer prior to use. Avoid evaporation or distillation, as distillation defeats the stabilizer added to the solvents. Ensure that containers are tightly sealed to avoid evaporation and that they are free of exterior contamination or crystallization. Never return unused quantities back to the original container and clean all spills immediately.

If old containers of peroxide forming chemicals are discovered in the laboratory, (greater than two years past the expiration date or if the date of the container is unknown), do not handle the container. If crystallization is present in or on the exterior of a container, do not handle the container. Secure the container and contact a qualified hazardous waste vendor to arrange for disposal.

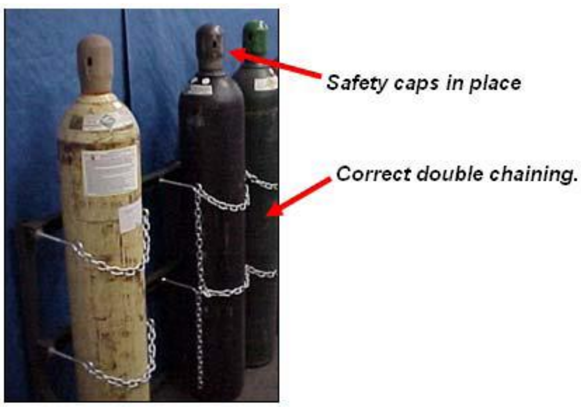
Corrosives

Store corrosive chemicals (i.e., acids, bases) below eye level and in secondary containers that are large enough to contain at least 10% of the total volume of liquid stored or the volume of the largest container, whichever is greater. Acids must always be segregated from bases and from active metals (e.g., sodium, potassium, magnesium) at all times and must also be segregated from chemicals which could generate toxic gases upon contact (e.g., sodium cyanide, iron sulfide).

Specific types of acids require additional segregation. Mineral acids must be kept away from organic acids and oxidizing acids must be segregated from flammable and combustible substances. Perchloric acid should be stored by itself, away from other chemicals. Picric acid is reactive with metals or metal salts and explosive when dry and must contain at least 10% water to inhibit explosion.

Special storage requirements

Compressed gas cylinders



Compressed gas cylinders that are stored in the laboratory must be secured to prevent tipping, dropping, and damage to the regulator. Large cylinders must be chained or strapped to the wall or other stable building member, with the safety cap in place. The cylinders must be restrained by two chains or straps; one chain must be placed at one third from the top of the cylinder, and the other placed at one third from the bottom of the cylinder. If this is not practical, contact EH&S for guidance. Bolted “clam shells” may be used in instances where gas cylinders must be stored or used away from the wall. Store liquefied fuel-gas cylinders securely in the upright position. Smaller cylinders of non-hazardous gas may be secured in a frame or rack that holds cylinders securely in an upright position. **Cylinders are not to be stored in a horizontal position**. Do not expose cylinders to excessive dampness, corrosive chemicals or fumes.

Certain gas cylinders require additional precautions. Flammable gas cylinders must use only flame-resistant gas lines and hoses which carry flammable or toxic gases from cylinders and must have all connections wired. Compressed oxygen gas cylinders must be stored at least 20 feet away from combustible materials and flammable gases.

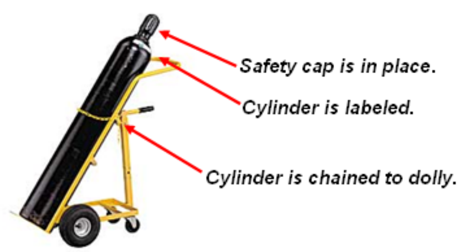
Gas cylinder connections must be inspected frequently for deterioration and must never be used without a regulator. Never use a leaking, corroded or damaged cylinder and never refill compressed gas cylinders. When stopping a leak between cylinder and regulator, always close the valve before tightening the union nut. The regulator should be replaced with a safety cap when the cylinder is not in use. Move gas cylinders with the safety cap in place using carts designed for this purpose.

Liquid nitrogen

Because liquid nitrogen containers are at low pressure and have protective rings mounted around the regulator, they need to be affixed to a permanent fixture such as a wall to prevent them from walking or rolling into the egress path in an earthquake. However, additional protection considerations should be addressed when storing liquid nitrogen in a laboratory. The primary risk to laboratory personnel from liquid nitrogen is skin or eye thermal damage caused by contact with the material. In addition, nitrogen expands 696:1 when changing from a cryogenic liquid to a room temperature gas. The gases usually are not toxic, but if too much oxygen is displaced, asphyxiation is a possibility. Always use appropriate thermally insulated gloves when handling liquid nitrogen. Face shields may be needed in cases where splashing can occur.

Transportation of hazardous chemicals

Precautions must be taken when transporting hazardous substances between laboratories. Chemicals must be transported in break-resistant, secondary containers such as commercially available bottle carriers made of rubber, metal, or plastic, that include carrying handle(s) and which are large enough to hold the contents of the chemical container in the event of breakage. When transporting cylinders of compressed gases, always secure the cylinder with straps or chains onto a suitable hand truck and protect the valve with a cover cap. Avoid dragging, sliding, or rolling cylinders and use a freight elevator when possible. The figure below illustrates correct cylinder transport.



Correct Cylinder Transport

The transportation of hazardous chemicals and compressed gases over public roads, or by air, is strictly governed by international, federal, and state regulatory agencies, including the U.S. Department of Transportation (DOT) and the International Air Transport Association (IATA). Any person who prepares and/or ships these types of materials must ensure compliance with pertinent regulations regarding training, quantity, packaging, and labeling. Without proper training and packaging, it is illegal to ship hazardous materials. Those who violate the hazardous materials shipment regulations are subject to criminal investigation and penalties. Any questions regarding requirements for shipment or transport of hazardous materials should be directed to UC ANR EH&S (530-750-1264).

Chemical spills

Chemical spills can result in chemical exposures and contaminations. Chemical spills become emergencies when:

- The spill results in a release to the environment (e.g., sink or floor drain)
- The material or its hazards are unknown
- Laboratory staff cannot safety manage the hazard because the material is too hazardous or the quantity is too large

Effective emergency response to these situations is imperative to mitigate or minimize adverse reactions when chemical incidents occur.

Factors to consider before spill clean-up

1. Size of spill area
2. Quantity of chemical
3. Toxicity
4. Volatility
5. Clean up materials available
6. Training of responders

In the event of a significant chemical exposure or contamination, immediately try to remove or isolate the chemical if safe to do so. When skin or eye exposures occur, remove contaminated clothing and flush the affected area using an eye wash or shower for at least 15 minutes. If a chemical is ingested, drink plenty of water. Obtain medical assistance as indicated. Remember to wear appropriate PPE before helping others. PIs must review all exposure situations, make sure affected employees receive appropriate medical treatment and/or assessment, and arrange for containment and clean-up of the chemical as appropriate.

Small chemical spills can be cleaned up by laboratory personnel who have been trained in spill clean-up and with the appropriate materials. A small spill is generally defined as < 1 liter of chemical that is not highly toxic, does not present a significant fire or environmental hazard, and is not in a public area such as a common hallway. Large chemical spills include spills of larger quantities, spills of any quantity of highly toxic chemicals, or chemicals in public areas or adjacent to drains. Large spills require emergency response. Call 911, evacuate to a safe area, and remain available in the evacuation area to communicate details of the incident to first responders.

What to do with a small chemical spill

- Evacuate all non-essential persons from the spill area;
- If needed, call for medical assistance by dialing 911;
- Help anyone who may have been contaminated. Use emergency eyewashes/showers by flushing the skin or eyes for at least 15 minutes;
- Post someone just outside the spill area to keep people from entering. Avoid walking through contaminated areas;
- You must have the proper protective equipment and clean-up materials to clean-up spills. Check the chemical's Material Safety Data Sheet (MSDS) in your laboratory for spill clean-up procedures, or call EH&S at 530-750-1264;
- Turn off sources of flames, electrical heaters, and other electrical apparatus, and close valves on gas cylinders if the chemical is flammable;
- Confine the spill to a small area. Do not let it spread;
- Avoid breathing vapors from the spill. If the spill is in a non-ventilated area, do not attempt to clean it up. Call for emergency personnel to respond and clean up the spill;
- Wear personal protective equipment, including safety goggles, gloves, and a laboratory coat or other protective garment to clean-up the spill;
- Work with another person to clean-up the spill. Do not clean-up a spill alone;

DO NOT TRY TO DILUTE OR NEUTRALIZE THE SPILLED CHEMICAL BY ADDING WATER

Use an appropriate kit to neutralize and absorb inorganic acids and bases. For other chemicals, use the appropriate kit or absorb the spill with sorbent pads, paper towels, vermiculite, dry sand, or diatomaceous earth. For mercury spills and specific procedures for all other spills contact EH&S. Collect the residue and place it in a clear plastic bag. Double bag the waste and label the bag with the contents and label it to be picked up a chemical waste.

What to do with a large chemical spill

Large chemical spills require emergency response. Call 911 and evacuate to a safe area. If the spill presents a situation that is immediately dangerous to life or health (IDLH) or presents a significant fire risk, activate a fire alarm, evacuate the area and wait for emergency response to arrive.

- Remove the injured and/or contaminated person(s) and provide first aid
- Call for emergency medical response
- As you evacuate the laboratory, close the door behind you, and:
- Post someone safely outside and away from the spill area to keep people from entering
- Confine the spill area if possible and safe to do so
- Leave on or establish exhaust ventilation
- If possible, turn off all sources of flames, electrical heaters, and other electrical equipment if the spilled material is flammable
- Avoid walking through contaminated areas or breathing vapors of the spilled material
- Any employee with known contact with a particularly hazardous chemical must shower, including washing of the hair as soon as possible unless contraindicated by physical injuries

Highly toxic chemical spills

All spills of these chemicals require emergency response, do not clean up by yourself

Aromatic amines
Hydrazine
Bromines
Nitriles
Carbon disulfide
Nitro-compounds
Cyanides
Organic halid

Hazardous Chemical Waste Management

Hazardous waste program

Each laboratory employee must comply with the Hazardous Waste Management Program requirements at their respective location and all applicable regulations. Laboratory personnel are responsible for identifying waste, labeling it, and storing it properly in the laboratory. The PI is responsible for coordinating the disposal of all chemicals from his/her laboratories prior to closing down laboratory operations. Laboratory clean-outs and disposal of high hazard compounds should be coordinated through the location safety coordinator.

Regulation of hazardous waste

In California, hazardous waste is regulated by the Department of Toxic Substance Control (DTSC), a division within the California Environmental Protection Agency (Cal/EPA). Federal EPA regulations also govern certain aspects of hazardous waste management, since most of our waste is treated and disposed out of state. These hazardous waste regulations are part of the Resource Conservation and Recovery Act, or RCRA.

Definition of hazardous waste

Federal and State regulations define hazardous wastes as a substance which poses a hazard to human health or the environment when improperly managed. A chemical waste is considered hazardous if it is either listed on one of the lists found in Federal or State regulations or if it exhibits one or more of the four following characteristics:

1. **Ignitable** - Ignitable wastes generally are liquids with a flash point below 60°C or 140°F (however, just because a material has a higher flash point, it still cannot be drain disposed).
2. **Corrosive** - Corrosive wastes are generally aqueous wastes with a pH less than or equal to two (2) or greater than or equal to 12.5
3. **Reactive** - Reactive wastes are those wastes that are unstable, explosive, and capable of detonation or react violently with water.
4. **Toxic** - A chemical that poses a hazard to health or the environment (this can be a gray area).

To assist in waste determination, review the Hazardous Chemicals List (www.ehs.ucr.edu/waste/hazardouschemicals.xls).

The EPA definition of hazardous waste also extends to the following items:

- Abandoned chemicals
- Unused or unwanted chemicals
- Chemicals in deteriorating containers
- Empty containers that have visible residues
- Containers with conflicting labels
- Unlabeled or unknown chemicals

Chemicals not in frequent use must be carefully managed to prevent them from being considered a hazardous waste. This is especially true for certain compounds that degrade and destabilize over time and require careful management so that they do not become a safety hazard (review "Wastes that Require Special Handling").

Extremely hazardous waste

Certain compounds meet an additional definition known as "extremely hazardous waste". This list of compounds includes carcinogens, pesticides, and reactive compounds, among others (e.g., formaldehyde, chloroform, and hydrofluoric acid). The Federal EPA refers to this waste as "acutely hazardous waste", but Cal/EPA has published a more detailed list of extremely hazardous waste. Both the State and the Federal lists are included in the EH&S list of extremely hazardous waste, through www.ehs.ucr.edu/waste. NOTE: While there is some overlap with the list of Particularly Hazardous Substances, the extremely hazardous waste list is specific to hazardous waste management.

Proper hazardous waste management

Training

On-line training presentations on Hazardous Waste Management and Waste Minimization are available through UC campus EH&S websites.

UC Davis hazardous waste training: http://safetyservices.ucdavis.edu/training/hazardous-waste-management-and-minimization

UC Riverside hazardous waste training: http://ehs.ucr.edu/training/index.html

Note: campus- based training modules are for information only and may not reflect local hazardous waste program requirements. Always confirm any waste management practices with your local safety coordinator or with UC ANR EH&S (530-750-1264).

Waste identification

All the chemical constituents in each hazardous waste stream must be accurately identified by knowledgeable laboratory personnel. This is a critical safety issue for both laboratory employees and those who handle the waste once it is turned over to EH&S. Mixing of incompatible waste streams has the potential to create violent reactions and is a common cause of laboratory accidents. If there is uncertainty about the composition of a waste stream resulting from an experimental process, laboratory workers must consult the PI, location safety coordinator, or UC ANR EH&S. In most cases, careful documentation and review of all chemical products used in the experimental protocol will result in accurate waste stream characterization.

The manufacturer's SDS provides detailed information on each hazardous ingredient in laboratory reagents and other chemical products, and also the chemical, physical, and toxicological properties of that ingredient. The UC SDS library (www.ehs.ucr.edu/services/msds.html) provides an extensive library of research chemicals. Waste streams that have a large percentage of ingredients listed as proprietary information should be discussed with the location safety coordinator and UC ANR EH&S.

Labeling of waste

All waste must be labeled to identify the generator of the waste, the specific composition of the waste, hazardous properties of the waste, and the accumulation state date when waste was first added to the container. A generic waste label may be downloaded from the UC ANR EH&S website: http://safety.ucanr.edu/files/2908.pdf.

Storage of waste

The hazardous waste storage area in each laboratory is considered a satellite accumulation area (SAA). According to EPA requirements, this area must remain under the control of the persons producing the waste. This means that it should be located in an area that is supervised and is not accessible to the public. Requirements for laboratory accumulation of hazardous waste at ANR Research and Extension Center are specified in UC ANR RECS policy (http://safety.ucanr.edu/files/2865.pdf).

SAA requirements include:

- Hazardous waste containers must be labeled with an waste tag at all times
- Waste must be collected and stored at or near the point of generation
- The maximum amount of waste that can be stored in a SAA is 55 gallons of a hazardous waste or 1 quart of extremely hazardous waste. If you reach these volumes for extremely hazardous waste, you must have the waste removed within 3 days
- The maximum amount of flammable solvents allowed to be stored in a laboratory includes flammable waste solvents
- All hazardous waste containers in the laboratory must be kept closed when not in use
- Hazardous waste streams must have compatible constituents, and must be compatible with the containers in which they are stored
- Hazardous waste containers must be stored in secondary containment at all times.
- Containers must be in good condition with leak proof lids
- Containers must be less than 80% full
- Dry wastes must be double-bagged in clear, 3-mil plastic bags

Segregation of waste

All hazardous materials must be managed in a manner that prevents spills and uncontrolled reactions. Stored chemicals and waste should be segregated by hazard class. Examples of proper segregation are:

- Segregate acids from bases
- Segregate oxidizers from organics
- Segregate cyanides from acids

Segregation of waste streams should be conducted in a similar manner to segregation of chemical products. Refer www.ehs.ucr.edu/hazardousmaterials for chemical segregation guidelines.

Incompatible waste streams

Mixing incompatible waste streams, or selecting a container that is not compatible with its contents, is a common cause of accidents in laboratories and waste storage facilities. Reactive mixtures can rupture containers and explode, resulting in serious injury and property damage. All chemical constituents and their waste byproducts must be compatible for each waste container generated. Waste tags must be immediately updated when a new constituent is added to a mixed waste container, so that others in the laboratory will be aware and manage it accordingly.

Some common incompatible waste streams include:

- Oxidizers added to any fuel can create an exothermic reaction and explode. The most frequent is acids oxidizing flammable liquids. For this reason, all flammable liquids are pH tested before they are consolidated
- Piranha etch solution is a specific waste stream that contains sulfuric acid and hydrogen peroxide, which form a reactive mixture that is often still fuming during disposal. For this waste stream, and other reactive mixtures like it, vented caps are mandatory

Wastes that require special handling

Unknowns

Unlabeled chemical containers and unknown/unlabeled wastes are considered unknowns, and additional fees must be paid to have these materials analyzed and identified. These containers must be labeled with the word "unknown".

Peroxide-forming chemicals

Peroxide forming chemicals, or PFCs, include a number of substances that can react with air, moisture or product impurities, and undergo a change in their chemical composition during normal storage. The peroxides that form are highly reactive and can explode upon shock or spark. Peroxides are not particularly volatile and thus tend to precipitate out of liquid solutions. It is particularly dangerous to allow a container of these materials to evaporate to dryness, leaving the crystals of peroxide on the surfaces of the container.

Each container of peroxide forming chemicals should be dated with the date received and the date first opened. There are three classes of peroxide forming chemicals, with each class having different management guidelines. A review of the safety information provided by the manufacturer can be used as a guide to managing PFCs.

Ensure containers of PFCs are kept tightly sealed to avoid unnecessary evaporation, as this inhibits the stabilizers that are sometimes added. Visually inspect containers periodically to ensure that they are free of exterior contamination or crystallization. PFC containers must be disposed of prior to expiration date. If old containers of peroxide forming chemicals are discovered in the laboratory, (greater than two years past the expiration date or if the date of the container is unknown), do not handle the container. If crystallization is present in or on the exterior of a container, do not handle the container. Secure it and contact UC ANR EH&S at 530-750-1264.

Dry picric acid

Picric acid (also known as trinitrophenol) must be kept hydrated at all times, as it becomes increasingly unstable as it loses water content. When dehydrated, it is not only explosive but also sensitive to shock, heat and friction. Picric acid is highly reactive with a wide variety of compounds (including many metals) and is extremely susceptible to the formation of picrate salts. Be sure to label all containers that contain picric acid with the date received, and then monitor the water content every 6 months. Add distilled water as needed to maintain a consistent liquid volume.

If old or previously unaccounted for bottles of picric acid are discovered, do not touch the container. Depending on how long the bottle has been abandoned and the state of the product inside, even a minor disturbance could be dangerous. Visually inspect the contents of the bottle, without moving it, to evaluate its water content and look for signs of crystallization inside the bottle and around the lid. If there is even the slightest indication of crystallization, signs of evaporation, or the formation of solids in the bottle, do not handle the container and contact EH&S immediately. Secure the area and restrict access to the container until it can be evaluated by qualified personnel.

Explosives and compounds with shipping restrictions

A variety of other compounds that are classified as explosives or are water or air reactive are used in research laboratories. These compounds often have shipping restrictions and special packaging requirements. When disposing of these compounds, employees must ensure that they are stored appropriately for transport. Flammable metals must be completely submerged in oil before they are brought to a waste pick-up. Many pyrophoric and reactive compounds can be stabilized using a quenching procedure prior to disposal. Chemicals classified by the Department of Transportation (DOT) as explosives (e.g., many nitro- and azo- compounds) will require special packaging and shipping, and may require stabilization prior to disposal. Consult with the EH&S for disposal considerations of these compounds.

Managing empty containers

Empty containers that held Extremely Hazardous waste must be managed as hazardous waste. Do not rinse or reuse these containers.

All other hazardous waste containers, if they are less than 5 gallons in size, should either be reused for hazardous waste collection, or should be cleaned and discarded or recycled. Proper cleaning involves triple rinsing the container, with the first rinse collected as hazardous waste. Then the labels should be completely defaced (remove it or mark it out completely).

Transportation

It is a violation of DOT regulations to transport hazardous waste in personal vehicles, or to carry hazardous waste across campus streets that are open to the public. Contact your site safety coordinator or UC ANR EH&S for guidance.

Accumulation and disposal

Frequent disposal will ensure that hazardous waste accumulation areas in labs are managed properly, and that accumulation limits are not exceeded. Hazardous chemical waste may be stored on site for up to one year – inclusive of the time spent in the laboratory and any other 90-day waste accumulation area. Lab personnel are encouraged to minimize the amount of waste held in the lab and should strive to limit accumulation times to 180 days in order to allow for ample time to arrange for disposal within proper time limits. Once a waste container is 80% full or it is near the time limit, it should be transferred to the local safety coordinator or an authorized waste vendor for disposal.

Drain disposal

Drain disposal of chemical wastes is not allowed at UC ANR facilities unless a specific dilution and/or neutralization method for a consistent waste stream has been reviewed and approved by EH&S. This applies to weak acid and base solutions. As indicated in previous sections, hazardous waste regulations specify that materials with a pH between 2.0 and 12.5 are not hazardous wastes. However, drain disposal of these materials is still not permitted, because local waste water discharge requirements have more restrictive pH thresholds. In addition, acid and base neutralization is considered waste treatment, a process that is strictly regulated by the Cal/EPA (see "Bench Top Treatment" below). Contact EH&S for specific questions about drain disposal options.

Benchtop treatment

Cal/EPA regulations allow some limited bench top treatment of certain chemical waste streams in laboratories provided that specific procedures are followed. Due to the stringent nature of these requirements, any treatment of hazardous waste in labs must be reviewed and approved by EH&S.

Hazardous waste minimization

In an effort to minimize the costs, health hazards, and environmental impacts associated with the disposal of hazardous waste, below are some guidelines regarding waste minimization:

ADMINISTRATIVE CONTROLS: When ordering chemicals, be aware of any properties that may preclude long term storage, and order only minimum volumes to be used. Using suppliers who can provide quick delivery of small quantities can assist with reducing surplus chemical inventory.

Inventory Control: Rotate chemical stock to keep chemicals from becoming outdated. Identify surplus/unused chemicals and attempt to redistribute these to other users.

Operational Controls: Review your experimental protocol to ensure that chemical usage is minimized. Reduce total volumes used in experiments and employ small scale procedures when possible. Instead of wet chemical techniques, use instrumental methods, as these generally require smaller quantities of chemicals. Evaluate the costs and benefits of off-site analytical services. Avoid mixing hazardous and non-hazardous waste streams. Use less hazardous or non-hazardous substitutes when feasible. Some examples include:

- Specialty detergents can be substituted for sulfuric acid/chromic acid cleaning solutions
- Gel Green and Gel Red are recommended in place of ethidium bromide

Chemical Hygiene Plan Definitions (8 CCR 5191)

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.

ACTION LEVEL -A concentration designated in Title 8, California Code of Regulations for a specific substance, calculated as an eight (8)-hour time weighted average, which initiates certain required activities such as exposure monitoring and medical surveillance.

AEROSOL - Liquid droplets or solid particles dispersed in air that are of fine enough size (less than 100 micrometers) to remain dispersed for a 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.

"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 as TLV-C or Threshold Limit Value - Ceiling. (See also Threshold Limit Value).

CARCINOGEN - A cancer-producing substance or physical agent in animals or humans. A chemical is considered a carcinogen or potential carcinogen if it is so identified in any of the following:

- National Toxicology Program, "Annual Report of Carcinogens" (latest edition)
- International Agency for Research on Cancer, "Monographs" (latest edition)
- OSHA, 29 CFR 1910, Subpart Z, Toxic and Hazardous Substances

CHEMICAL HYGIENE PLAN - A written program developed and implemented by the employer which sets forth procedures, equipment, personal protective equipment, and work practices that (1) are capable of protecting employees from the health hazards presented by hazardous chemicals used in that particular workplace and (2) meets the requirements of OSHA regulation 29 CFR 1910.1450.

COMBUSTIBLE LIQUID - Any liquid having a flashpoint at or above 100°F (37.8°C) but below 200°F (93.3°C) except any mixture having components with flashpoints of 200°F or higher, the total volume of which make up 99% or more of the total volume of the mixture.

COMPRESSED GAS - A gas or mixture of gases having, in a container, an absolute pressure exceeding 40 psi at 70°F (21.1°C), or; a gas or mixture of gases having, in a container, an absolute pressure exceeding 104 psi at 130°F (54.4°C) regardless of the pressure at 70°F (21.1°C), or; a liquid having a vapor pressure exceeding 40 psi at 100°F (37.8°C) as determined by ASTM D-32372.

CORROSIVE - A substance that, according to the DOT, causes visible destruction or permanent changes in human skin tissue at the site of contact or is highly corrosive to steel.

DESIGNATED AREA - An area which has been established and posted with signage for work involving hazards (e.g., "select carcinogens," reproductive toxins, or substances which have a high degree of acute toxicity). A designated area may be the entire laboratory, an area of a laboratory, or a device such as a laboratory hood.

EMERGENCY -Any potential occurrence, such as, but not limited to, equipment failure, rupture of containers, or failure of control equipment which could result in an uncontrolled release of a hazardous chemical into the workplace.

EXPLOSIVE - A chemical that causes a sudden, almost instantaneous release of pressure, gas, and heat when subjected to a sudden shock, pressure, or high temperature.

FLAMMABLE - A chemical that falls into one of the following categories:

1. 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 valve opening;
2. Flammable gas - a gas that, at ambient temperature and pressure, forms a flammable mixture with air at a concentration of 13% by volume or less; or a gas that, at ambient temperature and pressure, forms a range of flammable mixtures with air wider than 12% by volume, regardless of the lower limit;
3. Flammable liquid - any liquid having a flashpoint below 100°F (37.8°C), except any mixture having components with flashpoints of 100°F (37.8°C) or higher, the total of which make up 99% or more of the total volume of the mixture;
4. Flammable solid - a solid, other than a blasting agent or explosive as defined in1910.109(a), that is liable to cause fire through friction, absorption of 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 1500.44, it ignites and burns with a self-sustained flame at a greater than one-tenth of an inch per second along its major axis.

FLASHPOINT - The minimum temperature at which a liquid gives off a vapor in sufficient concentration to ignite in the presence of an ignition source or when tested as follows:

1. **Tagliabue Closed Tester** (See American National Standard Method of Test for Flashpoint by Tag Closed Tested, Z11.24-1979 (ASTM D-56-79) for liquids with a viscosity of less than 45 Saybolt Universal Seconds (SUS) at 100oF (37.8°C) or that contain suspended solids and do not have a tendency to form a surface film under test;
2. **Pensky-Martens Closed Tester** (See American National Standard Method of Test for Flashpoint by Pensky-Martens Closed Tester, Z11.7-1979 (ASTM D-73-79) for liquids with a viscosity equal to or greater than 45 SUS at 100oF (37.8°C), or that contain suspended solids, or that have a tendency to form a surface film under test; or,
3. **Setaflash Closed Tester** (See American National Standard Method of Test for Flashpoint of Setaflash Closed Tester (ASTM D-3278-78)). Organic peroxides, which undergo auto accelerating thermal decomposition, are excluded from any flashpoint determination methods specified above.

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, when the worker is close to where the contaminant is being generated, and where fire or explosion hazards are generated close to sources of ignition. (See Local Exhaust Ventilation)

HAZARD ASSESSMENT - A formal procedure undertaken by the supervisor in which occupational hazards for all employees are described per procedure or task, and by affected body part(s) or organ(s), and which is documented and posted in the workplace with all personal protective equipment requirements.

HAZARD WARNING - Any words, pictures, symbols or combination thereof appearing on a label or other appropriate form of warning which convey the hazards of the chemical(s) in the container(s).

HAZARDOUS MATERIAL - Any material which is a potential/actual physical or health hazard to humans.

HAZARDOUS MATERIAL (DOT) - A substance or material capable of posing an unreasonable risk to health, safety, and property when transported including, but not limited to, compressed gas, combustible liquid, corrosive material, cryogenic liquid, flammable solid, irritating material, material poisonous by inhalation, magnetic material, organic peroxide, oxidizer, poisonous material, pyrophoric liquid, radioactive material, spontaneously combustible material, an water-reactive material.

HAZARDOUS CHEMICAL - A chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees. The term "health hazard" includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, and neurotoxins, agents which act on the hematopoietic system, and agents which damage the lungs, skin, eyes or mucous membranes. A chemical is also considered hazardous if it is listed in any of the following:

1. OSHA, 29 CFR 1910, Subpart Z, Toxic and Hazardous Substances;
2. “Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment,” ACGIH (latest edition);
3. “The Registry of Toxic Effects of Chemical Substances,” NIOSH (latest edition)

HIGHLY TOXIC -A substance falling within any of the following categories:

1. A substance that has a median lethal dose (LD50) of 50 milligrams or less per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each;
2. A substance that has a median lethal dose (LD50) of 200 milligrams or less per kilogram 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 two and three kilograms each; or
3. A substance that has a median lethal concentration (LC50) in air of 200 parts per million by volume or less of gas or vapor, or 2 milligrams per liter or less of mist, fume, or dust, when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

IGNITABLE - A solid, liquid or compressed gas waste that has a flashpoint of less than 140°F. Ignitable material may be regulated by the EPA as a hazardous waste as well.

INCOMPATIBLE - The term applies to two substances to indicate that one material cannot be mixed with the other without the possibility of a dangerous reaction.

IRRITANT -A substance which, by contact in sufficient concentration for a sufficient period of time, will cause an inflammatory response or reaction of the eye, skin, nose or respiratory system. The contact may be a single exposure or multiple exposures. Some primary irritants: Chromic acid, nitric acid, sodium hydroxide, calcium chloride, amines, metallic salts, chlorinated hydrocarbons, ketones and alcohols.

LABEL - Any written, printed or graphic material displayed on or affixed to containers of chemicals, both hazardous and non-hazardous.

LABORATORY TYPE HOOD -A device located in a laboratory, enclosed on five sides with a movable sash or fixed partial enclosure on the remaining side; constructed and maintained to draw air from the laboratory and to prevent or minimize the escape of air contaminants into the laboratory; and allows chemical manipulations to be conducted in the enclosure without insertion of any portion of the employee's body other than hands and arms.

LABORATORY USE OF HAZARDOUS CHEMICALS - Handling or use of such chemicals in which all of the following conditions are met:

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

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. Advantages of local exhaust ventilation over general ventilation include: It removes the contaminant rather than dilutes it, requires less airflow and, thus, is more economical over the long term; and the system can be used to conserve or reclaim valuable materials; however, the system must be properly designed with the correctly shaped and placed hoods, and correctly sized fans and ductwork.

MEDICAL CONSULTATION - A consultation which takes place between an employee and a licensed physician for the purpose of determining what medical examinations or procedures, if any, are appropriate in cases where a significant exposure to a hazardous chemical may have taken place.

MIXTURE - Any combination of two or more chemicals if the combination is not, in whole or in part, the result of a chemical reaction.

MUTAGEN - Anything that can cause a change (or mutation) in the genetic material of a living cell.

NFPA - The National Fire Protection Association; a voluntary membership organization whose aims are to promote and improve fire protection and prevention. NFPA has published 16 volumes of codes known as the National Fire Codes. Within these codes is Standard No. 705, "Identification of the Fire Hazards of Materials". This is a system that rates the hazard of a material during a fire. These hazards are divided into health, flammability, and reactivity hazards and appear in a well-known diamond system using from zero through four to indicate severity of the hazard. Zero indicates no special hazard and four indicates severe hazard.

NIOSH - The National Institute for Occupational Safety and Health; a federal agency that among its various responsibilities trains occupational health and safety professionals, conducts research on health and safety concerns, and tests and certifies respirators for workplace use.

ODOR THRESHOLD - The minimum concentration of a substance at which a majority of test subjects can detect and identify the substance's characteristic odor.

OXIDIZER - Is a substance that gives up oxygen easily to stimulate combustion of organic material.

PERMISSIBLE EXPOSURE LIMIT (PEL) - An exposure, inhalation or dermal permissible exposure limit specified in 8CCR5155. PELs may be either a time-weighted average (TWA) exposure limit (8hour), a 15-minute short-term limit (STEL), or a ceiling (C).

PERSONAL PROTECTIVE EQUIPMENT - Any devices or clothing worn by the worker to protect against hazards in the environment. Examples are lab coats, respirators, gloves, and chemical splash goggles.

PHYSICAL HAZARD - A chemical for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive), or water-reactive.

PYROPHORIC - A chemical that will spontaneously ignite in the air at a temperature of 130°F (54.4°C) or below.

REACTIVITY - A substance's susceptibility to undergoing a chemical reaction or change that may result in dangerous side effects, such as explosion, burning, and corrosive or toxic emissions. The conditions that cause the reaction, such as heat, other chemicals, and 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).

RESPIRATOR - A device which is designed to protect the wearer from inhaling harmful contaminants.

RESPIRATORY HAZARD - A particular concentration of an airborne contaminant that, when it enters the body by way of the respiratory system or by being breathed into the lungs, results in some body function impairment.

SAFETY DATA SHEET (SDS) - Written or printed material concerning a hazardous chemical which is prepared in accordance with paragraph (g) of 29 CFR 1910.1200. (Formerly material safety data sheet, MSDS)

SELECT CARCINOGENS - Any substance which meets one of the following:

1. It is regulated by OSHA as a carcinogen; or
2. It is listed under the category, "known to be carcinogens," in the Annual Report on Carcinogens published by the National Toxicology Program (NTP) (latest edition);or
3. It is listed under Group 1 ("carcinogen to humans") by the International Agency for Research on Cancer Monographs (IARC)(latest editions); or
4. It is listed in either Group 2A or 2B by IARC or under the category, "reasonably anticipated to be carcinogens" by NTP.

SENSITIZER - A substance that may cause no reaction in a person during initial exposures, but afterwards, further exposures will cause an allergic response to the substance.

SHORT-TERM EXPOSURE LIMIT - Represented as STEL or TLV-STEL, this is the maximum concentration to which workers can be exposed for a short period of time (15 minutes) for only four times throughout the day with at least one hour between exposures. Also the daily TLV-TWA must not be exceeded.

SOLVENT - A substance, commonly water, but in industry or the laboratory often an organic compound, which dissolves another substance.

THRESHOLD LIMIT VALUE (TLV) -Airborne concentration of substances devised by the ACGIH that represents conditions under which it is believed that nearly all workers may be exposed day after day with no adverse effect. TLVs are advisory exposure guidelines, not legal standards, which are based on evidence from industrial experience, animal studies, or human studies when they exist. There are three different types of TLVs: Time-Weighted Average (TLV-TWA), Short-Term Exposure Limit (TLV-STEL), and Ceiling (TLV-C). (See also PEL).

TOXICITY -A relative property of a material to exert a poisonous effect on humans or animals and a description of the effect and the conditions or concentration under which the effect takes place.

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 lower boiling points will evaporate faster.

Appendices and SOPs

Appendices

Appendix 3a – Facility guidelines for chemical safety (ventilation controls)

Appendix 3b – Chemical Safety SOP template (UC Davis)

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