University of California, Davis

CHEMICAL HYGIENE PLAN


Biological Sciences


Agricultural and Environmental Sciences


Engineering


Letters and Science

School of Medicine


School of Veterinary Medicine

v2.1
May 2025

The most recent version of the campus Chemical Hygiene Plan can be accessed here:

safetyservices.ucdavis.edu/CHP

UNIVERSITY OF CALIFORNIA, DAVIS

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April 9, 2025

A Commitment to Safety in Research

At UC Davis, our research community thrives on curiosity, collaboration, and inclusive excellence. As part of our strategic vision, *To Boldly Go*, we are committed to "enabling and supporting research that matters at the frontiers of knowledge, across and between the disciplines, in support of a healthy planet and the physical and societal well-being of its inhabitants."

Ensuring the safety and well-being of our researchers is essential to sustaining this mission. People are our most valuable resource, and a strong culture of safety not only protects individuals but also strengthens the integrity and impact of our research. Simply put, good research is safe research.

The **UC Davis Principles of Safety** reflect our shared responsibility to foster a safe and healthy environment. A true culture of safety requires leadership at every level - from administration and supervisors to faculty, staff, and students. Advancing research and training the next generation of scholars requires competence in identifying and addressing potential hazards and the confidence to speak up about them - before accidents occur.

UC Davis is committed to supporting programs that promote health, security, and the protection of research at every level. Our Safety Services experts play a vital role in this effort, working in partnership with researchers to ensure best practices and continuous improvement.

We encourage all members of our research community to champion safety in all research activities, engage with Safety Services as a collaborative partner, and continue setting new standards of excellence - safely.

Best regards,

Gary S. May
Chancellor

Mary Croughan
Provost and Executive Vice Chancellor

UC DAVIS
UNIVERSITY OF CALIFORNIA

PRINCIPLES of SAFETY

The University of California, Davis is committed to the safety and well being of its community. Our ultimate goal is to provide a safe environment for our students, faculty, staff and visitors by implementing policies and procedures that protect people, facilities and resources.

OUR VISION

A Culture of Safety

We envision an incident-free campus where students and employees alike are educated and equipped to work safely. With support from campus safety professionals, they are empowered to take responsibility for safety at work, at home and in their communities.

OUR MISSION

Think Safe. Act Safe. Be Safe.

AS A CAMPUS: We actively support programs at all levels of the organization that promote health, security and the protection of resources.

AS INDIVIDUALS: We learn and follow safe practices. We take the initiative to identify unsafe or unhealthy conditions and to resolve them with a sense of urgency.

VALUES FOR A SAFETY CULTURE

Community Spirit

We recognize our professional and personal obligation to our community. By engaging in safe behaviors we show our respect for the well-being of those in our community.

Collaboration

We value collaboration in cultivating a sustainable culture of safety on our campus. We are open and responsive to individual concerns and ideas for improvement.

Adherence to Law and Policy

We follow all applicable laws and university policies regarding safe working conditions and procedures that protect people, facilities and the campus and its surroundings.

Investment

We allocate appropriate resources to safety programs.

Continuous Improvement

We recognize that safety and health can always be further enhanced, and we believe in continuous improvement in advancing a safety culture.

Accountability

We hold ourselves accountable for reporting our performance and progress.

Adopted December 2008
Revised August 2014

UC DAVIS

Revision History

<table>
<tr><th colspan="3">Chemical Hygiene Plan</th></tr>
<tr><td>Version: 2.1</td><td colspan="2">Approved by: Chemical and Laboratory Safety Committee</td></tr>
<tr><td rowspan="2">Next Review:
05/2026</td><td>Committee Chair:
Karen Bales, Ph.D.</td><td>Signature:
Date: 05/13/2025</td></tr>
<tr><td>Author:
Karen Gagnon, Ph.D.</td><td>Signature:
Date: 05/13/2025</td></tr>
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</table>

Version	Date Approved	Authors	Revision Notes:
2.1	05/13/2025	Karen Gagnon	Updates are summarized in *Appendix G* (with bookmark links)

Email *chem-safety@ucdavis.edu* for full revision history starting from version 1.0.

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LIST OF ACRONYMS

Acronym	Definition
ACGIH	American Conference of Governmental Industrial Hygienists
ACS	American Chemical Society
AL	Action Level
API	Active Pharmaceutical Ingredients
APLU	Association of Public & Land-Grant Institutions
BSC	Biological Safety Cabinet
BUA	Biological Use Authorization
Cal/EPA	California Environmental Protection Agency
Cal/OSHA	California Occupational Safety & Health Administration
CCR	California Code of Regulations
CFR	Code of Federal Regulations
CHO	Chemical Hygiene Officer
CHP	Chemical Hygiene Plan
CIS	Chemical Inventory System
CLSC	Chemical and Laboratory Safety Committee
CUPA	Certified Unified Program Agencies
DOT	Department of Transportation
DSC	Department Safety Coordinator
DTSC	Department of Toxic Substances Control
EH&S	Environmental Health and Safety
EIIR	Employee Injury and Illness Reporting
EPA	Environmental Protection Agency
EPO	Emergency Power Off
FM	Facilities Management
EPCRA	Emergency Planning and Community Right-to-Know Act
FR	Flame-resistant
GHS	Globally Harmonized System
IACUC	Institutional Animal Care and Use Committee
IARC	International Agency for Research on Cancer
IATA	International Air Transportation Association
IBC	Institutional Biosafety Committee
IDLH	Immediately Dangerous to Life or Health
IIPP	Injury and Illness Prevention Program
IUPAC	International Union of Pure and Applied Chemistry
JSA	Job Safety Analysis
LHAT	Laboratory Hazard Assessment Tool
LMS	Learning Management System
LOTO	Lockout Tagout

LSP	Laboratory Safety Professional
NIOSH	National Institute of Occupational Safety & Health
NFPA	National Fire Protection Association
NTP	National Toxicology Program
OSHA	Occupational Safety & Health Administration
PEL	Permissible Exposure Limit
PHS	Particularly Hazardous Substance
PI	Principal Investigator
PPE	Personal Protective Equipment
PO&M	Plant Operation and Maintenance
PPM	Policy and Procedure Manual
RCRA	Resource Conservation and Recovery Act
QAC	Qualified Applicator Certificate
QAL	Qualified Applicator License
REL	Recommended Exposure Limit
RSC	Radiation Safety Committee
SAA	Satellite Accumulation Area
SDS	Safety Data Sheet
SOP	Standard Operating Procedure
STEL	Short-term Exposure Limit
STOT	Specific Target Organ Toxicity
TLV	Threshold Limit Value
TSCA	Toxic Substances Control Act
TWA	Time-Weighted Average
UC	University of California
UCDH	UC Davis Health
UCDHS	UC Davis Health System
UCDMC	UC Davis Medical Center
UCOP	University of California, Office of the President
WHO	World Health Organization

I. LABORATORY SAFETY AT UC DAVIS

A. Introduction

Safety is an integral part of laboratory research and an essential component of workplace practice. Safety is also critical to achieving the University's goals of teaching, research, and public service, as well as preventing workplace injuries and illnesses, environmental incidents, and property losses or damage. Health and safety policies and procedures within the UC Davis Policy and Procedure Manual (PPM) relating to laboratory safety include:

Safety Management Program	*PPM 290-15*
Hazardous Chemical Communication Program	*PPM 290-27*
Care and Use of Animals in Research and Teaching	*PPM 290-30*
Minors in University Facilities	*PPM 290-32*
Protective Clothing and Equipment	*PPM 290-50*
Hearing Conservation	*PPM 290-53*
Biological Safety	*PPM 290-55*
Chemical Safety	*PPM 290-56*
Shop Safety Program	*PPM 290-58*
Controlled Substances	*PPM 290-70*
Radiological Safety - Health Physics	*PPM 290-75*
Lockout Tagout	*PPM 290-84*
Pesticide Applications	*PPM 290-95*
Procurement and Use of Tax-Free Alcohol	*PPM 350-20*
Campus Emergency Policy	*PPM 390-10*
Fire Safety	*PPM 390-40*
Laboratory Security	*PPM 390-60*

It is also essential to comply with all applicable health and safety, and environmental protection laws, regulations, and requirements, including California Code of Regulations (CCR), Title 8, Section 5191 (*8 CCR §5191*), also known as the "Laboratory Standard."

The risks associated with laboratory research are greatly reduced or eliminated when proper precautions and practices are followed. To better manage hazards and mitigate their associated risks, UC Davis has developed this Chemical Hygiene Plan (CHP). The plan is intended to be the cornerstone of your safety program and is designed to aid faculty, staff, and students in maintaining a safe environment to teach and conduct research. Given the complexity of laboratory safety, a glossary of relevant terminology has been provided in *Appendix A*.

Each laboratory using hazardous materials is required to have a copy of the CHP or ensure the CHP is readily available to all laboratory personnel (hardcopy and/or electronic is acceptable). Each laboratory worker must be familiar with the contents of the CHP and the procedures for obtaining additional safety information needed to perform their duties safely.

B. General Instructions

1. Department Chairs or Unit Heads

1. Make sure your department's Injury and Illness Prevention Program (IIPP) is complete, current, and readily available. *Additional information is available*, contact *iipp@ucdavis.edu* with any questions. Ensure all departmental employees have been trained on an annual basis on your IIPP.
2. Review the entire Chemical Hygiene Plan, especially *your responsibilities* on pages 14-15.

2. Principal Investigators/Laboratory Supervisors

1. Familiarize yourself with your department's IIPP. Ensure that the department IIPP is available to all laboratory personnel.
2. Review the entire Chemical Hygiene Plan, especially *your responsibilities* on pages 14-17.
3. Prepare a *Laboratory Safety Plan* that details the structure of the safety program for your laboratory if you choose to formally delegate any of your identified responsibilities to a qualified individual for completion, or if your laboratory has any of the criteria that require development of a *Laboratory Safety Plan*.
4. Complete and maintain your laboratory-specific standard operating procedures (SOPs). Ensure they are readily available and laboratory personnel have been trained. SOPs must be reviewed and updated as described on *pg. 40.*
5. Make sure all laboratory-specific training and all other required safety training documentation (e.g. *Site-Specific Safety Orientation & Training Checklist for New Laboratory Personnel* or equivalent) is complete, current, and readily available. Maintain related documentation and ensure it is readily available.
6. Conduct at least annual inspections (either *on paper* or *online* in *Inspect*) of your laboratory or other work environments and maintain all associated records, and ensure they are readily available.
7. Conduct laboratory *hazard and PPE assessments* as described and make sure all related documentation is maintained and readily available. Review any new information with your staff.

3. Personnel

1. Review your department's Injury and Illness Prevention Program. Familiarize yourself with your department contacts, how to report a hazard in your work environment, and how to report injuries.
2. Review the entire Chemical Hygiene Plan:
    a. Specifically, *your responsibilities* listed on pages 17-18.
    b. *Chapter II* to refresh your knowledge on how to identify hazardous chemicals which are described in greater detail in *Chapter III*.

   c. *Chapter IV* to understand how to reduce your potential for exposure to hazardous chemicals (engineering controls, administrative controls, and PPE).

3. Review *Chapter XI* with your PI/Laboratory Supervisor to ensure you know what to do to prepare for and respond to an emergency.
4. Review laboratory hazard and PPE assessments with your PI/Laboratory Supervisor, ensure you know how to properly use, maintain, and acquire additional or replacement PPE, and document your PPE training.
5. Review the laboratory-specific SOPs with your PI/Laboratory Supervisor and document your training. **All training, whether formal or on-the-job, must be documented.**
6. Ask for clarification if there are any questions related to your laboratory work before you begin a new task and seek prior approval for applicable work activities.

C. Laboratory Safety Programs

This CHP includes information on safe laboratory practices, the use of engineering controls, selection and proper use of personal protective equipment, emergency procedures, use and storage of chemicals, and the proper methods of waste disposal. This information is intended to be a resource and to help laboratory personnel manage hazards and mitigate associated risks.

In view of the wide variety of chemical products handled and equipment used in laboratories, it should not be assumed that the precautions and requirements stated in this plan are all-inclusive. Faculty, staff, and students are expected to learn about the hazards of chemical products and laboratory equipment before handling or using them. Principal Investigators (PIs) and Laboratory Supervisors must provide laboratory-specific supplemental information to augment the CHP (e.g., written standard operating procedures (SOPs), laboratory equipment manuals, safety data sheets, training records, etc.).

Laboratory operations that use lasers, radioactive materials, radiation producing machines, or include biological hazards, or shop activities must follow additional guidelines outlined in the associated hazard-specific UC Davis Safety Manuals and Programs (e.g. *Radiation Safety Manual*, *Laser Safety Manual*, *Biosafety Program*, *Shop Safety Manual*, etc.). Content covered by other UC Davis Safety Manuals are not included in the CHP except as necessary.

1. Departmental Injury and Illness Prevention Program

The development and implementation of the Department's Injury and Illness Prevention Program (IIPP) is a key step in strengthening the safety culture in the research laboratories. Every California employer is required by CCR, Title 8, Section 3203 (*8 CCR §3203*) to have an effective written IIPP. An effective Injury and Illness Prevention Program must be in writing and include the following elements:

1. Management commitment/assignment of responsibilities.
2. Safety communications system with employees.
3. System for assuring employee compliance with safe work practices.
4. Scheduled inspections/evaluation system.
5. Accident Investigation.
6. Procedures for correcting unsafe/unhealthy conditions.
7. Safety and health training and instruction.
8. Recordkeeping and documentation.

An IIPP provides a framework for departments to provide their employees with equipment and information necessary to work safely within their specific work environments. A well-integrated IIPP provides the information required to monitor activities and resources to reduce the risk of workplace injury and illness to maintain a safe work environment.

Each UC Davis department is required to establish and implement an IIPP. EH&S, in accordance with University Policy (*PPM 290-15*) and *8 CCR §3203*, have provided *additional information* for reference and guidance. Please contact *iipp@ucdavis.edu* with any questions.

2. Chemical Safety

The UC Davis Chemical Hygiene Plan (CHP) establishes a formal written program for laboratory personnel – including, but not limited to, faculty, staff, students, and visiting scholars – to protect against adverse health effects and safety hazards associated with the use, storage, and disposal of chemicals. The campus CHP must be made available to all laboratory personnel working with hazardous chemicals as required in *CCR, Title 8, Section 5191* "The Lab Standard." Personnel within a laboratory, or those whose work activities are research-related and involve the use of hazardous chemicals, are subject to the requirements of the campus CHP. Any changes to the campus CHP are reviewed and approved by the Chemical and Laboratory Safety Committee (CLSC). **Most laboratories are not required to develop or reproduce this information in a site-specific CHP. In some cases, laboratories may be required to develop a *Laboratory Safety Plan*.** More information on the Laboratory Safety Plan is available *online* and starting on *page 16*. Individual laboratories must augment the UC Davis Chemical Hygiene Plan with their lab-specific *SOPs* and training records to satisfy the campus CHP components necessary for their specific work environment, activities, and hazards.

Note in instances where a laboratory maintains accreditation through other state or federal agencies, the requirements of those accreditations augment the campus CHP for that work environment. Additional *guidance for clinical medical diagnostic laboratories* is provided by the Centers for Disease Control and Prevention based on recommendation of the Biosafety Blue Ribbon Panel.

3. Biosafety

The *Biological Safety (Biosafety) Office* oversees the safe use of infectious biological agents, recombinant or synthetic nucleic acids (rDNA), and the propagation and release of recombinant organisms including plants, animals, and microbial agents as part of research at UC Davis, as required by *PPM 290-55*. No work with infectious biological agents or rDNA is permitted on the UC Davis campus prior to approval of a Biological Use Authorization *(BUA)*. The BUA approval process by the Institutional Biosafety Committee (*IBC*) is based on guidelines from the Centers for Disease Control and Prevention and the National Institutes of Health. Contact EH&S for additional information on the Biosafety program via *biosafety@ucdavis.edu* or (530) 752-1493.

4. Radiation Safety

The *Radiation Safety Program* oversees the safe use of radioactive materials, x-ray producing machines, and high intensity light sources that include lasers. Three areas of radiological safety covered by this program include:

A. *Radioactive Materials*
B. *X-ray Producing Machines*
C. *High Intensity Light Sources/Lasers*

NO WORK with these materials and equipment can be performed on campus prior to approval of a Radiation Use Authorization (*RUA*), as required by *PPM 290-75*. Contact *radsafety@ucdavis.edu* or (530) 752-1493 on the Davis campus or *healthphysics@ucdavis.edu* or (916) 734-3355 on the Sacramento campus for more information regarding this program.

5. Animal Care and Use

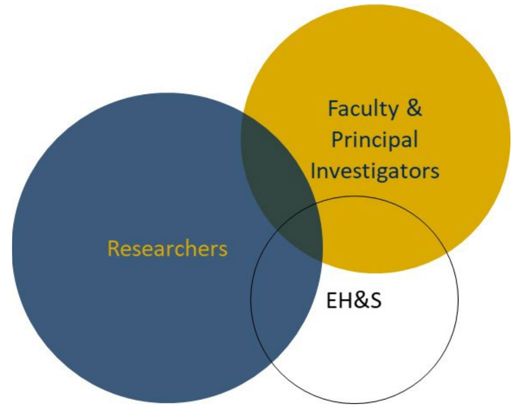
Use of animals in research and teaching activities at UC Davis is governed by the Institutional Animal Care and Use Committee (*IACUC*). This committee is tasked with assuring complete and adequate review of animal facilities, laboratory/study areas, procedures, and animal care and use protocols, consistent with the requirements of *PPM 290-30*. Contact the IACUC office via *iacuc-staff@ucdavis.edu* or (530) 752-2364 for additional guidance.

6. Shop Safety

The *Industrial & Shop Safety team* helps recognize, evaluate and control workplace conditions, to prevent worker injury or illness, governed by the UC Davis Shop Safety Committee. This committee is tasked with establishing campus policies and procedures for the acquisition and safe use of equipment in shop settings, including engineering and administrative control measures and required personal protective equipment to minimize occupational injuries or illnesses, consistent with the requirements of *PPM 290-58*. Contact *shopsafety@ucdavis.edu* or (530) 752-1493 for additional guidance.

7. Safety Training & Recordkeeping

Effective training is a critical component of a safe work environment. All employees must be trained in general safe work practices and be given specific instructions on hazards unique to their job assignment and laboratory. Achieving safety training requirements is a cooperative teamwork effort by Departments, PIs, Laboratory Supervisors, Laboratory Safety Officers, Laboratory Personnel, and EH&S. It is *strongly recommended* that PIs assign a designated safety person for their lab, and support and empower this person/role. The designated safety person should coordinate initial and refresher training and be a point of contact for inspections. The UC Davis Chemical and Laboratory Safety Committee (*CLSC*) approved a *Safety Training Matrix for Laboratory Personnel* for PIs and Laboratory Supervisors to use in determining the required safety training courses for their research activities. Furthermore, the CLSC approved a *Site-Specific Safety Orientation & Training Checklist for New Laboratory Personnel* to document that all personnel have been trained on topics that include the location and use of fire alarms, eye washes and safety showers, emergency action plans, engineering controls, CHP, SOPs, and more.



An effective health and safety training program must include appropriate oversight, proper recordkeeping, instruction on the proper use of equipment and personal protective equipment (*PPE*), and safe work practices. Accurate recordkeeping of training activities demonstrates a commitment to the safety and health of the UC Davis community, integrity of research, and protection of the environment. EH&S is responsible for maintaining completion records of training conducted by EH&S staff members in the Learning Management System (*LMS*). Departments or laboratories are required to document and maintain records of all health and safety training, including safety meetings, one-on-one training, classroom training, and online training. Safety training records, including records of EH&S conducted training, should be kept A) with the CHP, B) with departmental training records, or C) be readily available via the LMS.

8. Inspections, Safety Reviews, and Recordkeeping

EH&S conducts a comprehensive *Laboratory Safety Review Program* for all UC Davis laboratories. These Laboratory Safety Reviews are performed on an annual basis by EH&S Laboratory Safety Professionals (LSPs) to assist PIs/Laboratory Supervisors in maintaining a safe laboratory environment and to aid in compliance with Federal, State, County regulations and University policies. Most of the applicable standards are contained in *CCR, Title 8, Sections 3380–3385* and *5191*, *CCR, Title 19, Div.1, State Fire Marshal* and in *Title 40 of Code of Federal Regulations, Environmental Protection Agency*. The EH&S Laboratory Safety Professionals conduct Safety Reviews, issue reports, assist investigators with regulatory compliance, conduct follow-up reviews to ensure timely corrective actions, and provide training and advice on laboratory safety.

PIs/Laboratory Supervisors are required to inspect their own laboratory on a routine basis, at least annually. A self-inspection checklist that mirrors the Laboratory Safety Review Program checklist is available, either on *paper* or *online* through *Inspect*, for this purpose. Regular inspections performed by internal personnel have been shown to substantially improve safety conditions and will help to ensure fewer findings when Safety Reviews or inspections are performed by EH&S personnel or regulatory inspectors. All internal inspection reports must be maintained for a period of five years by the PI or Laboratory Supervisor, while records of the Laboratory Safety Review will be maintained by EH&S.

9. Hazard Assessments

Workplace hazard and PPE assessments are required, see *8 CCR §3380* "Personal Protective Equipment", for all locations where: A) there is use or storage of hazardous materials, or B) where equipment may present a physical hazard. Detailed UC Davis policy requirements and guidance are provided in *Protective Clothing and Equipment* (*PPM 290-50*). Related requirements include:

- Written hazard assessments.
- Identification of required PPE.
- Training and refresher training.
- Posting of area hazards and required PPE.

The Laboratory Hazard Assessment Tool (*LHAT*) categorizes chemical and other types of hazards and specifies the appropriate PPE for each hazard. Note that the LHAT does not identify all the hazards present in a particular work environment. PIs/Laboratory Supervisors must evaluate whether there are additional hazards in their laboratories not addressed by the LHAT. Once the appropriate PPE is identified for the active worker and individuals in the adjacent area, the PI/Laboratory Supervisor must provide the required PPE to all personnel and conduct and document training on the proper use of the PPE.

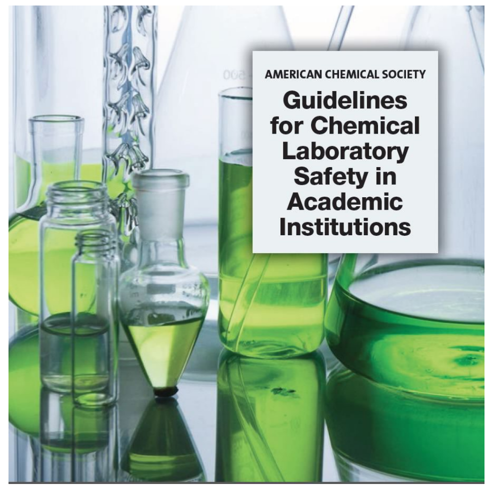
PIs and Laboratory Supervisors are required to provide information to EH&S concerning: the laboratory location, laboratory personnel roster, identity of the Laboratory or Facility Supervisor, the Laboratory Safety Coordinator, if applicable, and certify that the assessment and training was successfully completed. *LHAT instructions and forms* are provided on the UC Davis Safety Services website. The LHAT must be updated whenever hazards in the laboratory or facility change, or new hazards are identified and must be certified at least annually. The PI/Laboratory Supervisor is responsible to keep the laboratory location and personnel roster within LHAT updated at all times. The laboratory or facility's most recent hazard assessments must be maintained by the PI/Laboratory Supervisor and be readily available.

D. Questions

For further information on any health and safety related topics, please contact *EH&S* at (530) 752-1493 or *researchsafety@ucdavis.edu*.

II. CHEMICAL HYGIENE PLAN OVERVIEW

A. Purpose



UC Davis is committed to providing a healthy and safe working environment for the campus community. This campus Chemical Hygiene Plan (CHP) establishes a formal written program for managing the risks posed by health and safety hazards associated with the use of hazardous chemicals in laboratories and research. The CHP describes the proper use, handling, storage, and disposal practices and procedures to be followed by faculty, staff, students, visiting scholars, volunteers, and all other personnel working with hazardous chemicals at UC Davis. This plan is based on best practices identified in, among others sources, *Prudent Practices in the Laboratory*, published by the National Research Council, and the American Chemical Society's (*ACS*) *Guidelines for Chemical Laboratory Safety in Academic Institutions*, *Safety in Academic Chemistry Laboratories*, and *Creating Safety Cultures in Academic Institutions*, which are highly recommended reading for all laboratory personnel and are available to all from the provided hyperlinks.

The Association of Public & Land-Grant Institutions (*APLU*) has also released a guiding document to serve as a roadmap for higher-education institutions to enable and foster a culture of safety for academic research activities. The *entire report is available electronically*, and is a great resource for all administrators and researchers. In addition to the report, the APLU has issued:

1. A *set of core institutional values*.
2. *Twenty recommendations to implement and sustain a culture of laboratory safety*.
3. *A toolbox describing actions that strengthen a culture of safety* for all members of the University community.

All UC Davis research personnel are encouraged to review and implement these actions wherever possible. Lastly, *Dow Chemical Company* offers a number of training modules to help build and sustain a strong laboratory safety culture. If assistance is needed, please contact *chem-safety@ucdavis.edu* for support and guidance on implementing these recommendations and developing and sustaining a positive safety culture in your laboratory.

B. Scope

The CHP applies to personnel within a laboratory where hazardous chemicals are used or stored, or those whose work activities are research-related and involve hazardous chemicals. Use or storage of the hazardous chemicals must be consistent with "laboratory use" to be covered by *8 CCR §5191* and the CHP. "Laboratory use," means that:

1. Chemical manipulations are carried out on a "*laboratory scale*."
2. Multiple chemicals or chemical procedures are used.
3. Activities are not part of or simulating a production process.
4. Protective laboratory practices and equipment are available and in common use.

At a minimum, this definition includes employees who use chemicals in all UC Davis teaching and research laboratories, including at both the Davis and Sacramento locations, as well as off-site research locations. Also, it is UC Davis policy that students in laboratories, while not legally covered by this standard, are afforded the same level of protection as UC Davis employees.

The CHP does not apply to research involving exclusively radiological or biological materials, as these safety procedures and regulatory requirements are outlined in the *Radiation Safety Program* and *Biosafety Program* 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, authorizations, or programs.

UC Davis has also established a Hazard Communication Program (*HazCom*) that complies with CCR, Title 8, Section 5194 (*8 CCR §5194*), which is directly applicable to personnel who may handle hazardous chemicals in most non-laboratory workplaces. Consult *EH&S* with questions regarding the applicability of the HazCom Program.

The information presented in the CHP represents best practices and provides a broad overview of the information necessary for the safe operation of laboratories that utilize hazardous chemicals. **It is not intended to be all inclusive.** Laboratories, technical areas, or other work units engaged in activities with hazardous chemicals possessing unusual characteristics, or are otherwise not sufficiently covered in the written CHP and supporting materials, must augment the CHP with a laboratory-specific *Laboratory Safety Plan* addressing the hazards and how to mitigate their associated risks, as appropriate. Contact EH&S at *chem-safety@ucdavis.edu* for assistance with determining the need for a Laboratory Safety Plan and assistance with development of these materials.

C. Regulatory Requirements

The necessary work practices, procedures, and policies outlined in this CHP are required by the following State of California regulations:

- *8 CCR §3203*, "*Injury and Illness Prevention Program*"
- *8 CCR §3380*, "*Personal Protective Devices*"
- *8 CCR §5143*, "*General Requirements of Mechanical Ventilation Systems*"
- *8 CCR §5154.1*, "*Ventilation Requirements for Laboratory-Type Hood Operations*"
- *8 CCR §5164*, "*Storage of Hazardous Substances*"
- *8 CCR §5191*, "*Occupational Exposures to Hazardous Chemicals in Laboratories*"
- *8 CCR §5194*, "*Hazard Communication*"
- *8 CCR Article 110*, "*Regulated Carcinogens*"

Other applicable regulations include those promulgated by the U.S. Department of Labor including *29 CFR 1910.1450 Occupational Exposure to Hazardous Chemicals in Laboratories* (the "Laboratory Standard"). These regulations require that the CHP be readily available wherever potentially hazardous chemicals are used, handled, or stored. Also applicable is the *General Duty Clause* of the Occupational Safety and Health Act which states:

> *"Each employer:*
> 1. *Shall furnish to each of his employees employment and a place which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employee.*
> 2. *Shall comply with occupational safety and health standards promulgated under this Act.*
>
> *Each employee shall comply with occupational safety and health standards and all rules, regulations, and orders issued pursuant to this Act which are applicable to his own actions and conduct."*

EH&S will review and evaluate the effectiveness of the CHP at least annually and update it as necessary. Any updates to the CHP will be reviewed and approved by the *Chemical and Laboratory Safety Committee*.

D. Rights and Responsibilities

Employees and other personnel who work in University facilities have the right to be informed about the potential health hazards of the chemicals in their work areas and to be properly trained to work safely with these substances. This includes custodial staff and other personnel who work to clean and maintain laboratories. Employees have the right to *file a complaint with Cal/OSHA* (California Occupational Safety and Health Administration) if they feel they are being exposed to unsafe or unhealthy work conditions, and they cannot be discharged, suspended, or otherwise disciplined by their employer for filing a complaint or exercising these rights. *All personnel working with hazardous chemicals are encouraged to report (anonymously, if preferred) any concerns about unsafe work conditions to EH&S at (530) 752-1493 or by filling out the "Report an Incident or Concern" form on the Safety Services website.*

Responsibility for the health and safety of the campus community extends to the highest administrative levels of UC Davis. The Chancellor and Vice Chancellors are responsible for the implementation of UC Davis's Environmental Health and Safety policies at all facilities and properties under campus control. College Deans, Department Chairs, and Unit Heads are responsible for establishing and maintaining programs in their areas and for providing a safe and healthy work environment.

While the Chancellor, Vice Chancellors, Deans, Department Chairs, and Unit Heads are responsible for the broad implementation and enforcement of UC Davis's EH&S policies, the day-to-day responsibility for the management of laboratory safety and adherence to safe laboratory practices rests with the PI/Laboratory Supervisor within individual workplace units and associated departments. All personnel have a duty to fulfill their obligations to maintain a safe work environment and minimize the risks associated with their workplace hazards.

All employees and other personnel working with hazardous chemicals have the responsibility to conscientiously participate in training classes on general laboratory safety and read and be familiar with the contents of the CHP. Those working with chemicals are responsible for staying informed about the chemicals in their work areas, safe work practices (including available engineering controls), and proper PPE required for the safe completion of their work activities.

Failure to comply with these requirements will result in progressive disciplinary action in accordance with University policy and may result in temporary suspension of work activities until corrective action is implemented.

Specific duties and responsibilities of personnel who work in areas where potentially hazardous chemicals are present have been compiled in the document entitled General Rules for Laboratory Work with Chemicals and Equipment, found in *Appendix B*.

1. Responsibilities of the Chancellor and Provost

The Chancellor and Provost of the University have the ultimate responsibility for the overall campus Environmental Health and Safety Program at UC Davis. Campus policies relating to laboratory and chemical safety have been described in the UC Davis Policy and Procedure Manual (PPM *290-15*, *290-30*, *290-32*, *290-50*, *290-53*, *290-55*, *290-56*, *290-58*, *290-70*, *290-75*, *290-84*, *290-95*, *350-20*, *390-10*, *390-40,* and *390-60*) and this UC Davis Chemical Hygiene Plan. The Chancellor and Provost are responsible for the development and interpretation of these policies.

The Chancellor and Provost have delegated their responsibility for laboratory and chemical safety to the Office of Environmental Health and Safety, the campus Chemical and Laboratory Safety Committee, and specific individuals described below.

2. Responsibilities of School/College Deans and Vice Chancellors

Deans and Vice Chancellors are responsible for supporting Departments under their jurisdiction and ensuring compliance with all safety related policies, including, but not limited to, *PPM 290-15*. Such support demonstrates willingness of the School/College or Administrative Unit's to provide the necessary resources to promote a healthy and safe work environment, as well as aid the enforcement of UC Davis policies and procedures.

3. Responsibilities of Chemical and Laboratory Safety Committee

The *CLSC* is responsible for developing, facilitating, and implementing campus policies and procedures for the safe acquisition, storage, use, and disposal of hazardous chemicals in laboratories and research activities, as well as establishing laboratory processes that enhance safety. CLSC policies and procedures do not include radiological materials, biological materials, lasers, or animal care and use, all of which are covered under the auspices of their appropriate committee.

The CLSC is responsible for the following chemical and laboratory safety program areas:

1. Developing ways to share safety policies with the campus community.
2. Reviewing the chemical and laboratory safety classes and developing a long-term training plan.
3. Developing, facilitating, and implementing the campus-wide Chemical Hygiene Plan and associated SOPs.
4. Developing, facilitating, and implementing the Laboratory Safety Review Program, Laboratory Hazard Assessment Tool, and Personal Protective Equipment (PPE) policy.
5. Promoting the development of environmentally sustainable laboratories.

6. Reviewing the Facilities Planning and Laboratory Design Guide as it relates to Environmental Health and Safety.
7. Reviewing any special Program Areas (e.g., carcinogens, nanotechnology, chemical recycling, and physical hazards) associated with teaching and research.
8. Formulating strategy and policy to reduce risks from processes that are identified as posing a significant risk to the campus community.
9. The CLSC shall have the ability to enforce policy *PPM 290-56 Chemical Safety*. Policy enforcement may include any of the following:
    a. Supporting and participating in the progressive resolution procedure for *Laboratory Safety Review Program* when items of non-compliance are left unresolved.
    b. Suspending any laboratory activities that pose an unacceptable level of risk to laboratory personnel health and safety or University property.

4. Responsibilities of Department Chairs or Unit Heads

The Department Chairperson or Unit Head assumes the ultimate responsibility for personnel engaged in the laboratory or research use of hazardous chemicals within their Department or Unit. While the Chairperson or Unit Head has the ability to delegate some of these responsibilities, he or she must ensure that they are carried out to completion. The Department Chairperson or Unit Head is responsible for:

1. Establishing and maintaining Department/Unit programs that provide a safe and healthy work environment.
2. Providing resources necessary to mitigate risk from potential hazards, assuring appropriate training, and assisting in enforcement of campus policies and procedures.
3. Providing the Chemical Hygiene Officer with the support necessary to implement and maintain the CHP.
4. Assigning and supervising a Department/Unit Safety Coordinator (DSC) to perform the roles and responsibilities detailed in *SafetyNet #125 - Safety Management Program Guidelines for Department Safety Coordinators*.
5. May serve as the Chairperson of a Department/Unit Safety Committee (if one exists and so desired).
6. Ensuring that:
    a. The Department/Unit IIPP is reviewed, and updated if needed, on an annual basis.
    b. All new employees receive initial documented IIPP training.
    c. All employees receive documented annual refresher IIPP training.
7. Maintaining the Department/Unit's Emergency Action Plan, UC Ready mission continuity plan, and current contact and directory information for Department/Unit staff and students.
8. Ensuring that all chemical inventories for the Department/Unit are entered and maintained in the chemical inventory system (*RSS Chemicals*).
9. Reviewing the results of inspections, Safety Reviews, and audits for Department/Unit areas.
10. Ensuring corrective actions are completed to address any identified deficiencies and working to maintain compliance with all applicable Department/Unit, university, local, state, and federal codes and regulations.

11. Reviewing injury and illness reports that originated within the Department/Unit no less frequently than quarterly.
12. Paying fines resulting from citations as a result of action or failure of department to comply with health/safety or environmental laws and regulations.

5. Responsibilities of Principal Investigators & Laboratory Supervisors

The PI/Laboratory Supervisor has responsibility for the health and safety of all personnel in his or her workplace who handle hazardous chemicals. The PI/Laboratory Supervisor may delegate safety duties but remain responsible for ensuring that delegated safety duties are successfully completed. The PI/Laboratory Supervisor is responsible for:

1. Discussing the safety expectations for new employees and students on their first day and/or before they are granted access to the laboratory or other facility.
2. Identifying hazards in the laboratory or other facility, determining safe procedures and controls, and implementing and enforcing standard safety procedures. Maintaining current information on laboratory activities, laboratory personnel and laboratory locations within *LHAT*. Note that this includes hazards posed by off-campus or field research activities: more information is available on the *Field Research Safety Program webpage*, as well as in the *Field Operations Safety Manual* from University of California, Office of the President (UCOP). Contact *fieldsafety@ucdavis.edu* with any questions.
3. Training all laboratory or other personnel he/she supervises to work safely with hazardous materials, which includes:
   a. Providing and documenting a safety orientation for the workplace and training on common processes on the first day an individual is granted access to or assigned work activities within the PI/Laboratory Supervisor's laboratory. The CLSC has developed a *Site-Specific Safety Orientation & Training for New Laboratory Personnel* to document this expectation; existing equivalent checklists are also acceptable.
   b. Ensuring all personnel successfully complete the *UC Laboratory Safety Fundamentals* training prior to receiving unescorted access to the laboratory.
   c. Conducting laboratory-specific or other specialized training where applicable. Laboratory safety training must include information of the location and availability of hazard information.
   d. Training records must be maintained; electronic records are encouraged.
4. Requiring laboratory personnel have access to and comply with the CHP, applicable Safety Manual(s), and any Laboratory Safety Plan(s), and ensuring they do not operate equipment or handle hazardous chemicals without proper training.
5. Ensuring the availability of all appropriate PPE (e.g., laboratory coats, gloves, safety eyewear, etc.) and that the PPE is maintained in working order. Ensuring users know how to properly use and store PPE.
6. Knowing all applicable health and safety rules and regulations, training and reporting requirements, and SOPs associated with chemical safety for regulated substances. EH&S is currently reviewing and revising *SafetyNet #131 - Safety Program Guidelines for Principal Investigators* for guidance on the requirements and consistency with recent program and policy changes.

7. Establishing SOPs (general and protocol specific) and performing literature searches relevant to health and safety for laboratory-specific work. Providing prior approval for the use of restricted hazardous chemicals once personnel are appropriately trained.
8. Consulting with the campus Chemical Hygiene Officer (CHO) and/or the CLSC on use of higher risk materials, such as the use of particularly hazardous substances, or conducting higher risk experimental procedures so that special safety precautions may be taken.
9. Consulting with *Fire Prevention Services* (*fireprevention@ucdavis.edu*) regarding instructions or suggestions for precautionary risk mitigation measures concerning projects having inherent fire or explosion potential.
10. Monitoring the safety performance of personnel. Actions to correct deficient work practices must be taken if they may lead to illness or injury, these actions shall be documented.
11. Requiring visitors follow laboratory rules, and assuming responsibility for laboratory visitors. **NOTE** PIs/Laboratory Supervisors must follow the policies (both *UC* and *UC Davis* specific) regarding minors in University laboratories or shops where hazardous chemicals, biohazardous or infectious materials, radioactive materials or radiation-producing equipment, or where there are physical hazards including (but not limited to) compressed gases, high voltage, extreme temperatures, excessive noise, or lasers are present.
12. Maintaining an updated chemical inventory for the laboratory or facility.
13. Promptly disposing of unwanted or excess hazardous chemicals and materials following UC Davis, state, and federal waste disposal requirements.
14. Complying with all state and federal regulations for shipment of any hazardous materials. Consult with EH&S for further information on the requirements.
15. Restricting laboratory activities of undergraduates with respect to hazardous materials, equipment, or activities which may pose risks of injury or death. Written approval may be granted following completion and review of a risk assessment in conjunction with the individual.
16. Requiring the proper operation of appropriate workplace engineering controls (e.g., fume hoods) and safety equipment (e.g., emergency showers/eyewashes, fire extinguishers, etc.), and promptly notifying EH&S and/or Facilities Management should they become non-operational.
17. Conducting periodic *self-inspections* of laboratory or facility, at least annually, and maintaining records of inspections. Contact *researchsafety@ucdavis.edu* with any questions on self-inspections.
18. Ensuring the availability of appropriate resources and procedures for responding to an accident, including the cleanup of small chemical spills.
19. Immediately reporting *serious injuries* to EH&S by completing the Employee Injury and Illness Report (*EIIR*)as soon as practicable to comply with the Cal/OSHA 8-hour reporting time frame. Any doubt as to whether an injury is serious should favor reporting.
20. Immediately reporting any fires or fire extinguisher discharge to the Fire Department, even if the fire is extinguished.
21. Reporting all *accidents* and injuries requiring medical care to EH&S within 24 hours, and completing the *EIIR* if the injured person is a paid employee.
22. Investigating all *accidents*, *incidents*, and *near-misses* to determine the cause and implement corrective action for prevention of future occurrences. Near-misses should be discussed

collectively within the laboratory/research group. Contact EH&S for assistance with investigation and development of corrective actions.

23. Informing facilities personnel, other non-laboratory personnel, and any outside contractors of potential workplace-related hazards when they are required to work in the environment. This includes identifying and managing potential hazards to provide a safe environment for repairs and renovations.
24. Paying fines resulting from citations as a result of action or failure to comply with health/safety or environmental laws and regulations.
25. In the event that the PI/Laboratory Supervisor will be on extended leave (i.e., more than 14 days) provisions must be made to designate a responsible person for the workplace. In addition, the PI/Laboratory Supervisor may want to place limitations on the type or scope of work that is performed during the absence and review emergency procedures with all personnel. Exceptions can be made where the PI/Laboratory Supervisor is easily contacted by telephone or e-mail and maintains weekly interactions with the laboratory personnel.

Laboratory Safety Plan: Most PIs/Laboratory Supervisors have the option to create a site-specific Laboratory Safety Plan to augment the campus CHP. However, a Laboratory Safety Plan may be required for any of the following situations:

A. The PI/Laboratory Supervisor chooses to formally delegate any of their identified responsibilities to a qualified individual. Note that the responsibility can be delegated but the ultimate liability cannot.
B. The laboratory in question has:
   i. Atypical engineering controls not described in the CHP (e.g., down draft tables, floor-mounted fume hoods, specialized ventilation control).
   ii. Atypical laboratory equipment (e.g., industrial/shop equipment, high voltage equipment.). Modifications to the *Laboratory Safety Plan template* to include required elements of the Shop Safety Plan have been completed such that a single plan can be managed to meet obligations under both programs if desired.
   iii. Unique PPE expectations/policies (e.g., clean room).
   iv. A formally approved exception to the minimum attire required to enter a laboratory under the *UCOP PPE policy*.

The Laboratory Safety Plan can be customized to the exact workplace hazards present in the laboratory or facility and outline the safety program structure and expectations for the laboratory. A Laboratory Safety Plan will include information detailing the methods for completion of the identified CHP responsibilities and procedures to mitigate the risks associated with the laboratory hazards. While there are only certain specified situations where a Laboratory Safety Plan may be required, safety awareness and management in all laboratory environments will benefit from a Laboratory Safety Plan. Information in the Laboratory Safety Plan must receive approval from the PI/Laboratory Supervisor prior to implementation. The campus Chemical Hygiene Officer is available for assistance in the development of site-specific Laboratory Safety Plans, and a *Laboratory Safety Plan document template* approved by the CLSC is available. Contact EH&S at *researchsafety@ucdavis.edu* for further assistance.

6. Responsibilities of All Personnel Who Handle Potentially Hazardous Chemicals

All personnel in research or teaching laboratories that use, handle or store potentially hazardous chemicals are responsible for:

1. Reviewing, understanding, and following requirements of the: CHP; all applicable Safety Manual(s), Programs, and Policies; and any applicable individual Laboratory Safety Plans.
2. Following all required verbal and written workplace safety rules, regulations, and SOPs.
3. Developing good personal chemical hygiene habits including, but not limited to, keeping work areas safe and uncluttered, cleaning up following work activities, and practicing good housekeeping in the workplace.
4. Planning, reviewing, and understanding the hazards of materials and processes in their laboratory research or other work procedures <u>prior to</u> conducting work.
5. Utilizing appropriate measures to control identified hazards, including consistent and proper use of engineering controls, administrative controls, and PPE.
6. Understanding the capabilities and limitations of PPE issued to them, and properly maintaining this PPE.
7. Being prepared for laboratory accidents and knowing emergency response procedures.
8. Gaining prior approval from the PI/Laboratory Supervisor for the use of restricted chemicals and other materials or equipment.
9. Gaining prior approval from the PI/Laboratory Supervisor for the purchase of any new chemicals for the laboratory or research activities.
10. Consulting with PI/Laboratory Supervisor before using higher risk chemicals (e.g., particularly hazardous substances, explosives, and other highly reactive chemicals), or conducting certain higher risk experimental procedures. Notifying other laboratory members of the hazards posed by the chemicals/activities prior to beginning work.
11. Immediately reporting all *accidents*, *incidents* (including *near-misses*), injuries, and unsafe laboratory conditions/activities to the PI/Laboratory Supervisor.
12. Immediately reporting any fires or fire extinguisher discharge, even if the fire is extinguished, to the Fire Department and the PI/Laboratory Supervisor.
13. Immediately reporting any new or previously unrecognized workplace hazards within their department to their PI/Laboratory Supervisor or EH&S (via *Report an Incident or Concern*).
14. Completing all required health, safety, and environmental training and providing documentation to their supervisor.
15. Participating in Medical Surveillance, when required.
16. Informing the PI/Laboratory Supervisor of any work modifications ordered by a physician as a result of medical surveillance, occupational injury, or exposure.
17. Discussing with the PI/Laboratory Supervisor, and receiving prior approval for, any activities and procedures that are to be conducted while alone in the laboratory.
18. When performing independent research or work:
    a. Reviewing the written plan or scope of work for their proposed research with the PI/Laboratory Supervisor.
    b. Notifying in writing and consulting with the PI/Laboratory Supervisor in advance if they intend to deviate from previously reviewed procedures (Note: changes may include, but are not limited to, change in the objectives, change in PI, change in the duration, quantity, frequency, temperature, or location, increase or change in PPE, and reduction or elimination of engineering controls.).

c. Preparing SOPs and performing literature searches relevant to safety and health appropriate for their work.
d. Providing appropriate oversight, training, and safety information to laboratory or other personnel they supervise or direct.

19. On termination or transfer of laboratory personnel, all their related hazardous materials (including chemicals and samples) shall be properly disposed or transferred to the PI/Laboratory Supervisor or a designee, with the chemical inventory updated appropriately.

7. Responsibilities of Fire Prevention Services and campus Fire Marshal

UC Davis *Fire Prevention Services*, which includes the campus Fire Marshal, is responsible for plan review, construction inspections, fire clearance, fire prevention inspection, testing and consultative services to ensure that all facilities, programs, fire protection systems, and events are managed in compliance with applicable fire and life safety statutes, rules, and regulations. Additionally, Fire Prevention Services is responsible to ensure that potential fire and life safety liabilities are brought to the attention of those who are responsible (department heads, PIs, safety coordinators, facility managers, etc.) for abatement actions. Fire Prevention Services also completes activities related to fire investigations including, but not limited to, determining origin and cause of the fire or explosion, malicious transmission of a fire alarm, tampering with or damage to fire protection equipment, damage, or attempted damage of property by fire, suspicion that arson or attempted arson has been committed, and injury or death as a result of a fire. The campus Fire Marshal, with support from Fire Prevention Services staff, is specifically responsible for:

1. Ensuring that the campus complies with California statutes, and fire and life safety rules and regulations of the California State Fire Marshal as adopted or referenced in *Title 19* and *Title 24* (Parts 2, 3, 4, 5, and 9) of the California Code of Regulations.
2. Controlling access to, or initiating either complete or partial evacuation from, a building or complex in any unsafe, dangerous, or hazardous circumstance not involving an emergency response.
3. Inspecting assigned UC Davis facilities, processes, and fire protection systems to ensure conformance with State statutes, rules, regulations, and UC Davis fire safety policy (*PPM 390-40*).
4. Providing training, upon request, in fire prevention and use of fire extinguishers.

8. Responsibilities of EH&S and campus Chemical Hygiene Officer

UC Davis EH&S, which includes the campus Chemical Hygiene Officer (CHO), is responsible for administering and overseeing all areas of chemical safety and management, including the campus CHP. EH&S provides technical guidance to personnel at all levels of responsibility on matters pertaining to the use of hazardous materials. If situations are immediately dangerous to life or health (IDLH), EH&S Safety Professionals, including the campus CHO, have the authority to order the cessation of the activity until the hazardous condition is abated and risk sufficiently mitigated. The campus CHO, with support from other EH&S personnel, is specifically responsible for:

1. Informing PIs/Laboratory Supervisors of all health and safety requirements, and assisting with the selection of appropriate safety controls, including engineering controls, laboratory and other workplace standard practices, training, PPE, etc. to minimize the risks posed by laboratory hazards.
2. Assisting the PI/Laboratory Supervisors in the development of their SOPs and Laboratory Safety Plans.
3. Assisting the PI/Laboratory Supervisors in their laboratory hazard assessments, upon request.
4. Providing consultation to the EH&S Laboratory Safety Professionals on the results of their Safety Reviews and appropriate actions to abate hazards that may pose a risk to life or safety.
5. Providing technical consultation to the Chemical and Laboratory Safety Committee in the development and implementation of appropriate chemical hygiene policies and practices and development of SOPs.
6. Having working knowledge of current health and safety rules and regulations, training, reporting requirements, and standard operating procedures associated with regulated substances. Such knowledge may be supplemented and developed through research and training materials.
7. Providing technical guidance and investigation, as appropriate, for laboratory and other types of accidents, incidents, and injuries.
8. Promoting safety training offered by UC Davis (i.e., fire extinguisher training, equipment training, general workplace training, etc.) where appropriate.
9. Assisting Occupational Health Physicians in determining the appropriate medical surveillance requirements for personnel, if any.
10. Reviewing and evaluating the effectiveness of the campus CHP at least annually and updating it as appropriate. Continually seek ways to improve the CHP.
11. Provide support for the campus chemical inventory system and ChemTag program.
12. Supporting other units within EH&S by providing technical consultation and assistance with areas such as *environmental compliance* and *transport and disposal of hazardous waste.*

III. CHEMICAL HAZARD IDENTIFICATION

A. Introduction

UC Davis is responsible for providing information about the hazardous substances and activities in our workplaces including laboratories, the associated risks, and the measures to mitigate those risks. Proper hazard communication involves the active participation of the PI/Laboratory Supervisor, the campus Chemical Hygiene Officer, the EH&S Hazardous Communication Program Professional, the School/College Laboratory Safety Professionals, and the Department Safety Coordinators, who are each responsible for providing consultation and safety information to employees working with hazardous chemicals.

B. Chemical Inventory

All laboratories, technical areas, or shops are required to maintain an accurate chemical inventory using the UC Davis online chemical inventory system (*RSS Chemicals*). For each hazardous substance on their inventory, specific information on any associated health or safety hazards must be made readily available to all personnel. Compressed gases must also be included in the inventory list. Additional information related to storage and management of laboratory chemicals is provided on the *Safety Services website*, as well as in *SafetyNet #42 – General Guidelines for Storage and Management of Laboratory Chemicals*.

C. Chemical Hazard Communication

The term "hazardous substance" refers to any chemical which may present an asphyxiation hazard, environmental hazard, health hazard, physical hazard, or hazard not yet classified. Hazardous substances include, but are not limited to, those chemicals listed in the following:

1. "The Hazardous Substance List," commonly known as the Directors List of Hazardous Substances, *8 CCR §339.*
2. "Toxic and Hazardous Substances, Air Contaminants," *8 CCR, §5155.*
3. "Threshold Limit Values for Chemical Substances in the Work Environment," *ACGIH*, updated annually.
4. "*14th Report on Carcinogens*", NTP, 2016.
5. "*Monographs*," IARC, WHO.
6. Safety Data Sheets (*SDSs*) for reproductive toxins and cancer-causing substances.

Inventory items found on the above lists are subject to the requirements outlined below.

1. Safety Data Sheets

The Occupational Safety and Health Administration (*OSHA*) requires that an *SDS* must be available for each hazardous substance in a laboratory's or facilities chemical inventory. SDSs are available from the UC *SDS website*; additional resources are available on the *Safety Services SDS website*. PIs/Laboratory Supervisors are responsible for keeping SDSs current and making them available to all employees throughout the workday. SDSs must be in a central location that can be accessed immediately in the event of an emergency. Electronic copies may be used but must be accessible to all laboratory personnel.

A *SDS Quick Card* and more detailed information is available from *OSHA*.

2. Door Signage

Hazard identification signage is required at the entrances to locations where hazardous materials are stored, dispensed, used, or handled. Accurate door signage provides information about the hazards that can be found in the space and provides information to first responders that is helpful in the event of an emergency. The following elements are required:

- PI Name.
- Designated Safety Person.
- Contact Information for the PI (contact information for the Designated Safety Person is also strongly recommended).
- Room Number.
- Hazards associated with lab (including, but not limited to, biohazard, radiation, carcinogen, toxic, oxidizer, flammable, pyrophoric, water reactive, corrosive, magnetic fields, laser, etc.).

Signage must be updated as needed. Door placards are available through the chemical inventory system (*RSS Chemicals*) that identifies the chemical hazards present based on the chemical inventory: hazard warnings for biohazards, lasers, and radiation use need to be added manually. Additionally, some Departments, Colleges, or Schools may generate their own door placards.

3. Labels and Other Forms of Warning

Labeling requirements for all hazardous substances are summarized as follows:

- All manufacturer containers of hazardous materials must be labeled with the identity of the hazardous substance.
- The label must contain all applicable hazard warning statements.
- The name and address of the chemical manufacturer or other responsible party must be present.
- Manufacturer's product labels must remain on all containers and must not be defaced in any manner. Appropriate hazard warning statements must be present. If not, that information must be added.
- Labels must be legible, in English, and prominently displayed.
- Symbols or other languages are required for non-English speaking employees.
- *Secondary containers* (i.e., containers used for storing commercial chemicals that are not the original manufacturer packaging, such as spray bottles) must be labeled with the identity of the substance and appropriate hazard warnings.
- Laboratory-prepared solutions of hazardous chemicals and analytical samples containing hazardous chemicals must be labeled with the identity of the chemical(s) and an appropriate hazard warning(s); the date and the identity of the responsible party should be included whenever possible and practical.

- New synthesized compounds must be labeled with the appropriate hazard warnings based on the knowledge of the chemical and physical properties of that substance. If a lab-specific system of identifying synthesized compounds is developed, the system must be documented in the lab's Laboratory Safety Plan or an SOP.
- It is **strongly recommended** that containers of non-hazardous material (such as water) be labeled with the identity of the material.
- If a system of abbreviations is used within the laboratory for labeling, the abbreviations and their meanings must be posted in a conspicuous place and available to all personnel, including emergency response personnel.

Additional information on container labeling, laboratory personnel responsibilities, and potential labeling resources is provided in Appendix C.

4. Employee Information and Training

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. All training must be in the appropriate language, educational level, and vocabulary for laboratory personnel. Employees must be given the opportunity to ask questions. The training requirements and resources for laboratory and research personnel are summarized in *Training*.

5. Laboratory Hazard Assessment Tool

The online *University of California LHAT* was developed to broadly identify activities involving chemical and other types of laboratory hazards, and it functions as a component of hazard communication. The LHAT captures information on hazard categories, the location of the hazard(s), the name of the PI/Laboratory Supervisor, the laboratory personnel roster, and helps to identify the minimum proper PPE that should be used by the active researcher and by other individuals in adjacent areas. Once the required PPE is identified, the laboratory is required to conduct and document training for laboratory personnel on the use and maintenance of PPE. It must be updated whenever hazards in the laboratory or facility change, or new hazards are identified and certified at least annually. The LHAT will not identify all the hazards within a laboratory and serves as one tool to aid PIs/Laboratory Supervisors to assess hazards within the workplace. It is intended to be used in conjunction with the Job Safety Analyses contained within a Department's IIPP.

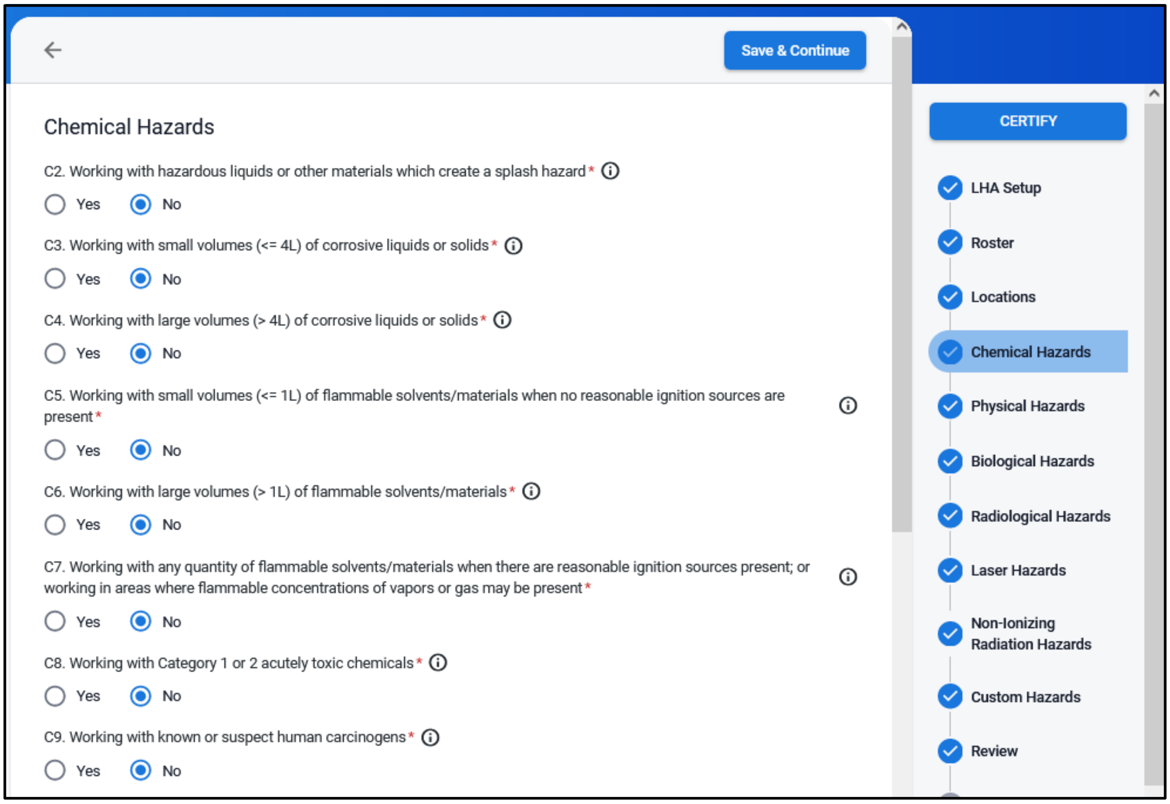


Figure III-I. Example of Chemical Hazards section in LHAT

The ACS has prepared guidance on hazard assessment in "*Identifying and Evaluating Hazards in Research Laboratories*," which should be consulted when completing workplace hazard assessments. A *complimentary video is available* from ACS's Division of Chemical Health and Safety on the value and process of risk assessment related to laboratory hazards and research activities. The ACS and their Committee on Chemical Safety has further developed *tools supporting their hazard recognition and risk assessment technique methodologies* described on their website:

> *It should be understood that laboratory hazard assessments involve all potential hazards associated with laboratory work including physical, radiological, laser, biological, as well as chemical hazards. Non-chemical hazards should not be overlooked.*

6. Novel Chemicals

Unique chemical hazard identification situations exist when novel materials are prepared in research. For new materials synthesized in the laboratory, the following campus requirements will be implemented:

1. When the chemical composition is known, and the material is produced only for use in the laboratory of origin, the PI/Laboratory Supervisor will provide and document training on the hazards as described in this CHP.
2. If the chemical composition is not known with 100% certainty, the PI/Laboratory Supervisor will assume the substance is *particularly hazardous* and implement applicable elements of the CHP.

3. New chemical substances synthesized or produced in a laboratory and used or shared outside of the laboratory of origin may require the preparation of an SDS. Contact the campus CHO at (530) 752-1493 or *chem-safety@ucdavis.edu* for more information on necessity for preparing new SDSs.

7. Chemicals Falling Under the Toxic Substances Control Act

Imported chemicals may fall under the Toxic Substances Control Act (*TSCA*); these are chemicals that , under the Environmental Protection Agency (*EPA*) , are considered a "*new chemical substance*" in U.S. commerce. When an imported chemical is subject to TSCA regulation, EH&S works with the importing PI and Supply Chain Management to ensure (a) timely delivery of the material, and (b) researchers are aware that the hazards of the imported material may not be fully known.

When a chemical is identified as being subject to TSCA regulation, the PI is responsible to:

1. Label containers for R&D use only,
2. Maintain records of any information supplied by the manufacturer of any risk to health which may be associated with the material, and
3. Ensure researchers handling the material aware that the health risks of the imported material are unknown. This can be accomplished through labeling the material "Hazards unknown. Handle as Toxic."

Additional requirements apply to chemicals that are imported under TSCA. These requirements, including quantity limits, requirements for handling, distribution limitations, and proper waste disposal, are communicated to the PI in writing when a chemical is identified as falling under TSCA. Contact *chem-safety@ucdavis.edu* for additional information.

IV. CLASSES OF HAZARDOUS CHEMICALS

A. Introduction

Chemicals pose health and safety hazards to personnel due to inherent chemical, physical, and toxicological properties. Chemicals can be grouped into several different hazard classes. The hazard class will determine how similar 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. More detailed hazard information for specific chemicals can be found by referencing the SDS for that chemical.

The *Globally Harmonized System* (GHS) is an international standardized system for identifying and classifying chemical hazards. Information on identified hazards is conveyed on container labels and SDSs. GHS provides consistency in the structure and content of a SDS and applicable hazard warning information on chemical labels. The hazard pictograms are summarized in *Appendix D* for the GHS system. Written hazard ratings are structured as Hazard Codes (H-Codes) and corresponding Hazard Statements.

It is important to note that GHS uses an inverse scale with 0 representing the greatest hazard and subsequent higher numbers represent lower hazard. An example for oral toxicity would be the H-Code of H300 corresponds to "Fatal if swallowed", H301 corresponds to "Toxic if swallowed", and H302 corresponds to "Harmful if swallowed." Comprehensive information on GHS is provided in the *OSHA guide on GHS*, and helpful reference graphics are available from Millipore-Sigma that outline the *H-Codes* and also the Precautionary Statements (*P-Codes*).

An older hazard posting and labeling methodology is described by the National Fire Prevention Association (NFPA), *Standard 704*, for building and/or door placarding that provides an overview of the key chemical hazards contained within that building or room. *NFPA diamond* postings have the familiar four color 1-4 number rating, which quickly supplies the hazard information broken down into four hazard classes. The four chemical hazard types correspond to the four colored areas: red indicates a flammability hazard, yellow indicates a reactive hazard, blue indicates a health hazard and the white area is reserved for special hazards that are identified by hazard symbols or labels to indicate hazards such as radioactivity, biohazard, water reactive chemicals, etc. Each of these hazards has a different set of safety precautions associated with them. **Figure IV-I** illustrates the NFPA rating system.

It is important to note that under the NFPA system lower numbers (e.g., 1) represents a lower level of hazard than a higher number (e.g., 4). In comparing NFPA to GHS for the earlier example of oral toxicity, under the NFPA diamond an acutely toxic chemical via ingestion would be given a Health Hazard rating of "4" but under GHS it would be assigned the H300 code (Fatal if swallowed). A side-by-side comparison of the two is available *online*.

It is essential that all personnel be trained to understand and identify the types of chemical hazards and the associated risks, recognize the potential routes of exposure, and are familiar with the major hazard classes of chemicals. In many cases, the specific hazards associated with new compounds and mixtures will not be known, so it is recommended that all chemical compounds be treated as if they were potentially harmful and to use available engineering controls and PPE.

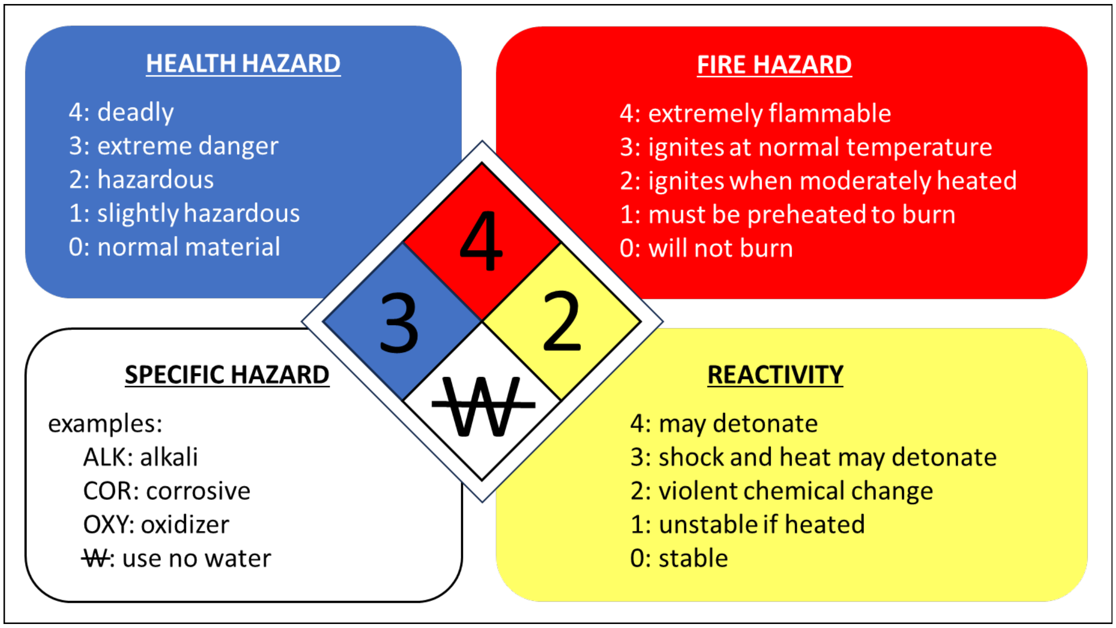


Figure IV-I. NFPA posting

B. Flammability and Combustibility Hazards

A number of highly flammable substances are in frequent use in campus laboratories. Flammable liquids include those chemicals that have a *flashpoint* of less than 100 degrees Fahrenheit (°F), and combustible liquids have a flashpoint between 100-200 °F. These materials must be stored in flammable storage cabinets if aggregate quantities of 10 gallons/room or more are stored in the lab. Guidance on proper flammable liquid storage is provided in *SafetyNet #514 – Flammable and Combustible Liquids* from UC Davis Fire Prevention.

Flame-resistant (FR) laboratory coats must be worn when:

- Working with large volumes of flammable materials (>1L);
- Working with any quantity of flammable solvents/materials when there are reasonable ignition sources present;
- Working in areas where flammable concentrations of vapors or gas may be present;
- Working with pyrophoric chemicals or reagents; and/or
- Working with an open flame.

These materials pose a significant risk and should be treated with care, even though 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.

It is the vapors from flammable liquids that burn, rather than the liquids themselves. For a fire to occur, there must be: 1) vapor concentration between the lower and upper *flammability limits*; 2) source of oxygen (often air); and 3) an ignition source. Careful handling of chemicals and use of chemical fume hoods are typically sufficient to prevent high vapor concentrations. Do not use open flames where flammable vapors may be present. Ensure that containers are properly bonded and grounded before transferring flammable liquids between metal containers or equipment.

Pyrophoric chemicals are a special class of materials that spontaneously ignite when in contact with air and require laboratory-specific training. FR laboratory coats and FR hand protection **must** be worn when handling pyrophoric chemicals. Individuals working with pyrophoric materials **must** know the appropriate method(s) to quench the chemicals being used. Additional information related to pyrophoric and water-reactive materials is provided in *SafetyNet #135 – Procedures for Safe Use of Pyrophoric/Water Reactive Reagents*. Helpful safety videos on *reactive* and *pyrophoric* chemicals are available from the Dow Chemical Company, and *handling pyrophorics* from Dartmouth College.

C. Reactivity and Stability Hazards

Reactive and unstable substances are materials which may violently decompose, rapidly condense, vigorously polymerize, or become self-reactive under conditions of shock, friction, temperature, pressure, light, or contact with other materials, with the release of large volumes of gas or heat. Some examples of such chemicals include explosives, peroxides, azo compounds, and azido compounds. These substances pose an immediate hazard and procedures for their use and storage must be carefully reviewed and followed. Such materials must also be stored in a manner to protect from light, heat, shock, friction, static discharge, contact with a catalyst, or other conditions to which they are sensitive. Some materials, such as *peroxide formers*, may not be explosive, but may form explosive substances over time or upon concentration.

1. Peroxide-Forming Chemicals (Time-Sensitive Materials)

Peroxide-forming chemicals (e.g., ethers, alkenes, alkynes, etc.) include a number of substances which 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, thereby concentrating any peroxides that may have formed in the container.

There are three classes of peroxide-forming chemicals: those that form potentially explosive peroxides without concentration, those that form potentially explosive peroxides on concentration, and those that autopolymerize as the result of peroxide accumulation. Each class has different management guidelines, outlined in *SafetyNet #23 - Peroxide Formation in Chemicals*).

These chemicals should be periodically tested for the presence of peroxides and the results documented quarterly. Minimize the quantity of peroxide-forming chemicals stored in the laboratory and dispose peroxide-forming chemicals as prescribed in *SafetyNet #23*. Refer to *SafetyNet #23* for specific guidelines and/or contact *chem-safety@ucdavis.edu* with questions on peroxide forming chemicals or peroxide testing.

Ensure containers of peroxide-forming chemicals are stored in airtight containers in a dark, cool, and dry place and segregated from other classes of chemicals (e.g., acids, bases, oxidizers) that could create a serious hazard to life or property should an accident occur. Ensure they are kept tightly sealed to avoid unnecessary evaporation, as this inhibits the stabilizers that are sometimes added. Visually inspect containers periodically to ensure they are free of exterior contamination or crystallization. Peroxide-forming chemicals must be disposed prior to expiration date or according to the guidelines in *SafetyNet #23*.

Keep an inventory of peroxide-forming chemicals for your workplace, and never purchase more quantity than can be consumed prior to the manufacturer's expiration date or the recommended disposal date outlined in *SafetyNet #23*.

D. Oxidizers

Oxidizers present a fire and explosion hazard when they come into contact with flammable, combustible materials, or other fuels. They can: 1) speed the development of a fire and increase intensity, 2) cause substances which are normally stable in air to rapidly burn, and 3) lead to spontaneous combustion of materials without an obvious ignition source. Oxidizers are classified on a scale of 1-4 by the NFPA based on their potential to initiate spontaneous combustion, with 1 being the lower hazard and 4 being a greater hazard. In addition to the flammability hazards posed by oxidizers, they can also be corrosive or toxic.

E. Health Hazards

Cal/OSHA uses the following definition for health hazard in *8 CCR §5191*:

> *"A chemical that is classified as posing one of the following hazardous effects: Acute toxicity (any route of exposure); skin corrosion or irritation; serious eye damage or eye irritation; respiratory or skin sensitization; germ cell mutagenicity; carcinogenicity; reproductive toxicity, specific target organ toxicity (single or repeated exposure); aspiration hazard."*

Criteria by which a specific chemical is classified as a *health hazard* can be found in *8 CCR §5194*, including the definition of a "*simple asphyxiant*." An overview of the major classes of "hazardous" and "particularly hazardous substances" and their related health and safety risks are detailed below in Sections a-i.

1. 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, and 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, bromine, perchloric acid, and nitric acid.

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 shown in a *video from UCSD*. As a physical hazard, corrosive substances may corrode materials they come into contact with and may be highly reactive with other substances. It is important to review information: 1) regarding the materials they may corrode, 2) on their reactivity with other substances, and 3) on health effects. In most cases, these materials should be segregated from other chemicals and require *secondary containment* during storage.

2. Irritants

Irritants are 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. Consequently, eye and skin contact with all laboratory chemicals should **always** be avoided. Smoke is a common example of an irritant which can irritate the nasal passages and respiratory system. Symptoms of exposure can include reddening or discomfort of the skin and irritation to respiratory systems.

3. 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, many phenol derivatives, and latex proteins. Sensitizer exposure can lead to all of the symptoms associated with allergic reactions or can exacerbate an individual's existing allergies.

4. Hazardous Substances with Specific Target Organ Toxicity (STOT)

STOT- single exposure (STOT-SE) refers to the adverse, non-lethal, organ-specific health effects of a toxic substance that manifest following a single exposure. Substances included in this category include:

- Hepatotoxins – substances that produce liver damage, such as nitrosamines and carbon tetrachloride.
- Nephrotoxins – agents causing damage to the kidneys, such as certain halogenated hydrocarbons.
- Neurotoxins – substances which produce their primary toxic effects on the nervous system, such as mercury, acrylamide, and carbon disulfide.
- Hematopoietic agents – substances that impede the function of hemoglobin and prevent oxygen from reaching blood tissues, such as carbon monoxide and cyanides.
- Respiratory toxicants – agents that target lung tissue, such as asbestos and silica.

Personnel working with these materials need to review the SDS for the specific chemical being used and take special note of the symptoms of exposure.

5. Particularly Hazardous Substances

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

1. *Hazardous chemicals*
2. *Particularly hazardous substances*

Substances that pose such significant threats to human health are classified as "particularly hazardous substances" (PHS). The Cal/OSHA "Laboratory Standard" (*8 CCR §5191*) requires that special provisions be documented in laboratory SOPs to prevent the exposure of laboratory personnel to PHSs, including:

i. Establishment of designated areas,
ii. Use of containment devices (e.g., fume hoods, glove boxes),
iii. Procedures for contaminated waste disposal, and
iv. Decontamination procedures.

Supplemental information on particularly hazardous substances is provided in *Appendix E*. Particularly hazardous substances are divided into three primary types.

a. 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, their 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. Many of these compounds can also be classified as corrosives, irritants, sensitizers, *Select Agent Toxins*, or *Specific Target Organ Toxins*. Laboratory use of acutely toxic material requires the preparation of an SOP, which may be the *Acutely Toxic Gases SOP*, the *Acutely Toxic Solids and Liquids SOP*, or both. Refer to the *decision matrix* to determine which SOP is required by UC Davis.

b. Reproductive Toxins

Reproductive toxins include any chemical that may affect reproductive capabilities, including causing chromosomal damage (mutagenesis), effects on fetuses (teratogenesis), and adverse effects on sexual function and fertility. **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 embryo lethality (death of the fertilized egg, embryo, or fetus), malformations (teratogenic effects), and postnatal functional defects. For men, exposure can lead to sterility.

Women of childbearing potential should note that embryo toxins have the greatest impact during the first trimester of pregnancy. A pregnancy sometimes goes undiscovered well into 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 those intending to become pregnant should consult with their personal physician, supervisor, and EH&S before working with substances that are suspected to be reproductive toxins. Additional information for laboratory personnel is available through EH&S via *SafetyNet #107 - Pregnancy and Reproductive Hazards in the Workplace: Physical and Biological Hazards*, *SafetyNet #108 - Pregnancy and Reproductive Hazards in the Workplace: Chemical and Radiological Hazards*, as well as through Occupational Health for those working in animal care environments (*Reproductive Hazards for Working in the Animal Care Environment*). Laboratory use of reproductive hazards requires the preparation of a *Reproductive Toxins SOP*.

c. Carcinogens

Carcinogens are chemical or physical agents capable of causing cancer or tumor development. Generally, they are chronically toxic substances; that is, they cause damage after repeated or long-duration exposure, and their effects may only become evident after a long latency period. Chronic toxins are particularly insidious because they may have no immediately apparent harmful effects.

Current UC Davis requirements related to carcinogen use are detailed in the *Carcinogens SOP*. If you have any questions regarding the campus requirements for carcinogen use or personnel monitoring contact *EH&S* for assistance. Laboratory use of carcinogens requires the preparation of a *Carcinogens SOP*. Additional chemical-specific guidance is available for formaldehyde and dichloromethane in *SafetyNet #139 – Guidelines for Handling Formaldehyde* and *SafetyNet #140 - Guidelines for Handling Dichloromethane (Methylene Chloride)* respectively.

6. Hazardous Drugs, including Active Pharmaceutical Ingredients (API)

Hazardous drugs are a broad class of materials designed to address many different illnesses and disorders in humans and animals. Each hazardous drug has unique properties, and any given hazardous drug may have many different potential health effects associated with it.

Of particular note within this class are antineoplastics, or drugs that act to prevent, inhibit, or stop the development or progression of a neoplasm (tumor). Antineoplastic agents, also referred to as anticancer or chemotherapy drugs, by their nature are harmful to healthy cells and tissues as well as neoplasms. The National Institute for Occupational Safety and Health (NIOSH) has consolidated a *list of antineoplastic and other hazardous drugs*, as well as *developed guidance for handling and preparing such materials*.

A variety of hazardous drugs are used in laboratories across campus, and it is vital that these materials be handled with care as they are designed specifically to affect the human body. Laboratory use of hazardous drugs requires the preparation of a *Hazardous Drugs SOP*. Contact *chem-safety@ucdavis.edu* for further assistance or questions.

7. Nanomaterials

The increasing use of nanomaterials in research laboratories warrants consideration of the hazards they may pose. As is the case with many new technologies, the health effects of nanomaterials have not been thoroughly investigated. Consequently, the uncertainty surrounding the toxicity of nanomaterials merits a cautious approach when working with them.

Nanomaterials include any materials or particles that have an external dimension in the nanoscale (~1 – 100 nanometers, 10^{-9} meter). Nanomaterials occur naturally in the environment, are products of incomplete combustion, and are produced via chemical synthesis. Synthesized nanomaterials are referred to as Engineered Nanomaterials (ENMs). Some examples of ENMs include fullerenes (carbon *buckyballs* C_{60}), carbon nanotubes, carbon nanofibers, quantum dots, and metal oxide nanoparticles. Materials whose properties do not differ significantly between their nanoscale and larger forms are generally excluded from ENMs.

Nanomaterials are categorized by the risk of potential exposure they pose to personnel. This risk is impacted by the physical state, surface area, and the conditions in which they are used. In general, the risk of exposure is lowest when nanomaterials are bound in a solid matrix with little potential to create airborne dust or when in a non-volatile liquid suspension. The risk of exposure increases when nanomaterials are used as fine powders or are suspended in volatile solvents or gases (i.e., aerosolized). The parent compound of the nanomaterial should also be taken into consideration when evaluating the potential hazards associated with exposure (e.g., a highly toxic compound such as cadmium should be anticipated to be at least as toxic and possibly more toxic when used as a nanomaterial). Laboratory personnel using or preparing nanomaterials must utilize a combination of engineering controls, SOPs, and personal protective equipment to minimize potential exposure to their self and others.

The UC Davis Chemical and Laboratory Safety Committee has adopted the detailed guidance related to nanomaterials from the California Nanosafety Consortium of Higher Education's "*Nanotoolkit: Working Safely with Engineered Nanomaterials in Academic Research Settings*" and the National Institute of Occupational Safety & Health's (NIOSH) "*Safe Practices for Working with Engineered Nanomaterials in Research Laboratories*." A useful video on *nanoparticle safety* is available from the Dow Chemical Company. Given the uncertainty of the health and environmental hazards posed by nanomaterials, SOPs are <u>required</u> for the preparation, use, storage, and disposal of nanomaterials. All nanomaterials, including solutions containing nanomaterials, are to be disposed as hazardous waste. *SafetyNet #132 - Nanotechnology: Guideliness for Safe Research Practices* has been prepared to provide additional guidance on these materials, and a summary of available resources for nanotechnology laboratory safety is available from the *National Nanotechnology Initiative*. Contact *chem-safety@ucdavis.edu* for additional information if needed.

8. Compressed Gases & Cryogenic Liquids

Compressed gases and cryogenic liquids present pressure and asphyxiation hazards in the workplace. Both compressed gases and cryogenic liquids may also present additional health hazard and/or flammability concerns. Given these hazards, special handling and storage requirements must be followed to mitigate the associated risks. More detailed information on compressed gases can be found in *SafetyNet #60 - Compressed Gas Safety*, while additional information on cryogenic liquids is contained in *SafetyNet #58 - Safety Precautions for Cryogenic Liquids*.

9. Pesticides

Pesticides, as defined by the *California Food and Agricultural Code §12753*, are chemicals used to control unwanted species including, but not limited to, insecticides, fungicides, herbicides, rodenticides, nematicides, plant growth regulators, fumigants, and desiccants. In many instances these chemicals present known or suspected human health hazards and must be managed accordingly. While pesticides may be involved in research activities, it is how these materials are being applied that determines regulatory obligations. If the chemical is being used as directed by the manufacturer its use must include one of the following:

1. Person applying the chemical (Applicator) is in possession of a Qualified Applicator Certificate (QAC) or Qualified Applicator License (QAL).
2. Applicator is under the direct supervision of an individual with a QAC or QAL.
3. Applicator with a QAC or QAL has been contracted to apply the chemical in question.

If the use of pesticide differs from the manufacturers' directions, then this use of material would be considered research use. Some examples of research use of pesticides may include, but are not limited to, the following:

1. Applying different concentrations of the chemical for efficacy assessment.
2. Applying multiple chemicals at the same time to examine synergistic effects, toxicity effects, degradation timelines, etc.
3. Applying novel chemicals to examine pesticide efficacy.

Application of pesticides within enclosed spaces that are located within other enclosed spaces (e.g., growth chambers, growth rooms, etc.) may present challenges with respect to ventilation control and pesticide exposures. Please contact *pesticide-safety@ucdavis.edu* prior to applying pesticides within such spaces to determine appropriate chemical exposure risk mitigation steps.

V. HOW TO REDUCE EXPOSURES TO HAZARDOUS CHEMICALS

A. Regulatory Requirements

The necessary work practices, procedures, and policies outlined in this chapter are required by the following:

- *8 CCR §3380*, "Personal Protective Devices"
- *8 CCR §5141*, "Control of Harmful Exposure to Employees"
- *8 CCR §5154.1*, "Ventilation Requirements for Laboratory-Type Hood Operations"
- *8 CCR §5191*, "Occupational Exposures to Hazardous Chemicals in Laboratories"
- *8 CCR Article 110*, *"Regulated Carcinogens"*

B. Introduction

Hazardous chemicals require a carefully considered, multi-tiered approach to effectively manage their associated risks. There are four primary routes of exposure for chemicals that have associated health hazards (illustrated in **Figure V-I**):

1. Inhalation,
2. Ingestion,
3. Injection (skin being punctured by a contaminated sharp object or uptake through an existing open wound), and
4. Absorption (through the skin or eyes).

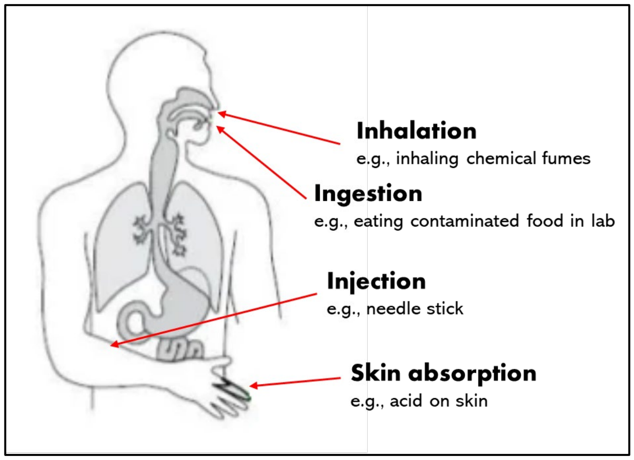


Figure V-I. Routes of exposure

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

The methodology for controlling exposures to hazardous chemicals typically proceeds through the following *hierarchy of controls*:

- Elimination
- Substitution
- Engineering Controls
- Administrative Controls
- Personal Protective Equipment

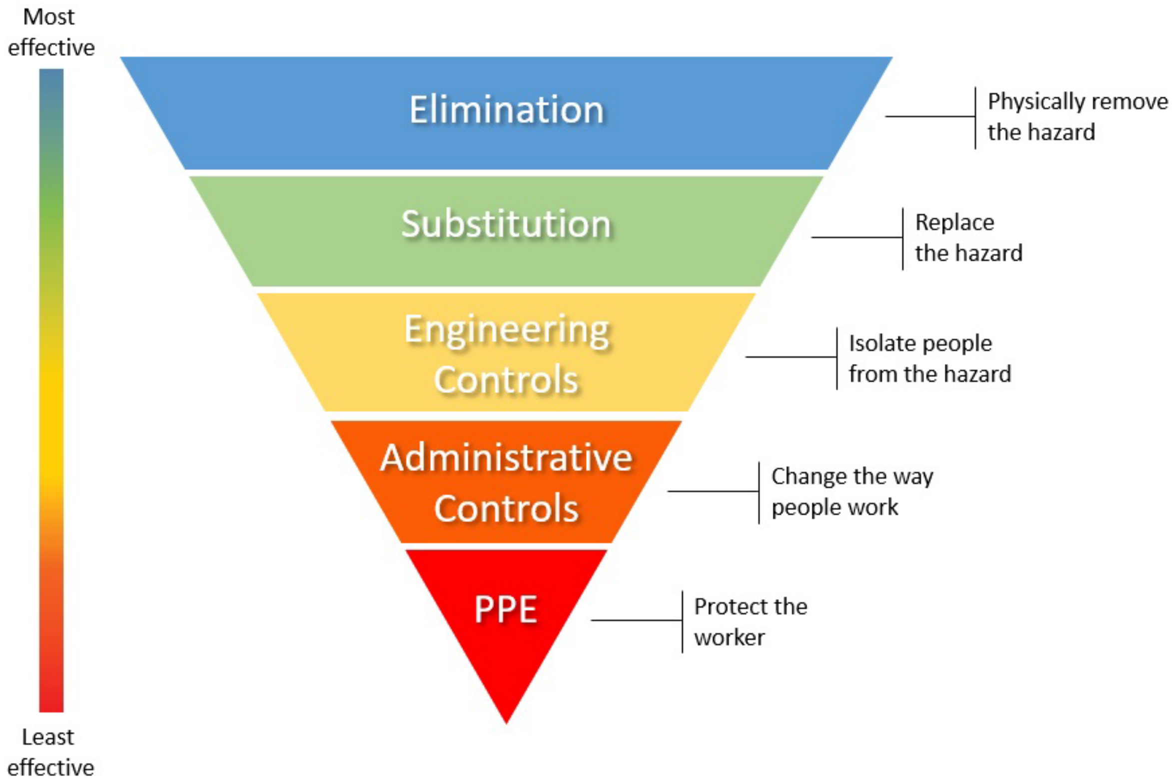


Figure V-II. The Hierarchy of Controls

A graphical representation of the hierarchy of controls is illustrated in **Figure V-II**. Although various illustrations have been used to depict the hierarchy of controls, it is typically represented as an inverted triangle, as developed by the National Institute of Occupational Safety and Health (*NIOSH*). The rationale behind this hierarchy is that the control methods at the top of graphic are more effective and protective than those at the bottom. Typically, elimination or substitution are most easily considered and can be implemented while processes are still under development and design. Existing processes often pose greater challenges for implementing elimination or substitution, and thus are typically addressed using the other safety controls available.

C. Safety Controls

Beyond Elimination and Substitution control approaches, the remaining safety controls are grouped into three main classifications:

1. Engineering Controls.
2. Administrative Controls.
3. Protective Apparel and Equipment.

Elements of these three classes are typically applied in a layered approach to mitigate the risks associated with hazardous chemicals. The principles of each safety control group are described below.

1. Engineering Controls

NIOSH states that:

> *"Engineering Controls are used to remove a hazard or place a barrier between the worker and the hazard. Well-designed engineering controls can be highly effective in protecting workers and will typically be independent of worker interactions to provide this high level of protection."*

Following elimination and substitution, engineering controls offer the first line of protection to prevent exposures to hazardous chemicals. Engineering controls can be very effective and are the preferred method for reducing exposures. Examples of engineering controls include, but are not limited to, general room ventilation, chemical fume hoods, glove boxes, "elephant trunks" (or "snorkels"), flammable material storage equipment, ventilated balance enclosures, and downdraft tables. Note that elements of "Isolation" and "Segregation" accompany use of various engineering controls.

a. General Laboratory Ventilation

Laboratory spaces shall have mechanically generated and conditioned supply and exhaust air. All laboratories shall exhaust 100% to the outside. Air intakes for laboratory ventilation systems shall supply outside fresh air. General laboratory room ventilation should meet a minimum of 6 air change per hour (0.1 cfm of mechanical exhaust per cubic foot of laboratory gross room volume) whenever the laboratory is occupied. Laboratories should be kept at negative pressure to adjoining low-hazard non-laboratory space to prevent the spread of hazardous chemicals. In cases where 100% exhaust and/or negative pressure are not desirable, a formal evaluation **must** be made by EH&S to determine what work can be done in the space and under what special conditions or limitations. See the *UC Davis Campus Standards and Design Guide* for additional information on laboratory ventilation.

Note that environmental rooms, such as rooms kept at elevated or reduced temperatures (warm or cold rooms) typically use recirculated ventilation: review *SafetyNet #153: Environmental Rooms*. With isolated exceptions, hazardous chemicals should not be used in enclosed spaces that have recirculated ventilation, please contact *healthandsafety@ucdavis.edu* if you have any questions about the suitability of the space in which you would like to use hazardous chemicals for a site- and chemical-specific evaluation.

b. Fume Hoods

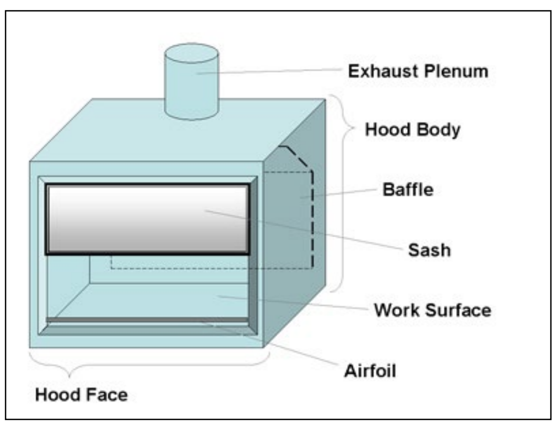


Figure V-III. Fume hood components

Chemical fume hoods are an effective way to control exposure to hazardous chemicals. Fume hoods are the most commonly used local exhaust system on campus. 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). The exhausts 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. **Figure V-III** displays the key components of a fume hood. It is important to note that the correct type of fume hood to be used is dependent upon the materials involved in the activities. A helpful *fume hood overview video* is available from Dow Chemical; and guidance for proper use of a fume hood can be found in *SafetyNet #35 – How to Use a Chemical Fume Hood Safely* and augmented with the *UC Davis Fume Hood Training Course*.

Chemical fume hoods should be used for the safe handling of noxious, corrosive, or volatile chemicals whenever possible. If these materials cannot be handled in a fume hood, and the potential for exposure to lab personnel is reasonably expected, *EH&S* should be contacted for a hazard evaluation. In addition, volatile/semi-volatile chemicals and *PHS*s should be handled under ventilation engineering controls (e.g., fume hoods). Note that a fume hood should not be used as a substitute for a biosafety cabinet or a laminar flow hood.

Routine maintenance and repairs of fume hoods are conducted by Facilities Management (*FM*) (Davis campus) or Plant Operations and Maintenance (*PO&M*) (Sacramento campus). If any problem with a chemical fume hood occurs, discontinue use of the fume hood and **immediately** call FM at (530) 752-1655 on the Davis campus or PO&M at (916) 734-2763 on the Sacramento campus to arrange for repairs. Make sure to indicate the urgency of the matter and indicate a health and safety deficiency.

General Rules for Fume Hood Use

The following general rules should be followed when using laboratory 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, or six months if using one of the carcinogens listed in *8 CCR §5209*.
2. Before beginning work in a fume hood check the fume hood flow indicator to verify proper air flow and make sure the audio alarm has not been disabled.
3. Always keep hazardous chemicals more than six inches behind the plane of the sash, see *Protective Air Barrier*.
4. **Never** put your head inside an operating laboratory hood. The plane of the sash is the barrier between contaminated and uncontaminated air. Keep the sash clean so your vision is unobstructed.
5. Work with the hood sash in the **designated operating height range.** The maximum operating sash height for vertical sash hoods should be clearly marked. Contact FM or PO&M there is no sash height indicated on your fume hood. The sash also acts as a physical barrier in the event of an accident.
6. 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. Clutter inside the hood may disrupt air flow and thus reduce capture efficiency.
7. Do not make any modifications to hoods, duct work, or the exhaust system without first contacting EH&S at **(530) 752-1493**.
8. 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.
9. Avoid sudden movements while working in the fume hoods. Such movements can create turbulence which may disrupt air currents and pull vapors out of the fume hood.
10. For energy efficiency, make sure to shut your sash when the hood is not in use.

The use of perchloric or hydrofluoric acids in chemical fume hoods necessitates additional considerations. Perchloric acid when heated above ambient temperature can form potentially explosive perchlorate salts in the fume hood and its associated duct system and hood fan. Perchloric acid can also form explosive mixtures with organic compounds. Hydrofluoric acid can dissolve glass and is very corrosive to many metals. For these reasons, the use of perchloric and hydrofluoric acids in fume hoods must be carefully evaluated prior to use, contact EH&S at (530) 752-1493 or *chem-safety@ucdavis.edu* for more information. Additional information can be found in *SafetyNet #18 - Safe Use of Perchloric Acid* and *SafetyNet #70 - Safe Use of Hydrofluoric Acid*.

At least once per year, all fume hoods are evaluated and certified by *FM* or *PO&M*, as outlined in **Table V-I**. Fume hoods used for the carcinogens listed in *8 CCR §5209* are evaluated semi-annually. These evaluations verify the proper fume hood air flow velocity to ensure that the unit will operate as designed. Data on fume hood monitoring is maintained by FM/PO&M.

Each chemical fume hood should have a current calibration sticker and a marker indicating the highest sash height to be used when working with hazardous materials. All chemical fume hoods must also have an audible and visual alarm to show proper operation. The average face velocity should not exceed 120 fpm. Fume hood users should be familiar with the requirements for safe fume hood operation, outlined in **Table V-I**, and contact *FM* or *PO&M* for a hood evaluation if any aspect of the fume hood is not working correctly.

Table V-I. Fume hood inspections

Fume Hood Performance Inspections (FM/PO&M Personnel)	Physical Inspections (Laboratory Personnel)
Evaluate the overall hood performance to ensure that it is functioning properly. This involves checking the: • Average face velocity and minimum face velocity, which is used to determine the rating of the hood and what the hood can be used for. • Noise generated by the fume hood, to ensure that it is below 85 dB. • If fume hood does not pass inspection, it will be labeled with a "DO NOT USE" sign until it can be repaired.	Evaluate the physical condition of the hood and the materials being used in the hood. This includes checking for: • Improper storage of materials inside the fume hood. • Use of proper materials. • General hood cleanliness. • Physical damage to the fume hood (e.g., broken sash). • Fully functioning lighting, fume hood indicator, airflow monitor, and alarm.

Laboratory fume hoods are vital pieces of equipment for protecting personnel from exposure to hazardous chemicals. Chemical fume hoods must be inspected upon installation, renovation, when a deficiency is reported, or a change has been made to the operating characteristics of the hood. Please contact *chem-safety@ucdavis.edu* if you have any questions on ventilation controls for the chemicals needed in your research.

c. Glove Boxes and Ventilated Containment Devices

In addition to chemical fume hoods, some laboratories use contained glove boxes (dry boxes) or other ventilated containment units for working with reactive chemicals under an inert atmosphere, working with very toxic substances in a completely closed system, or for creating a stable, draft-free, system for weighing hazardous or reactive materials. These units can be very effective because they offer complete containment. Personnel **must** be trained in the proper use of this equipment, and the training must be documented.

d. 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 refrigerator or freezer reduced-temperature storage, flammable and explosive materials must be kept in units specifically designed and rated for storing these respective materials. It is common for laboratories to use a "lab-safe" refrigerator approved for the safe storage of flammable chemicals. These units should be visibly labeled with a rating from Underwriters Laboratory or other certifying organization. Lab-safe refrigerators do not contain internal electrical components that could spark and trigger an ignition, and the cooling elements are external to the unit. While lab-safe refrigerators can safely store chemicals which may emit flammable vapors, these refrigerators should not be used in locations that contain explosive vapors. If you need a refrigerator or freezer for chemical storage in a location with explosive vapors, contact EH&S for assistance with an explosion-proof refrigerator. See *SafetyNet#523 - Flammable Liquid Storage* for additional information.

In addition to chemical-focused engineering controls in the laboratory, there are other mechanical and electrical devices that may find application in laboratory settings. Analytical tools/instrumentation, process equipment, and power tools may include machine guarding, interlocks, Emergency Power Off (EPO) buttons, dust collection systems, and barriers. Modern equipment is far more likely to come equipped with these engineering controls. If you have older equipment in your laboratory that may lack some of these safeguards, please contact *healthandsafety@ucdavis.edu* for an assessment and consultation.

1. Biological Safety Cabinets

Biological Safety Cabinets (BSCs or biosafety cabinets) are primary containment devices used in laboratories for working safely with biohazardous agents. There are three classes of biosafety cabinets: Classes I, II, and III, each with different performance characteristics and applications. The most commonly used BSCs at UC Davis are Class II BSCs.

Class II BSCs provide protection for the user, biological agents used, and the environment. Class II BSCs use High Efficiency Particulate Air (HEPA) filters to control airborne particles and may be ventilated into the room or ducted out of the building.

Class II BSCs must be tested and certified to meet NSF/ANSI Standard 49 specifications when first installed on an annual basis, and whenever they are moved. Purchase and placement of BSCs within the laboratory must be approved by EH&S. Contact *biosafety@ucdavis.edu* for additional information.

2. Laminar Flow Benches

Laminar flow benches ("clean benches") provide a high quality, clean work surface and environment for manipulation of materials. There are three types of laminar flow benches:

a. **Forward flow** (towards the operator): The operator sits directly downstream from the clean bench airflow. This type of clean bench must **never** be used for handling toxic, infectious, or sensitizing materials. Only handling of **non-hazardous** materials is allowed in this type of laminar flow bench. While it is understood that ethanol solutions are typically used with such equipment, note that this puts the operator at an increased risk of injury should a fire ignite where the flames may be blown towards the operator.
b. **Vertical flow** (top to bottom): These benches are designed to protect samples and processes from contamination where operator protection is not required. Only handling of **non-hazardous** materials is allowed in this work setting.
c. **Reverse flow** (away from operator): The operator sits upstream of the clean bench airflow - the airstream blows away from the operator. These benches provide effective laboratory protection for a variety of low to moderate hazard materials - aqueous liquids, small quantities of volatile materials, etc. One common application for reverse flow laminar benches is for chemical weighing/dispensing of solid materials.

It is important to note that laminar flow benches are not the same as downdraft tables, which find application in anatomy and engineering laboratories. Also, a laminar flow bench is NOT a biosafety cabinet, and some models may recirculate the airstream back into the general laboratory space following filtration. For additional information on the correct application of laminar flow benches contact *EH&S*.

2. Administrative Controls

Administrative controls consist of policies and procedures to reduce or prevent exposures to laboratory hazards. These controls are generally not 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. Note that elements of "Isolation" and "Segregation" may be contained in an administrative control.

a. Prior Approval

Several committees and programs at UC Davis are tasked with reviewing research protocols and/or approving/monitoring the use of hazardous materials. These committees or programs are as follows:

i. Chemical and Laboratory Safety Committee (*CLSC*)
ii. *Controlled Substances Program*
iii. Institutional Animal Care and Use Committee (*IACUC*)
iv. Institutional Biosafety Committee (*IBC*)
v. Institutional Review Board (*IRB*)
vi. *Radiological Safety*
vii. *Select Toxin Registration*

In addition to the identified committees and programs with their respective emphasis, the campus Chemical Hygiene Officer is available to work with investigators prior to beginning laboratory operations that involve any of the following:

i. Working with potentially explosive chemicals, extremely reactive chemicals, acutely toxic chemicals, or large quantities of material that could potentially be released to the environment.
ii. When it is likely that a Cal/OSHA Action Level or *Permissible Exposure Limit* (see *Chapter V*) could be exceeded.

Contact *chem-safety@ucdavis.edu* to request an evaluation.

Finally, the PI/Laboratory Supervisor is strongly encouraged to establish rules for the following activities and chemical usage in their laboratory operations that involve an increased level of risk:

i. Working alone in the laboratory. The *CLSC* has formalized the requirement that a *Working Alone SOP* is required for all laboratories. The Working Alone SOP is a laboratory-specific SOP that defines laboratory activities that may not be undertaken while alone in the laboratory.
ii. Unattended laboratory operations.
iii. Modifying a procedure in such a manner that the overall hazard is increased substantially. One such example is the scale-up of a reaction. The capability of the existing protective mechanisms to accommodate the changes in the thermodynamics of the chemical system must be considered. It is strongly recommended that the PI/Laboratory Supervisor establish upper limits for quantities of material use and require prior approval for work when these limits need to be exceeded.

b. Standard Operating Procedures

While general guidance regarding laboratory work with chemicals is contained in this Chemical Hygiene Plan, PIs/Laboratory Supervisors are required to develop and implement laboratory-specific SOPs for hazardous chemicals, including *PHS*, that are used in their laboratories. SOPs identify safety precautions and requirements specific to the hazardous chemicals and/or process. This is a Cal/OSHA requirement - *8 CCR §5191*, subpart (e)(3)(A). Development and implementation of laboratory-specific SOPs is a core component of promoting a strong safety culture at UC Davis and helping to promote a safe work environment. The campus CHO, *chem-safety@ucdavis.edu*, and Department Safety Coordinators (*DSCs)* are available to assist PIs/Laboratory Supervisors with the development of SOPs.

Several SOP templates have been prepared under the direction of the CLSC and are available on the *Safety Services website*. Baseline campus requirement and recommendation expectations reviewed and endorsed by the CLSC are outlined in Table 1 of the *SOP guidance document.* The guidance document also provides additional information to help define and identify applicable materials. Laboratory-specific SOPs must be prepared in writing by personnel who are most knowledgeable about the experimental process and approved by PI/Laboratory Supervisor prior to starting work. Laboratory personnel must be trained on all SOPs for the hazardous chemicals they will be using and shall be trained on emergency procedures for all chemicals contained in the laboratory. Laboratory-specific SOPs should be developed on a case-by-case basis for hazardous procedures unique to the laboratory. For certain hazardous chemicals, *PHS*, or specialized practices, consideration must be given to whether additional consultation with safety professionals is warranted or required.

> The UC Davis SOP library aims to cover the most common hazards encountered in a lab. **Your lab may need additional SOPs to ensure that procedures for the safe handling, storage, and disposal of laboratory-specific hazardous chemicals are covered, as required by Cal/OSHA.** A generic *SOP template* is available for those hazardous materials in your lab that may not have an SOP template in the SOP library.

The PI/Laboratory Supervisor, or their qualified designee, must train all personnel responsible for performing the procedures detailed in the SOP, and must document training on the material. The trainer demonstrates the procedures/techniques described in the SOP, and then observes the trainees while they complete those procedures/techniques, demonstrating competence to perform the procedure/techniques.

Training must be clear and unambiguous: training records must state which SOP has been trained on, version number, and date of training. If a chemical is "in storage" in the lab, at least one person must be trained on the relevant SOP. Training on an SOP and demonstration of competence must be completed before the researcher begins working with that material, and every three years thereafter unless the SOP has been revised, as described below.

The *content and accuracy* of SOPs shall be reviewed, and revised as needed, when one of the following criteria is met:

i. Nature of the hazard changes (e.g., previously unknown hazard is identified, use of vacuum or pressure, increased/decreased temperature, etc.).
ii. Chemical changes (e.g., quantity increase or scale-up, increase in concentration, new chemical supplier, etc.).
iii. Equipment changes.
iv. An unexpected outcome occurs (e.g., unanticipated rise or fall in temperature, increased gas production, unexpected color change or phase separation, etc.).
v. At a minimum, every three years.

PI/Laboratory Supervisor review and re-approval is required following any SOP revision. Laboratory personnel must be trained on any SOP revisions, and documentation of the training must be maintained. Once laboratory personnel have been trained on the content of an SOP, they may prepare an Executive Summary document for quick reference. The PI/Laboratory Supervisor must approve an Executive Summary to ensure that it accurately reflects the expectations for safe handling, storage, and disposal of the hazardous chemicals in the SOP. Such an Executive Summary **may not** be used for training, as training must be completed on the entire content of the SOP.

Circumstances requiring prior approval from the PI/Laboratory Supervisor or designee must also be stated 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, but are not limited to, 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., pyrophoric or water reactive chemicals), reaction scale-up, or the use of carcinogens.

When preparing an SOP, consider the type and quantity of the chemical being used, along with the frequency and manner of use. The *SDS* for each hazardous chemical should be referenced during SOP development. The SDS lists important information, such as hazard warnings, chemical/physical properties, type of toxicity, symptoms of exposure, and exposure limits. If a novel chemical will be produced during the experiment, an SDS will not 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. In most every instance of SOP preparation (and revision) a risk assessment for the materials and manner of use is of great value. The ACS has provided a *short video that describes the risk assessment process and value*; use of risk assessments for laboratory activity planning and SOP preparation is strongly encouraged. If you have questions or would like assistance in completing a risk assessment for your laboratory activities contact *researchsafety@ucdavis.edu* for assistance.

SOPs should be maintained as hardcopy and/or electronic format in such a way as to be readily available to laboratory personnel. The SOP storage location and organizational structure is at the discretion of each PI/Laboratory Supervisor. Additional guidance on writing SOPs is available on the *EH&S website*.

Several control-banded *SOP templates* are currently available, and the CLSC and EH&S are developing tools and resources to further assist with the SOP development process. Details are available at *EH&S Chemical and Laboratory Safety*, and additional information can be obtained from *chem-safety@ucdavis.edu*.

3. Protective Apparel and Equipment

a. Personal Protective Equipment

Personal protective equipment serves as a researcher's last line of defense against chemical exposures. Specific minimum requirements for PPE use during operations involving chemicals are contained in *Protective Clothing and Equipment* (*PPM 290-50*).

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

- Closed-toe/closed-heel shoes and full-length pants, or equivalent (i.e., no exposed skin from waist to toes).
- Protective gloves, laboratory coats, and eye protection when working with, or adjacent to, hazardous chemicals.
- Flame resistant laboratory coats for pyrophoric and high-hazard flammable materials use. For more information, see *PPM 290-50*.

The CLSC has approved a *PPE Selection Guide* to assist in selecting the appropriate equipment for work activities and hazards.

Additionally, it is **strongly recommended** that safety eye protection be worn in the laboratory at all times. Several videos from UCSD highlight the *importance of vision protection*, the dynamic character of the *splash zone in a laboratory*, and a *reminder of the benefits of PPE*. **Figure V-IV** provides some examples of eye and face protection. *SafetyNet #5 – Eye and Face Safety Protection for Laboratory Workers* provides additional guidance on selecting and using eye and face protection.

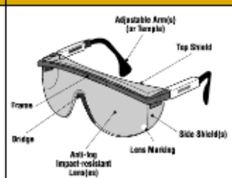
PPE	Specific Type (example)	Characteristics	Applications
Safety glasses		Polycarbonate lens, side shields for eye protection. Personnel with corrective lenses will need prescription safety glasses or overglasses.	Working with chemical, biological, radiation, physical hazards.
Goggles		Protects eyes from impact, spray, paint, chemicals, flying, chips, dust particles, etc.	Working with chemical liquids with likely splash probability or high splash hazard.
Laser Eyewear		Appropriately shaded goggles: optical density based on beam parameters.	Working with Class 3 or Class 4 lasers, consult laser use authorization for specific applications.
Surgical / Procedure Mask		Protects nose and mouth from direct contact with biological and chemical fluids; prevent spread of aerosolized infectious biological agents.	Anatomical, surgical, medical, and clinical settings.
Face Shield		Impact and chemical resistant face shield, must be combined with safety glasses or goggles.	For use with potential chemical splash or projectiles, apparatus under pressure or vacuum, cryogenics handling.

Figure V-IV. Examples of eye and face protection

The primary goal of PPE is to reduce the risk associated with handling hazardous substances and performing hazardous activities. Be sure to select the PPE that is appropriate to the activity, including the type of lab coat worn. *SafetyNet #155 - Body Protection for Laboratory Workers*, as

well as the *PPE selection guide* can help determine the correct PPE. Additional, more protective PPE may be needed for certain activities and chemical hazards.
When selecting appropriate gloves consider the following:

A. Chemical(s) being used.
B. Anticipated chemical contact (e.g., immersion, incidental, etc.).
C. Manufacturer's permeation and degradation data.
D. Whether a combination of different gloves is needed.

Additional guidance is provided in *SafetyNet #50 – Guidelines for the Selection of Chemical-Resistant Gloves* which includes links to online glove permeation charts from glove manufacturers. An informative video on PPE is available from *UCSD.*

UC Davis policy (*PPM 290-50*) requires a hazard assessment be completed for all personnel prior to beginning work. This hazard analysis will help identify the minimum needed PPE and equipment needed. The online *Laboratory Hazard Assessment Tool* is available to assist with this analysis. Note that the LHAT may not address all the potential hazards within a laboratory. Additional resources to guide hazard assessment are available from the ACS, *Identifying and Evaluating Laboratory Hazards*; contact EH&S at (530) 752-1493 or *researchsafety@ucdavis.edu* for assistance.

b. How to Use and Maintain PPE

Personal protective equipment (PPE) should be kept in a dry, sanitary storage space where it will not become contaminated and where its shape and material integrity is protected. PPE 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 replaced and properly discarded as hazardous waste. See the *PPE FAQs* or email *chemsafety@ucdavis.edu* for additional questions or help related to PPE. PPE may be reassigned to other laboratory personnel provided that it fits appropriately and in good condition. A *lab coat fitting guide* is available on the EH&S website.

For additional requirements and information on selection of PPE, see *PPM 290-50*, and *SafetyNet #5 - Eye and Face Safety Protection for Laboratory Workers*.

c. 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, radiological, and biological hazards. However, under certain circumstances respiratory protection may be needed. Examples may include any of the following:

- An accidental spill such as:
  - chemical spill outside the fume hood.
  - spill of biohazardous material outside a biosafety cabinet.
- Performance of an operation involving hazardous materials that cannot be conducted under the fume hood or biosafety cabinet, particularly for extended periods.
- When weighing powdered chemicals or microbiological media outside a glove box or other protective enclosure.

- 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.

Detailed requirements related to respiratory protection are described on the *UC Davis Respiratory Protection Program website*, which includes information on how to obtain a respirator, requirements for voluntary use of N-95 disposable respirators, requirements for respirator training, medical surveillance, and fit testing. **Always** contact EH&S or your DSC before proceeding with the use of a respirator, even a disposable N-95 one. Voluntary use of an N-95 respirator is generally recommended for low levels of nuisance dusts: if the chemicals are hazardous, a respirator may be required. Disposable dust masks can be used for comfort around low-level nuisance dust, although users should be aware that they offer no quantifiable protection. Contact *EH&S* if you would like help evaluating a respiratory hazard and to identify the appropriate respiratory protection.

d. Safety Shields

Face shields protect the face, neck, and ears from splash or flying particles. They are worn over safety glasses or chemical splash goggles and should be worn when major splashing may occur.

Standing shields, affixed to the countertop and of good rigidity and strength, protect the face, neck, and upper torso from projectiles when over-pressurization or implosion may occur. These shields must meet the impact test criteria in the ANSI Z87.1 Eye and Face Protection Standard. Standing shields should be considered for the following:

i. Work with potentially explosive compounds.
ii. Systems under high or low pressure.
iii. Scaling up reactions.

4. Safe Laboratory Habits

As detailed above, a safety program must include policies and protective equipment to promote a safe working environment, but to truly achieve effectiveness, a number of fundamental elements must become an integral part of our safety culture. According to the American Chemical Society (ACS):

> *"To build a strong safety culture, all faculty, staff, and students need the skills to recognize hazards, to assess the level of risk of exposure to those hazards, to minimize the risk, and to be prepared to respond to laboratory emergencies."*

ACS has prepared a report on "*Creating Safety Cultures in Academic Institutions*" that has been endorsed by the *CLSC*. The CLSC highly recommends that all researchers review this report.

Some of the fundamental or operational elements of an effective safety program and safety culture are detailed below:

a. Personal Protective Equipment

- Wear closed-toe/closed-heel shoes and full-length pants, or equivalent, at all times when in the laboratory (i.e., no exposed skin from waist to toes).
- Perform hazard assessments to determine the necessary PPE.

- Use appropriate PPE while in the laboratory and while performing procedures that involve the use, movement, or disposal of hazardous chemicals or materials.
- Wear appropriate eye protection in the laboratory.
- Do not manipulate contact lenses while in the laboratory. If they are used, inform the PI/Laboratory Supervisor that they are being worn. Contact lens wearers should review the NIOSH publication *Contact Lens Use in a Chemical Environment* for more information.
- Long hair should be tied back or otherwise confined.
- Secure neckties or other articles of clothing or jewelry that might become entangled in equipment.
- Remove laboratory coats or gloves immediately on significant contamination, as well as before leaving the laboratory.
- Do not touch common surfaces (e.g., door handles, elevator buttons) or personal items (e.g., cell phones, keys) etc.) with a gloved hand.
- Do not reuse disposable gloves; they are a single-use item of PPE.

b. Chemical Handling

- Review the SDS to better understand the hazards of any new chemical to be handled and reexamine as needed.
- Properly label and store all chemicals.
- Deposit chemical waste in appropriately labeled receptacles and follow all other waste disposal procedures specified in the Chemical Hygiene Plan, *WASTe*, and SOPs.
- Do not dispose of any hazardous chemicals down the sink.
- Do not smell or taste chemicals.
- Never use mouth suction for pipetting or starting a siphon.
- 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. Minor chemical spill information is described in the *CHP* and also in *SafetyNet #13 - Guidelines for Chemical Spill Control*.

c. Equipment Storage and Handling

- Use the proper safety equipment for your activities, which may include a chemical fume hood, glove box, biosafety cabinet, shields, or other equipment.
- 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.
- Do not use uncertified fume hoods or glove boxes for hazardous chemical handling.
- Store laboratory glassware with care to avoid damage.
- Inspect all glassware and equipment prior to use; do not use damaged items.
- Use extra care with Dewar flasks and other evacuated glass apparatus; shield or wrap them to contain chemicals and fragments should implosion occur.

- Handle broken glass and sharps with caution and appropriate hand protection: properly dispose of these materials.
- Keep fume hood sash closed when you are not working in the fume hood.
- Avoid storing materials in fume hoods.
- Do not block vents or impede air flow.

d. Laboratory Operations

- Know the location of all exits for the laboratory and the building.
- Know the location and proper operation of eyewashes and/or safety showers (including activation and deactivation), and first-aid kits.
- Know where the fire extinguishers and alarm pull boxes are located and how they operate.
- Know the location of the nearest phone that can be used in an emergency. Critical phone numbers should be posted near the phone.
- Be prepared for laboratory accidents, chemical spills, and other emergency situations.
- Be prepared for seismic activity, including guidance provided in *SafetyNet #83 - Non-Structural Seismic Safety*.
- Know the potential hazards of the materials, facilities, and equipment with which you will work. If you are uncertain, ask your PI/Laboratory Supervisor or contact EH&S.
- Research staff and students should never work alone on procedures involving hazardous chemicals, biological agents, or other physical hazards unless the PI/Laboratory Supervisor has granted formal approval for the laboratory activities being performed and outlined restrictions in the *Working Alone SOP*.
- Follow electrical safety guidance as described in *SafetyNet#512 - Electrical Safety* and *PPM 290-85 Electrical Safety*.
- 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.
- Follow written protocols or instructions. Perform only authorized experiments. Do not create shortcuts to procedures.
- When using unfamiliar equipment complete a "dry run" of your experiment using a less hazardous chemical to familiarize yourself with the proper operation of the equipment and PPE.
- If cooling water is required for laboratory activities ensure that the chosen system is not single-pass, utilizing recirculating baths or other water-less alternatives (e.g., *Findenser™*), consistent with *UCOP Sustainability Policy*.
- Vacuum lines must be protected with traps to prevent vacuum system component contamination. Operations requiring a vacuum must use a trapping device to protect the vacuum source, personnel, and the environment. Do not allow water, solvents, or corrosive gases to be drawn into a building vacuum system. When the potential for such a problem exists, use a cold trap and/or protection (HEPA/hydrophobic) filter.
- If unattended operations are unavoidable and have been approved by the PI/Laboratory Supervisor, 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

(e.g., cooling water). Highly exothermic, potentially explosive reactions, or sudden polymerization reactions must never be left unattended.

- Notify other laboratory personnel when an explosion hazard is present or may be produced, through direct announcement and prominent warning signs.
- Be alert to unsafe conditions and ensure that the PI/Laboratory Supervisor is notified of such conditions, and they are corrected promptly.
- Do not move or disturb equipment in use without consent of the user.
- Do not engage in distracting behavior such as practical jokes in the laboratory. This type of conduct may confuse, startle, or distract another worker.
- Use of headphones in the laboratory, for non-research purposes, is strongly discouraged, some of the risks are highlighted in a *video from Cornell*. If headphones are used in the laboratory for non-research purposes leave one ear unobstructed to be able to hear any sounds and language of any emergency events.
- If personal electronic devices (e.g., laptop, cellular phone, MP3 player, etc.) are used in the laboratory, take precautions to prevent contamination with hazardous materials.
- Wash hands carefully before leaving the laboratory. Beware of contamination on clothing, doorknobs, doorframes, etc.
- Maintain good laboratory cleanliness, including:
    - Clean bench tops, work areas, and equipment regularly.
    - Prevent the accumulation of dirty glassware, unneeded samples/chemicals, and trash.
    - Keep aisles and areas around eyewashes and showers clear to allow for unobstructed exit and easy access to safety equipment in emergency situations.
    - Ensure all compressed gas cylinders are properly restrained.
    - Practice good refrigerator and freezer management by preventing overcrowding, using secondary containment, and completing periodic defrosting procedures.
- Follow guidance described in the *EH&S and Fire Prevention SafetyNets*.
- Immediately report all accidents, injuries, and near-misses, however small, to the PI/Laboratory Supervisor. Report any fires or the discharge of any fire extinguisher to the Fire Department, even if the fire is extinguished.

e. Food/Drink

- No eating, drinking, gum chewing, tobacco chewing, handling contact lenses, and the application of cosmetics (including lip balm) where biological hazards, radioactive materials, or hazardous chemicals will be stored or used. Food must not be kept in refrigerators or cold rooms used for hazardous chemicals or other hazardous materials. Refrigerators used for food and beverage storage shall not be located in the laboratory.

5. Guidance for Support Personnel Entering a Laboratory

a. Custodial Staff

- To aid proper recognition of laboratory hazards complete the *Lab Safety for Support Personnel* training before entering a laboratory environment.
- Rooms that have a Caution Sign or any other warning stickers on laboratory doors, may contain materials or equipment which, if used improperly, could cause harm.
- Any container (box, bottle, carton, etc.) that holds hazardous material should be clearly marked with an appropriate warning label. Do not touch, move, or handle containers of any chemicals or materials in a laboratory. If items need to be moved in order to perform your duties, have the PI/Laboratory Supervisor arrange for this to be completed or contact your immediate supervisor.
- If the contents of any laboratory container are spilled, **do not touch it or attempt to clean it up**. Evacuate the area, close the laboratory door as you leave, and contact your supervisor. Call **9-1-1** for assistance with cleanup or to report a chemical spill.
- Wear appropriate laboratory coat or work uniform and eye protection.
- Do not eat, drink, apply cosmetics, handle contact lenses, or take medications in a laboratory.
- Chemical bottles should not be disposed as regular trash unless they have been completely emptied, air dried, label defaced, and the cap removed. If in doubt about the containers, leave them in the laboratory.

b. Facilities Maintenance & Information Technology

- To aid proper recognition of laboratory hazards complete the *Lab Safety for Support Personnel* training before entering a laboratory environment.
- **Before** working in a laboratory or chemical fume hood, notify the PI/Laboratory Supervisor or laboratory personnel about the problem, the length of time anticipated to accomplish the corrective actions, and when the work will be performed. **Before** work starts, adequately notify lab personnel so equipment which could cause injury or be damaged is turned off or moved.
- The PI/Laboratory Supervisor is responsible for making sure your work area within the room is free from physical, chemical, and/or biological hazards. Your work area could include hoods, sinks, cabinets, benches, bench tops, floors, and/or equipment.
- Do not handle or move chemicals in the laboratory. If you need chemicals moved in order to perform your work, have the laboratory supervisor arrange for this to be done.
- Do not move or handle equipment in the laboratory. If your work requires you to move, remove, or replace a piece of equipment, have the PI/Laboratory Supervisor assure you that the equipment is free of any physical, chemical, and/or biological hazards.
- Do not eat, drink, apply cosmetics, handle contact lenses, or take medications in the laboratory.
- In situations where the hazard cannot be totally removed, specific work procedures will be developed in conjunction with the PI/Laboratory Supervisor and EH&S.
- If there is a chance your work could bring you in contact with chemical hazards (e.g., working on laboratory sinks, working in areas where there is a chance of chemical contamination) or when working in rooms where chemical experiments are taking

place, consult with the PI/Laboratory Supervisor on the appropriate coveralls and eyewear.

- If working on a hood, ask the room supervisor if the hood is used for perchloric acid or radioactive material. Contact EH&S before performing maintenance on any part of a perchloric acid or radioactive material fume hood system (including hood, base, duct, fan, and stack). Lubricate perchloric acid hood fans with fluorocarbon grease only.
- If you have any questions, contact the PI/Laboratory Supervisor first, your supervisor next, or EH&S.

VI. HAZARD ASSESSMENT AND CHEMICAL EXPOSURE MONITORING

A. Regulatory Overview

It is University policy to comply with all applicable health, safety, and environmental protection laws, regulations, and requirements. Under *Article 107 of Title 8* Cal/OSHA requires that all employers:

> *"Measure an employee's exposure to any substance regulated by a standard which requires monitoring if there is reason to believe that exposure levels for that substance exceed the action level (or in the absence of an action level, the exposure limit)."*

Repeated monitoring may be required if initial monitoring identifies employee exposure over the action level or exposure limit.

Cal/OSHA regulates Permissible Exposure Limits (*PELs*) for airborne contaminants to which *"nearly all workers may be exposed daily during a 40-hour workweek for a working lifetime (of 40 years) without adverse effect,"* based on an 8-hour Time-Weighted Average (TWA) exposure. Thus, an airborne contaminant's PEL is the maximum 8-hour TWA concentration permitted **without** the use of respiratory protection. Cal/OSHA has also defined Short Term Exposure Limits (*STELs*) as the maximum TWA exposure during any 15-minute period, provided the daily PEL and Ceiling (C) exposures are not exceeded at any time.

Cal/OSHA has listed established PELs, STELs and Ceiling exposures for chemical contaminants identified in *8 CCR §5155 (Airborne Contaminants) Table AC-1*. In the absence of a published Ceiling limit, Cal/OSHA requires employee exposure to concentrations above the PEL be controlled to prevent harmful effects. Further, Cal/OSHA has promulgated specific standards covering several regulated carcinogens, which may include an Action Level (*AL*), triggering medical surveillance requirements or the imposition of a specific Excursion Limit (such as for asbestos) with a unique measurement of the duration of an exposure.

B. Exposure Assessment Overview

All University employees require protection from exposure to hazardous chemicals above PELs, STELs, and Ceiling concentrations. Principal Investigators and supervisors are responsible for assessing hazards. For concerns of airborne chemical exposure, contact *EH&S* for consultation and further evaluation. Per Cal/OSHA, chemical exposure monitoring must be performed by or under the direction of a person competent in industrial hygiene. At UC Davis, EH&S provides this expertise and serves this role. Contact EH&S at *healthandsafety@ucdavis.edu* or (530) 752-1493 for general questions regarding exposure assessments.

Minimizing an exposure may be accomplished by elimination, substitution, or using a combination of engineering controls, administrative controls, and PPE, listed in order of priority. Assessing exposure to hazardous chemicals may be accomplished through a number of methods performed by EH&S, including employee interviews, evaluation of chemical properties, visual observation of chemical use, evaluation of engineering controls, use of direct-reading instrumentation, or the collection of analytical samples. An exposure assessment may be performed:

1. Based on chemical inventories, review of SOPs, types of engineering controls present, laboratory inspection results and/or review of hazard assessments.
2. If a user of a hazardous chemical has a concern or reason to believe an exposure is not minimized or eliminated through use of engineering controls or administrative practices and the potential for exposure exists. The user should inform their PI/Laboratory Supervisor, who will in turn contact EH&S to assess exposure potential.
3. Based on a suspected exposure incident following an Employer's First Report.
4. If a Cal/OSHA investigation determines the need for exposure monitoring.

Any serious injury or exposure, including a chemical splash should be immediately reported by **calling 9-1-1** and obtaining emergency medical treatment. Do not wait for an exposure assessment to be performed before seeking medical care. Be sure to have an SDS available to aid medical personnel in treatment.

1. Exposure Assessment Protocol

The EH&S Industrial Hygiene group conducts exposure assessments for members of the campus community. Per *8 CCR §340.1* employees have a right to observe testing, sampling, monitoring, or measuring of employee exposure. They are also allowed access to the records and reports related to the exposure assessment. Exposure assessments may be performed for hazardous chemicals, as well as for physical hazards including noise and heat stress to determine if exposures are within PELs or other appropriate exposure limits that are considered safe for routine occupational exposure. In summary, the general protocol in conducting an exposure assessment may include any of the following:

a. Employee interviews.
b. Visual walkthrough and observation of chemical usage and/or laboratory operations.
c. Evaluation of simultaneous exposure to multiple chemicals.
d. Evaluation of potential for absorption through the skin, mucus membranes or eyes.
e. Evaluating existing engineering and administrative controls, as well as PPE.
f. Measuring levels of hazardous substances using various methods.

If exposure monitoring determines an employee exposure to be over the Action Level (or the PEL) for a hazard for which Cal/OSHA has developed a specific standard (e.g., lead), the medical surveillance provisions of that standard shall be followed. It is the responsibility of the PI/Laboratory Supervisor to ensure that any necessary medical surveillance requirements are met. When necessary, EH&S will make recommendations regarding adjustments to engineering controls, administrative procedures, and/or PPE requirements to maintain exposure below any applicable PEL.

In assessing exposure to hazardous chemicals for which Cal/OSHA has not published a PEL, STEL or Ceiling exposure, EH&S may defer to the Threshold Limit Values (*TLVs*) established by the American Conference of Governmental Industrial Hygienists (*ACGIH*) or the Recommended Exposure Limits (*RELs*) established by *NIOSH*. OSHA has consolidated most of this information at *Permissible Exposure Limits – Annotated Tables.*

2. Notification

The Industrial Hygienist will promptly notify the employee and their PI/Laboratory Supervisor of the results in writing after the receipt of any monitoring results. The Industrial Hygienist will establish and maintain an accurate record of any measurements taken to monitor exposures for each employee. Records, including monitoring provided by qualified vendors, will be managed in accordance with *8 CCR §3204* "Access to Employee Exposure and Medical Records."

3. Exposure Assessment to Determine and Implement Controls

EH&S and Occupational Health Services will use any of the following criteria to determine required control measures to reduce employees' occupational exposure:

a. Verbal information obtained from employees regarding chemical usage.
b. Visual observations of chemical use or laboratory operations.
c. evaluation of existing engineering control measures, administrative practices, or PPE usage.
d. Recommendations expressed in Safety Data Sheets.
e. Regulatory requirements of Cal/OSHA.
f. Recommendations from professional industrial hygiene organizations.
g. Employee exposure monitoring results.
h. Medical evaluation, examination and/or surveillance findings.

Particular attention shall be given to the selection of safety control measures for chemicals that are known to be extremely hazardous. Per Cal/OSHA "Control of Harmful Exposure to Employees" (*8 CCR §5141*), the control of harmful exposures shall be prevented by implementation of control measures in the following order:

a. Elimination, whenever possible.
b. Substitution, whenever possible.
c. Engineering controls, whenever feasible.
d. Administrative controls whenever engineering controls are not feasible or do not achieve full compliance and administrative controls are practical.
e. Personal protective equipment, including respiratory protection:
    i. During the time period necessary to install or implement feasible engineering controls.
    ii. When engineering and administrative controls fail to achieve full compliance.
    iii. In emergencies.

a. Medical Evaluation

All employees, student workers, medical health services volunteers, or laboratory personnel who work with hazardous chemicals shall have an opportunity to receive a free medical evaluation, including supplemental examinations which the evaluating physician determines necessary, under the following circumstances:

1. Whenever an employee develops signs or symptoms possibly associated with a hazardous chemical to which an employee may have been exposed in a laboratory.
2. Whenever an uncontrolled event takes place in the work area such as a spill, leak, explosion, fire, etc., resulting in the likelihood of exposure to a hazardous chemical.
3. Upon reasonable request of the employee to discuss medical issues and health concerns regarding work-related exposure to hazardous chemicals.
4. When a measured exposure level requires medical evaluation in accordance with Cal/OSHA regulations.

All work-related medical evaluations and examinations will be performed under the direction of UC Davis campus Occupational Health Services or UC Davis Health (UCDH) Employee Health Services by licensed physicians or staff under the direct supervision of a licensed physician. Evaluations and examinations will be provided without cost to the employee, without loss of pay, and at a reasonable time and place.

Any laboratory employee or student who exhibits signs and symptoms of adverse health effects from work-related exposure to a hazardous chemicals should report to *Occupational Health Services* (Davis employees), *Student Health and Counseling Services* (Davis students), or *Employee Health Services* (Sacramento) immediately for a medical evaluation. Off-site employees should report to their nearest Emergency Room.

Refer to your Department's IIPP for procedures on how to obtain medical evaluation under the above-listed circumstances. Please contact *iipp@ucdavis.edu* with any questions.

b. Information to Provide to the Clinician

At the time of the medical evaluation, the following information should be provided to Health Services:

1. Personal information such as age, weight, and University employee ID number.
2. Common, trade, and/or International Union of Pure and Applied Chemistry (IUPAC) name of the hazardous chemicals to which the individual may have been exposed.
3. A description of the conditions under which the exposure occurred.
4. Quantitative exposure data, if available.
5. A description of the signs and symptoms of exposure that the employee is experiencing, if any.
6. A copy of the SDS of the hazardous chemical or material in question.
7. History of exposure including previous employment and non-occupational (recreational) hobbies.
8. Any additional information helpful to Health Services in assessing or treating an exposure or injury such as a biological component of exposure or existence of an antitoxin.

It is *strongly recommended* to bring a copy of the SDS of the hazardous chemical or material in question to any medical evaluation.

c. Physician's Written Opinion

For evaluation or examinations required by Cal/OSHA, the employer shall receive a written opinion from the examining physician which shall include the following:

1. Recommendation for further medical follow-up.
2. Results of the medical examination and any associated tests, if requested by the employee.
3. Any medical condition which may be revealed in the course of the examination which may place the employee at increased risk as a result of exposure to a hazardous chemical found in the workplace.
4. A statement that the employee has been informed by the physician of the results of the consultation or medical examination and any medical condition that may require further examination or treatment.

d. Confidentiality & Individual's Access to Personal Medical Records

All patient medical information is protected by California and Federal Law and is considered strictly confidential. Health Services, both campus and UCDH, are prohibited from disclosing any patient medical information that is not directly related to the work-related exposure under evaluation and should not reveal any diagnosis unrelated to exposure. Any patient information disclosed by Health Services to the employee's supervisor will be limited to information necessary in assessing an employee's return to work, including recommended restrictions in work activities, if any. Any patient information disclosed by Health Services to EH&S will be limited to information necessary to develop a course of exposure monitoring, or perform hazard assessments and incident investigations, if appropriate. Health Services will otherwise disclose patient medical information only as required by California and Federal law, such as for Worker's Compensation Insurance claims. Each employee has the right to access his/her own personal medical and exposure records. Health Services will provide an employee with a copy of his/her medical records upon written request.

e. Medical Surveillance

Medical surveillance is the process of using medical examinations, questionnaires and/or biological monitoring to determine potential changes in health as a result of exposure to a hazardous chemical or other hazards. Certain Cal/OSHA standards require clinical examination as part of medical surveillance when exposure monitoring exceeds an established AL or PEL.

Health Services and/or outside vendors may provide medical surveillance services. Medical surveillance is required of employees who are routinely exposed to certain hazards as part of their job description (such as asbestos) and may be offered to other employees based upon quantifiable or measured exposure. See **Table VI-I** for some common examples of hazards monitored through the medical surveillance program.

Table VI-I. Examples of hazards monitored through the medical surveillance program

• Asbestos • Beryllium • Bloodborne pathogens • *Crystalline Silica* • Formaldehyde • Lead	• Dichloromethane • Noise (*Hearing Conservation Program*) • Radioactive Materials (*Bioassay Program*) • Respirator Use (*Respiratory Protection Program*) • Other Particularly Hazardous Substances

Individuals with questions regarding work-related medical surveillance are encouraged to contact campus *Occupational Health Services* (Davis) at (530) 752-6051, *Employee Health Services* (Sacramento) at (916) 734-3572, or *EH&S* at (530) 752-1493 for more information.

f. Record Keeping

UC Davis Health Services maintains records for each employee included in the medical surveillance program. These records include any measurements taken to monitor employee exposures and any medical consultation and examinations including tests or written opinions.

Employee exposure monitoring records are maintained by EH&S. Exposure records include environmental monitoring and related collection and analytical methodologies, calculations, and other background data relevant to interpretation of the results, biological monitoring results, and specific Safety Data Sheets.

The UC Davis Health Services will maintain medical records for each employee in strict confidence. Medical records of employees who have worked for less than one year for the University need not be retained beyond the term of employment if they are provided to the employee upon termination of employment.

VII. INVENTORY, LABELING, STORAGE, AND TRANSPORT

A. Regulatory Requirements

The necessary work practices, procedures, and policies outlined in this chapter are required by the following:

- *8 CCR §5154.1*, "Ventilation Requirements for Laboratory-Type Hood Operations"
- *8 CCR §5164*, "Storage of Hazardous Materials"
- *8 CCR §5191*, "Occupational Exposures to Hazardous Chemicals in Laboratories"
- *8 CCR §5194*, "Hazard Communication"
- *8 CCR §5209*, "Carcinogens"

B. Chemical Inventories

Each PI/Laboratory Supervisor is required to maintain a current comprehensive chemical inventory, through the chemical inventory system (*RSS Chemicals*), which lists the hazardous chemicals and compressed gases used and stored in the labs and the quantity of these chemicals. This information is managed and reported to meet obligations under the Emergency Planning and Community Right-to-Know Act (EPCRA) that is managed in California by the Certified Unified Program Agencies (*CUPA*). This inventory needs to be updated:

1. At least annually.
2. Whenever new chemicals are introduced into the laboratory.
3. Whenever a chemical is completely removed from the laboratory.

The chemical inventory is used to aid compliance with storage limits, reporting requirements, fire and life safety regulations, and may be used in emergency situations to identify potential hazards to emergency response personnel. Additionally, an accurate chemical inventory aids the operational and financial management of laboratory activities. Active chemical inventory management can also deter chemical diversion, and quickly identify instances where diversion may have occurred. Given the multitude of advantages afforded by an accurate and current chemical inventory, efforts should be taken to actively manage the laboratory's chemical inventory through RSS Chemicals.

Management of the laboratory chemical inventory should include the following aspects:

1. Chemical inventory reviewed prior to chemical procurement.

2. Chemical purchases target the minimum quantities necessary for the research, and never exceed quantities that can be consumed within one year.
3. When new chemicals are added to the laboratory, each laboratory group must confirm they have access to the SDS for that chemical, and update their *RSS Chemicals* information to reflect the addition of the chemicals to the laboratory.
4. Each chemical container is dated upon receipt so expired chemicals can be easily identified for disposal.
5. Unneeded chemicals should be culled from the inventory and properly disposed to reduce laboratory risk from storage of hazardous materials.
6. Chemicals beyond their expiration dates should be removed via proper disposal (See *Chapter IX*).
7. Prompt chemical disposal of any visible evidence of chemical or container degradation including:
    - Cloudiness in liquids
    - Color change
    - Evidence of liquids in solids, or solids in liquids
    - "Pooling" of material around outside of containers
    - Pressure build-up within containers
    - Obvious deterioration of containers (e.g., corrosion, cracked lids, etc)
8. Chemical quantities are updated frequently, especially after large changes.
9. Chemicals are returned to their designated storage area when not in use.
10. Chemical storage locations are inspected regularly.

Access to hazardous chemicals, including toxic and corrosive substances, should be restricted at all times, as discussed in *SafetyNet #118 - Laboratory Security Tips for Hazardous Materials Users* and in *Chapter X*. 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 may be required in the case of acutely toxic or hazardous chemicals, tax-free alcohol (see *PPM 350-20*), *select toxins*, and *controlled substances*. Acutely toxic chemicals may include those associated with very low immediately dangerous to life or health (*IDLH*) conditions. For guidance on locked storage requirements, please contact EH&S at (530) 752-1493 or *chem-safety@ucdavis.edu*.

Additional information related to storage and management of laboratory chemicals is provided in *SafetyNet #42 – General Guidelines for Storage and Management of Laboratory Chemicals*, and guidance on the current *chemical inventory system* is available on the EHS website.

Lastly, on termination or transfer of laboratory personnel, all their related hazardous materials (including chemicals and samples) shall be properly disposed of, or transferred to, the PI/Laboratory Supervisor or a designee, with the chemical inventory updated appropriately.

C. Chemical Labeling

All chemicals found in the laboratory should be properly labeled. Hazardous chemicals, including dilute solutions, must be labeled properly including the associated hazards (consistent with *PPM 290-27*, *Appendix C*, and *SafetyNet #42 - General Guidelines for Storage and Management of Laboratory Chemicals*). It is ***strongly recommended*** that containers of non-hazardous material (such as water) also be labeled with the identity of the material following the guidance listed above. Commercial chemicals come with a manufacturer's label which contains the necessary information. Care should be taken to not damage or remove these labels. Commercial chemical labels should be augmented with the date of receipt and date of opening, to aid in determining if chemicals are expired and require disposal. When novel chemicals are synthesized, their containers must be labeled with the identification name, date, and hazard information; the generator or other party responsible for this chemical should be noted on the container so they may be contacted if questions arise about the contents. The Dow Chemical Company provides an excellent *video* highlighting the importance of chemical labeling for a safe working environment.

Additional guidance and resources on the labeling of chemical containers is provided in *Appendix C*.

In addition to the labeling requirements outlined in *Appendix C*, peroxide forming chemicals (e.g. ethers, alkenes, alkynes, etc.), see *SafetyNet #23 – Peroxide Formation in Ethers and Other Chemicals*, must also be labeled with:

A) Date of receipt, and
B) Date of opening.

An example label for this purpose is contained in *SafetyNet #23*.

These chemicals can degrade to form highly reactive compounds sensitive to shock, heat, and friction, and need to be stored and labeled very carefully. Chemicals which may form peroxides have varying shelf lives; consult *SafetyNet #23* for additional information on the types of chemicals of concern and their associated storage and disposal timelines.

PHSs have additional labeling requirements; consult *EH&S* for guidance. The storage area for these materials must be labeled with the appropriate hazard information. It is advised to store PHSs segregated from less hazardous chemicals to aid access restriction, inventory control, and hazard identification.

D. Chemical Storage & Segregation

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

Storage guidelines for flammable, oxidizing, corrosive, water reactive, explosive, and acutely toxic materials are described in the following materials. The manufacturers specific SDS should **always** be consulted when doubts arise concerning chemical properties, compatibilities, associated hazards, and storage recommendations. All storage procedures must comply with Cal/OSHA, California Fire Code, and California Building Code regulations. **Always** wear appropriate PPE (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. **Table VII-I** lists chemical safety storage priorities.

Table VII-I. Chemical safety storage priorities

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, 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 or refrigerator/freezer rated for the storage of flammable liquids.
2. **ISOLATE.** If the material will contribute significantly to a fire (e.g., oxidizers), it should be isolated from the flammables. Water-reactive material must be sufficiently segregated from flammable and combustible materials.
3. **CORROSIVITY.** Isolate acids from bases, and further segregate by organic vs. inorganic origin. Segregate oxidizing inorganic acids from flammable and combustible materials.
4. **SPECIAL HAZARD.** Be sure to consider chemicals requiring special handling and storage (e.g., air/water reactive, peroxide forming chemicals, reduced temperature storage, inert atmosphere storage, etc.).
5. **TOXICITY.** Finally, consider the toxicity of the material, with particular attention paid to regulated materials. In some cases, this may mean certain chemicals will be isolated within a storage area. For example, a material that is an extreme poison but is also flammable, should be secured in the flammable storage cabinet to protect it against accidental release.

There will always be some chemicals which 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. For instances where a chemical has multiple hazardous properties (e.g., corrosive and oxidizer) the initial assignment would be the hazard of greatest risk. When this assignment results in chemical incompatibility, the multiple-hazard chemical will require additional segregation within its assigned hazard class. Consult *SafetyNet#42* or *EH&S* for further information.

1. 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. These specific storage locations must be kept as part of the inventory in RSS Chemicals to ensure that chemicals can be easily located. Acceptable chemical storage locations may include corrosive cabinets, flammable storage cabinets, laboratory shelves/cabinets, and appropriate refrigerators or freezers, as discussed in *SafetyNet #42*. Fume hoods should not be used as general storage areas for chemicals, as this may seriously impair the ventilating capacity of the hood and its capture efficiency. **Figure VII-I** depicts improper fume hood

Figure VII-I. Improper fume hood chemical storage

storage. Chemicals should not be routinely stored on bench tops and should never be stored on the floor. Chemicals used in animal research should not be stored in the vivarium or procedural space locations, but rather returned to the laboratory for proper segregation and storage. Additionally, bulk quantities of chemicals (i.e., larger than 1 gallon) should be stored in a separate storage area, such as a stockroom or supply room.

Laboratory shelves used for chemical storage must have a raised lip along the outer edge or a railing to prevent containers from falling. Hazardous chemicals should not be stored above a height of 5 feet. Chemicals which are acutely toxic or corrosive must be stored below a height of 5 feet and shall be stored in chemically compatible and durable *secondary containment*.

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. Be sure to consider chemical compatibility before storing laboratory chemicals: guidance is provided in **Figure VII-II** and *Appendix F*.

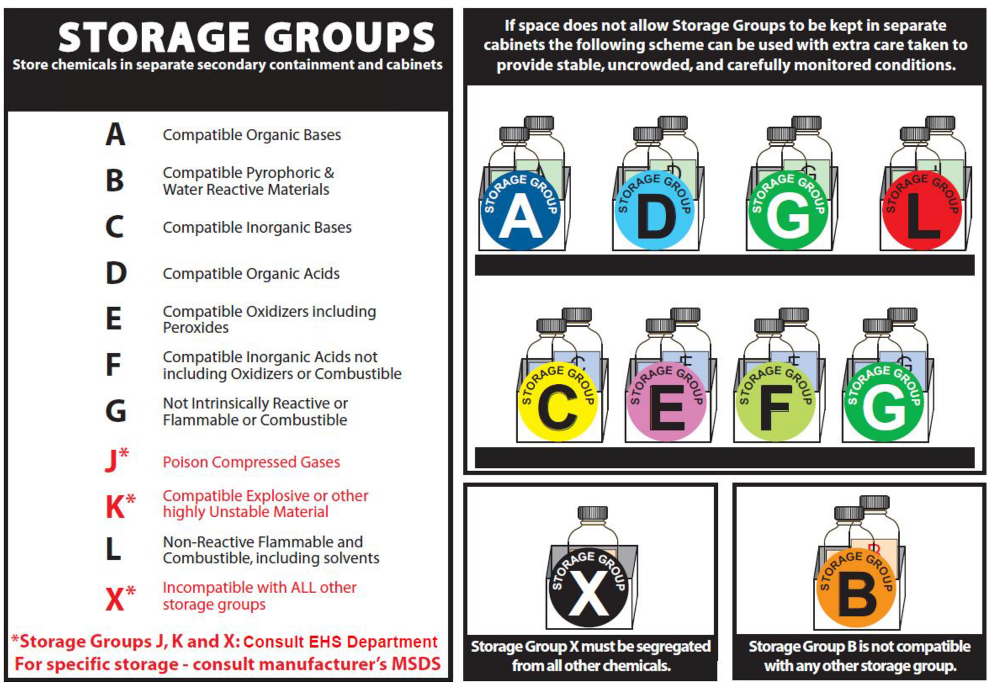


Figure VII-II. Chemical segregation guidance.[1]

Implementation of the storage approach shown in **Figure VI-II** is **strongly** recommended. Additional information to aid implementation of this segregation approach is available in *Prudent Practices in the Laboratory including classification group codes for some common laboratory chemicals*. 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. Note that Group X materials typically require special storage considerations and may not be appropriate to store as

[1] Provided with permission from Environmental Health and Safety, Stanford University, 2013

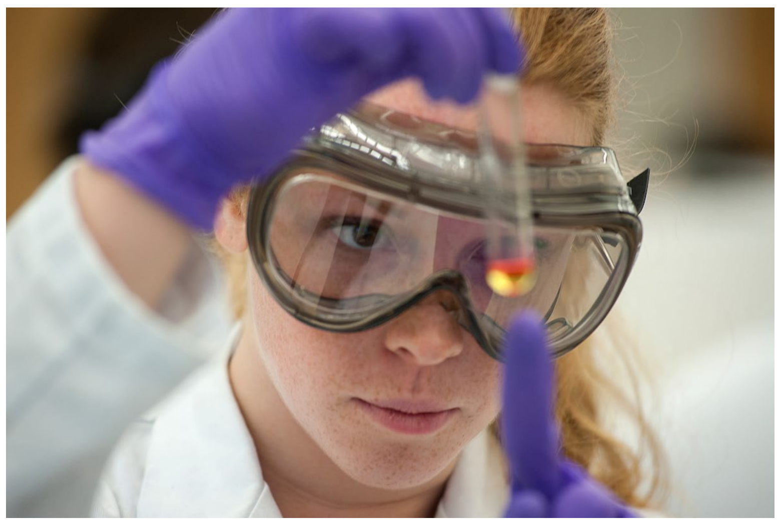
a collective group. Please contact *EH&S* for assistance with appropriate storage guidance of these materials.

All chemical containers and research samples must be appropriately labeled and tightly capped to prevent vapor interactions and to alleviate nuisance odors. Flasks with 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 consumables or dry ice. Freezers should be defrosted periodically so chemicals do not become trapped in ice formations. Storage of peroxide formers (e.g., ether) in a refrigerator is not recommended.

2. Flammable and Combustible Liquids

Large quantities of *flammable* or *combustible* materials should not be stored in the laboratory. No more than **10 gallons** of flammable or combustible liquids, *including* flammable/combustible hazardous waste, are allowed to be kept outside a flammable storage cabinet, safety can, or approved refrigerator/freezer. The maximum total quantity of *Class 1A flammable liquids* must not exceed **60 gallons** within a flammable storage cabinet. The total volume of flammable and combustible liquids must not exceed 120 gallons per cabinet. 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.



Always segregate flammable or combustible liquids from oxidizers, including oxidizing acids (e.g., nitric, perchloric, chromic, sulfuric). Only the amount of material required for the experiment or procedure should be stored in the work area. Additional guidance on flammable/combustible liquid storage is available from the UC Davis *SafetyNet #523*.

Handle flammable and combustible materials only in areas free of ignition sources and use the chemical in a fume hood whenever possible. Ignition sources may include electrical equipment, open flames, static electricity, and hot surfaces. If heating of a flammable liquid is required, it should be limited to heating mantles, heating tapes, and water/oil/sand baths.

Always transfer flammable and combustible chemicals from glass containers to glassware or from glass container/glassware to plastic. If transferring flammable liquids between metal equipment, ensure that the containers are bonded together and connected to a common ground. When transferring or dispensing highly flammable liquids with the aid of a pump, the pump shall be constructed of metal rather than plastic due to better chemical resistivity and the ability to bond the pump/bulk container to the receiving container. Do not pour directly from metal drum into receiving flask. Failure to follow these guidelines for flammable liquid transfer may present an increased fire hazard due to static electricity. The transfer of flammable liquid from 5 gallon or larger metal containers should **not** be performed in the laboratory. Flammable and combustible liquids may be stored in safety cans, less than 2 gallons in volume. Contact *fireprevention@ucdavis.edu* for more guidance regarding bonding and grounding.

3. Pyrophoric & Water-Reactive Materials

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 of these chemicals are also toxic, and many are dissolved or immersed in a flammable solvent. Other common hazards include corrosivity, teratogenicity, or peroxide formation. Some examples of pyrophoric and water-reactive materials are listed in **Table VII-II**. **All** users of pyrophoric and water-reactive materials at UC Davis must know and follow the guidance provided in *SafetyNet #135 - Procedures for Safe Use of Pyrophoric/Water-Reactive Reagents*. An appropriate quenching method must be defined prior to starting work and outlined in the required *Pyrophorics SOP*. The use of these materials is never allowed when alone in the laboratory.

Table VII-II. Examples of pyrophoric and water-reactive chemicals

Chemical Type	Example(s)	Chemical Type	Example(s)
Grignard Reagents	RMgX (R=alkyl, X=halogen)	**Non-metal hydrides**	R_3B, R_3P, R_3As
Metal alkyls/aryls	Alkyl lithium, tert-butyl lithium	**Group I (alkali) metals**	Lithium, potassium, sodium
Metal carbonyls	Lithium carbonyl, nickel tetracarbonyl	**Gases**	Silane, dichlorosilane, diborane, phosphine, arsine
Metal powers (finely divided)	Cobalt, iron, zinc, zirconium	**Metal hydrides**	NaH, $LiAlH_4$

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

SDS, and compliant with *CCR Title 8* and the *California Fire Code.* Suitable storage locations may include inert gas-filled desiccators or glove boxes; however, some pyrophoric materials must be stored in a dedicated refrigerator or freezer rated for the storage of flammable liquids. It is further recommended that an inert gas-filled desiccator also be used in conjunction with reduced temperature storage. If pyrophoric or water reactive reagents are received in a specially designed shipping, storage or dispensing container (e.g. *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. Do not store reactive chemicals with flammable materials or in a flammable storage cabinet with other flammable liquids. A flammable storage cabinet may be used but it must be dedicated to storing pyrophoric or water-reactive materials only.

Storage of pyrophoric gases is described in the *California Fire Code, Chapter 64*. 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. Please contact *chem-safety@ucdavis.edu* for assistance with appropriate storage guidance of these materials.

Additional information on proper handling, disposal, safety equipment, emergency procedures, and excess chemical storage for these materials is contained in the *Pyrophorics SOP* and associated *pyrophoric flow spill chart*, *SafetyNet #135 - Procedures for Safe Use of Pyrophoric/Water-Reactive Reagents.* Incredibly helpful videos are available from the *Dow Chemical Company* and from UCSD on *preparation for pyrophoric reagents*, and *transfer of pyrophoric liquids*, and *working with reactive metals*.

4. Oxidizers

Oxidizers (e.g., hydrogen peroxide, halogens, potassium permanganate, ferric chloride, potassium dichromate, sodium nitrate, etc.) should be stored in a cool, dry place and kept away from flammable and combustible materials, such as wood, paper, Styrofoam, plastics, flammable organic chemicals, and away from reducing agents (e.g., zinc, alkaline metals, metal hydrides, formic acid).

5. Peroxide-Forming Chemicals

Ensure containers of peroxide-forming chemicals stored in an airtight container in a dark, cool, and dry place and segregated from other classes of chemicals (e.g., acids, bases, oxidizers) that could create a serious hazard to life or property should an accident occur. Ensure they are kept tightly sealed to avoid unnecessary evaporation, as this inhibits the stabilizers that are sometimes added. Visually inspect containers periodically to ensure they are free of exterior contamination or crystallization. Peroxide-forming chemicals must be disposed prior to expiration date or according to the guidelines in *SafetyNet #23*.

Each container of peroxide-forming chemicals must be dated with the <u>date received</u>; it is highly recommended to also include the date first opened. This information, along with the chemical identity should face forward to minimize container handling during inspection.

These chemicals should be periodically tested for the presence of peroxides and the results documented quarterly. Minimize the quantity of peroxide-forming chemicals stored in the laboratory and dispose peroxide-forming chemicals as prescribed in *SafetyNet #23*. Refer to *SafetyNet #23* for specific guidelines and/or contact *chem-safety@ucdavis.edu* with questions on peroxide forming chemicals or peroxide testing.

Keep an inventory of peroxide-forming chemicals for your workplace, and never purchase more quantity than can be consumed prior to the manufacturer's expiration date or the recommended disposal date outlined in *SafetyNet #23*.

6. Corrosives

Store *corrosive chemicals* (e.g., acids, bases) below a height of five feet and in *secondary containment* that is 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 <u>must</u> **always** be segregated:

- From bases and active metals (e.g., sodium, potassium, magnesium), and
- From chemicals which could generate toxic gases upon contact (e.g., sodium cyanide, iron sulfide, potassium ferricyanide).

Specific types of acids require additional segregation:

- Mineral acids <u>must</u> be kept away from organic acids, and
- Oxidizing acids <u>must</u> be segregated from flammable and combustible materials.

Pressure-relief or vented caps must be used on containers for waste streams of oxidizing inorganic acids or pressure generating materials (e.g., piranha, aqua regia). See *storage of hazardous wastes* for further hazardous waste storage criteria. Additional guidance for handling and storage of nitric and perchloric acid is provided in *SafetyNet #14 - Safe Use of Nitric Acid* and *SafetyNet #18 - Safe Use of Perchloric Acid* respectively.

7. Acutely Toxic Chemicals

Acutely toxic chemicals should be stored based on their hazards and physical properties. Storage for acutely toxic solids and liquids includes secondary containment in a well-ventilated area. Containers should be closed with tape or other sealant. Storage areas for acutely toxic chemicals and their containers must be meticulously labeled. Acutely toxic chemicals shall be stored no higher than eye level (~5ft).

8. Special Storage Requirements

a. Compressed Gas Cylinders

Compressed gas cylinders must be secured to prevent tipping, falling, or rolling caused by contact, vibration, seismic activity, or transportation. Methods for properly storing and securing cylinders include:

- Store compressed gas cylinders with the safety cap in place.
- Segregate gas cylinders by hazard class.
- Secure cylinders upright with at least one, but preferably two, non-combustible restraints,

such as chains: one restraint should be placed at 1/3 from the top of the cylinder, and the other at 1/3 from the bottom of the cylinder (see **Figure VII-III**).

- Cylinders must be secured to:
  - a substantial fixed surface such as a wall or permanent bench,
  - a rack, rail framework, or similar assembly designed for such use, or
  - a bolted "clam shell" holder if the gas cylinder must be stored or used away from walls or racks.
- Nesting of cylinders is allowed if a minimum of 3-points of contact can be achieved.
- Secure cylinders on carts or other mobile devices designed for the movement of cylinders, when transporting cylinders.
- Drainage, overhead cover, and security from theft or vandalism are required for outdoor storage.

Do not expose cylinders to excessive dampness or temperatures >125 °F, nor corrosive chemicals or fumes. Certain gas cylinders and chemicals require additional precautions. Compressed oxygen gas cylinders must be stored at least 20 feet away from combustible materials and flammable gases, or separated by a non-combustible partition (contact *fireprevention@ucdavis.edu* for more information). Liquefied fuel gas cylinders must be stored securely in the upright position. Materials used to convey and dispense compressed gases (e.g., piping, tubing, valves, fittings, etc.) shall be constructed from compatible materials and designed to properly contain and deliver the specific gases for which they are used.

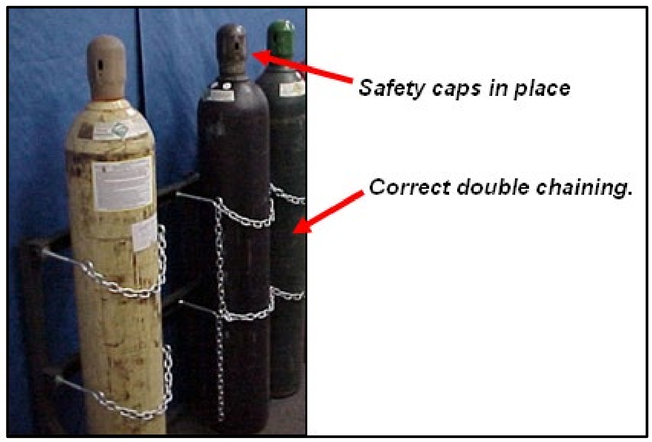


Figure VII-III. Proper compressed gas cylinder storage

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. Gas cylinders must be moved with the safety cap in place using carts designed for this purpose. Separate empty from full cylinders in storage areas and arrange full cylinders such that the oldest materials are utilized first. Refer to *SafetyNet #60 - Compressed Gas Safety*: a helpful video is also available from the *Dow Chemical Company*. **Toxic, corrosive, flammable, oxidizing, and pyrophoric gases have special handling and storage requirements.** Contact *Fire Prevention* and *chem-safety@ucdavis.edu* for additional information.

b. Cryogenic Liquids

Because cryogenic liquid (e.g., nitrogen, argon, helium, etc.) containers are at low pressure and have protective rings mounted around the regulator, they are not required to be affixed to a permanent fixture such as a wall. However, additional protection considerations should be addressed when storing cryogenic liquids in a laboratory. The primary risk to laboratory personnel from cryogenic liquids is skin or eye damage caused by contact with the material. Additionally, all cryogenic liquids have large expansion volumes, typically greater than 500:1 when transitioning from a cryogenic liquid to a room temperature gas. This volumetric increase can create high pressure hazards if confined to a closed system; pressure relief valves must **always** be functional and unobstructed. While the gases are usually not toxic, a significant risk of asphyxiation is a possibility due to oxygen displacement. Consult with *EH&S* prior to locating cryogenic liquids in confined spaces or areas without adequate ventilation.

Always use appropriate thermally insulated gloves when handling cryogenic liquids. Face shields may be needed in cases where splashing can occur. Refer to the UC Davis *SafetyNet #58 - Safety Precautions for Cryogenic Liquids* and the *cryogen safety video* from the Dow Chemical Company for further information. Training on *Cryogen Safety* is available through the LMS.

c. 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. Picric acid must be stored wet with at least 30% water, in a cool, dry, well-ventilated area, away from heat sources. Picric acid is considered a flammable solid when wet >30% water; recurring inspection and rehydration should be completed every six months to ensure it does not dry out to <10% water. When dehydrated, picric acid becomes unstable: it can be explosive and 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 six months. Add distilled water as needed to maintain a consistent liquid volume. See *SafetyNet #104 - Safe Use and Management of Picric Acid* for additional information.

E. On-Campus Transport of Hazardous Chemicals

Precautions must be taken when transporting hazardous materials between laboratories and buildings. Chemicals must be transported in durable, *secondary containment* 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. It is strongly recommended that hazardous materials, in quantities less than the *Department of Transportation Materials of Trade exception* limit, be transported in a university vehicle. Cryogens and/or simple asphyxiants must be secured during transport and should never be transported in the passenger compartment or the trunk of a vehicle. Never transport more than 1 liter of cryogenic material in an elevator (see *SafetyNet #58 - Safety Precautions for Cryogenic Materials*).

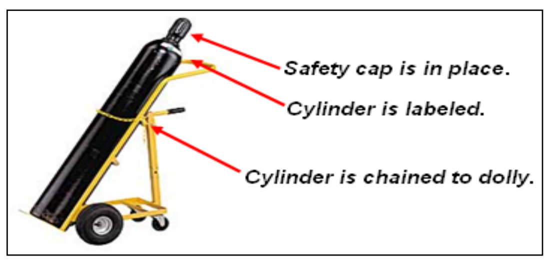


Figure VII-IV. Correct transport of compressed gas cylinder

When transporting cylinders of compressed gases, **always** secure the cylinder with straps or chains onto a suitable hand truck (dolly) and protect the valve with a safety cap. Avoid dragging, sliding, or rolling cylinders and use a freight elevator when possible. **Figure VII-IV** illustrates correct cylinder transport. **Never transport a cylinder with a regulator attached.** When transporting by vehicle, compressed gas cylinders must be secured upright.

Consult UC Davis *PPM 290-56 Chemical Safety* for more information on campus policy regarding chemical transportation. Additional guidance regarding the transportation of *hazardous material* or *biological samples* through public spaces is available on the Safety Services website.

Individuals who wish to use a university vehicle (strongly recommended) to transport hazardous chemicals, cryogens, or compressed gases on-campus must contact EH&S at (530) 752-1493 for assistance.

F. Off-Campus Shipment or Transport of Hazardous Chemicals

All off-campus shipping of hazardous materials must proceed through *AggieShip*. 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 limits, packaging, labeling, documentation, and hazard communication. **Without proper training, it is illegal to ship hazardous materials.** Those who violate the hazardous materials shipment regulations are subject to criminal investigation and penalties. UC Davis campus personnel who sign hazardous materials manifests, shipping papers, or those who package hazardous material for shipment, must be properly trained and certified. Contact *AggieShip* for more information regarding chemical transportation and shipping.

Researchers interested in shipping hazardous material outside the United States must also contact the Office Of Research *Export Controls in Research* to complete an export control check.

Individuals who wish to ship or transport hazardous chemicals or compressed gases off-campus, whether using a UC Davis (strongly recommended) or a personal vehicle, must contact EH&S at (530) 752-1493 or *hazshipping@ucdavis.edu* for assistance.

VIII. TRAINING

A. Regulatory Requirements

The necessary work practices, procedures, and policies outlined in this chapter are required by the following:

- *8 CCR §3380*, "Personal Protection Devices"
- *8 CCR §5191*, "Occupational Exposures to Hazardous Chemicals in Laboratories"
- *8 CCR §5194*, "Hazard Communication"
- *8 CCR §5209*, "Carcinogens"
- *19 CCR §2659*, "Training"

B. Introduction

Effective training is critical to facilitate a safe and healthy work environment and prevent laboratory accidents. All PIs/Laboratory Supervisors must participate in formal safety training and ensure that all their employees have appropriate safety training before working in a laboratory. Comprehensive resources are available on the *EH&S website.* A *training matrix* is available to help inform laboratory personnel about what training must be completed before starting work in a laboratory.

C. Types of Training

All laboratory personnel must complete the online *UC Laboratory Safety Fundamentals* training course before beginning work in a laboratory. Additionally, before being granted unescorted access to a laboratory, personnel must complete and document site-specific safety orientation and training. Guidance on materials that need to be covered in the site-specific safety orientation and training is provided in the *Site-Specific Safety Orientation & Training Checklist for New Laboratory Personnel*, which includes documentation of training on the campus CHP and any applicable *Laboratory Safety Plans*. Note: equivalent existing checklists and documentation are also acceptable.

Additional training may be needed when:

1. New hazards are introduced into the workplace.
2. New work activities/processes are to be implemented.
3. New equipment is introduced into the workplace.

EH&S offers *general classroom and online training*, plus resource materials to assist laboratories in implementing laboratory-specific training. Questions regarding laboratory safety training can be directed to *researchsafety@ucdavis.edu*.

1. UC Laboratory Safety Fundamentals Training

The *UC Laboratory Safety Fundamentals* training includes:

- Review of laboratory rules and regulations, including the Chemical Hygiene Plan and the "Laboratory Standard."
- Recognition of laboratory hazards.
- Use of engineering controls, administrative controls, and PPE to mitigate hazards.
- Exposure limits for hazardous chemicals.
- Signs and symptoms associated with exposures to hazardous chemicals.
- Chemical exposure monitoring.
- Review of reference materials (e.g., SDS) on hazards, handling, storage, and disposal of hazardous chemicals.
- Procedures for disposing of hazardous chemical waste.
- Fire safety and emergency procedures.
- Information required by *8 CCR §3204* regarding access to employee exposure and medical records.

All laboratory personnel must take and successfully complete the online *UC Laboratory Safety Fundamentals* online course prior to working in the laboratory and being granted unescorted access. *Refresher training* for "Fundamentals" is required every three years.

2. Laboratory-Specific Safety Orientation & Training

PIs/Laboratory Supervisors must also provide site-specific *safety orientation and training* before allowing unescorted access to the laboratory. The use of an existing equivalent checklist documenting training of these topics is also accepted. Topics that require specific training include:

- Location and use of the Chemical Hygiene Plan (CHP), Safety Data Sheets (SDSs) and other regulatory information (e.g., "Laboratory Standard" *8 CCR §5191*).
- Review of departmental Injury and Illness Prevention Plan (IIPP) and Emergency Action Plan (EAP), including location of emergency equipment and exit routes.
- Specialized equipment, including Engineering Controls.
- Administrative Controls, including Standard Operating Procedures (SOPs).
- Personal Protective Equipment (PPE).
- Chemical Spill Response (*see SafetyNet #13*).
- Specialized procedures and protocols.
- Particularly Hazardous Substances including physical and health hazards, potential exposure, medical surveillance, and emergency procedures.
- Methods and observations to detect chemical releases.
- Any applicable *Laboratory Safety Plans*.

General laboratory safety training requirements are summarized on the EH&S *Safety Training Matrix for Laboratory Personnel*. A complete list of available health and safety training is provided at the *Safety Services Training webpage*. This includes classroom, as well as online training.

D. Training Frequency

The following provides an outline of the expected general laboratory safety training and frequency intervals:

A. <u>Initial</u> (before beginning work in a laboratory):

i. UC Laboratory Safety Fundamentals
ii. Site-Specific Safety Orientation and Training (includes, IIPP, EAP, CHP, SOPs, Laboratory Safety Plan, etc.)
iii. Fume hood operation (included in Laboratory Safety Fundamentals) or biosafety cabinet operation (if necessary)
iv. LHAT – PPE Training
v. Lab-specific Chemical Spill Response (SafetyNet #13)
vi. Cryogen Safety (if necessary)

B. <u>Annual</u>:

i. IIPP, EAP, CHP updates, Laboratory Safety Plan if applicable
ii. Chemical Spill Response (SafetyNet#13)
iii. Lab-specific safety topics (e.g., laser, radiation, respiratory protection)

C. <u>Triennial</u>:

i. UC Laboratory Safety Fundamentals refresher
ii. SOPs (if no revision has triggered earlier training)

EH&S provides additional assistance in planning laboratory-specific training upon request.

E. Documentation of Training

Accurate recordkeeping is a critical component of health and safety training. Per OSHA regulations, departments or laboratories are responsible for documenting health and safety training, including safety meetings, one-on-one training, classroom, and online training. Documentation should be maintained with the CHP or be otherwise readily available. An example of a safety training form for the acutely toxic materials SOP is shown in **Figure VIII-I**. Additional information on recordkeeping can be found in *Chapter VIII*.

A generic *safety training attendance form* is available on the UC Davis EH&S website.

UCDAVIS
SAFETY SERVICES
Environmental Health and Safety

Documentation of Training
Acutely Toxic Materials

(signature of all users is required)

- ✓ Prior to conducting any work with (SOP Title) **Acutely Toxic Materials**, laboratory personnel must be trained on the hazards involved in working with this SOP, how to protect themselves from the hazards, and emergency procedures.
- ✓ Ready access to this SOP and to a Safety Data Sheet for each hazardous material described in the SOP must be made available.
- ✓ The Principal Investigator (PI), or the laboratory supervisor if the activity does not involve a PI, must ensure that his/her laboratory personnel have attended appropriate laboratory safety training or refresher training within the last three years.

Designated Trainer: *(signature is required)*

I have read and acknowledge the contents, requirements, and responsibilities outlined in this SOP:

Name	Signature	Trainer Initials	Date

V1 011113

Figure VIII-I. Example of a safety training form

IX. INSPECTIONS AND COMPLIANCE

A. Regulatory Requirements

The necessary work practices, procedures, and policies outlined in this chapter are required by the following:

- *8 CCR §3203*, "Injury Illness Prevention Program"
- *8 CCR §5191*, "Occupational Exposures to Hazardous Chemicals in Laboratories"

B. Laboratory Self-Inspections

The primary goal of safety inspections is to identify both existing and potential incident-causing hazards, activities, procedures, and faulty operations that can be corrected **before** an incident occurs. Regular laboratory inspections performed by laboratory personnel have been shown to substantially improve laboratory safety conditions, reduce accidents and incidents, and should help to ensure fewer findings when inspections are performed by regulatory personnel or other campus inspectors.

PIs/Laboratory Supervisors are required to self-inspect their laboratories on a routine basis, **at least annually**. While inspections are a snapshot in time and cannot identify every accident-causing condition, they do provide important information on the overall operation of a particular laboratory. Laboratory personnel may use the self-inspection checklist that mirrors the Laboratory Safety Review Program checklist, available either on *paper* or *online* through *Inspect*, or use an alternate inspection checklist at the discretion and preference of laboratory personnel that best meets the needs of the laboratory. Follow-up and documentation related to any identified corrective actions is very important. Inspection documentation for recent inspections and follow-up actions should be maintained and readily available.

C. Laboratory Safety Reviews – EH&S

Under the direction of the *CLSC*, EH&S has instituted a comprehensive *Laboratory Safety Review Program* to assist laboratories and other facilities in maintaining a safe work environment. This program assists in maintaining compliance with regulations and fulfills UC Davis's commitment to protecting the health and safety of the campus community. These safety reviews are meant to supplement laboratory self-inspections. The safety reviews can also help to identify weaknesses that may require more systematic action across a broader spectrum of laboratories, and strengths that should be fostered in other laboratories. Information about the *Laboratory Safety Review Program* is available from the EH&S website.

Once the review is completed, a Laboratory Safety Review Report is issued via *Inspect*. The report will identify deficiencies in the laboratory, both serious and non-serious. All findings must be corrected within 30 days.

If corrective action is not undertaken in the identified time period, an escalation process will be initiated. Depending on the severity of the deficiency, the EH&S Laboratory Safety Review Program Supervisor, in consultation with the Chairperson for the CLSC, may temporarily suspend research activities until the deficiency is corrected. In some cases, the PI/Laboratory Supervisor may be required to provide a corrective action plan to the CLSC prior to resuming research activities.

D. Recordkeeping Requirements

Accurate recordkeeping demonstrates a commitment to the health and safety of the UC Davis community, integrity of research, and protection of the environment. EH&S is responsible for maintaining records of safety reviews, accident investigations, monitoring equipment calibration, and training conducted by EH&S staff. Per OSHA regulations, departments or laboratories must document health and safety training, including safety meetings, one-on-one training, classroom training, and online training. A copy of recent Laboratory Safety Review Report and self-inspection documentation must also be maintained or otherwise be readily available. Additionally, the following records must be retained in accordance with the requirements of state and federal regulations:

1. Measurements taken to monitor employee exposures.
2. Inventory and use records for high-hazard substances.
3. Any medical consultation and examinations records, including tests or written opinions required by *8 CCR §5191*.

X. HAZARDOUS CHEMICAL WASTE MANAGEMENT

A. Regulatory Overview

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 (*RCRA*). Local enforcement authority is administered by the *Yolo County Environmental Health Services - Hazardous Materials Programs*.

B. Hazardous Waste Program

The EH&S Hazardous Waste Program manages the shipment and disposal of all hazardous waste generated on campus. All laboratory personnel must comply with the campus Integrated Hazardous Waste program requirements and all applicable regulations. A regular pick-up service is provided to most research buildings equipped with labs, and a pick-up is available upon request to other locations where hazardous waste is generated. Laboratory personnel are responsible for identifying, labeling, and properly storing hazardous waste in the laboratory. Comprehensive UC Davis requirements and guidance related to hazardous waste are provided on the *Hazardous Materials Management & Disposal webpage*, including a *list of hazardous wastes*, current definitions of hazardous waste, and related guidance.

Additional hazardous chemical waste information is available from:

- *SafetyNet #8 - Guidelines for Disposal of Chemical Waste*
- *SafetyNet #34 - Managing Chemical Waste Streams to Reduce Disposal Cost*
- *SafetyNet #43 - Identification and Segregation of Chemical Waste*
- *SafetyNet #110 - Guidelines for Completing the Chemical Waste Label*
- *SafetyNet #124 - Empty Container Management*

1. Definition of Hazardous Waste

EPA regulations define hazardous waste as substances having one of the following hazardous characteristics:

- **Corrosive**: pH ≤ 2 or ≥12.5[2]
- **Ignitable**: liquids with flash point below 60°C or 140°F (e.g., methanol, acetone)
- **Reactive**: unstable, explosive or reacts violently with air or water, (e.g., sodium metal) or produces a toxic gas when combined with water, or contains cyanides or sulfides that can create a toxic gas or vapor
- **Toxic**: Determined by toxicity testing (e.g., mercury)

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

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

Chemotherapeutic waste or 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 which degrade and destabilize over time and require careful management so they do not become a safety hazard (see *Waste Which Requires Special Handling*). **NOTE:** the campus has more stringent waste restrictions as it relates to *drain disposal* of materials, be sure to consult the *numerical Local Limits* list and contact *local_limits@ucdavis.edu* with any questions prior to placing any materials into any campus drain.

2. 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., cyanides, sodium azide, 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 Federal lists are included in the *EH&S List of Extremely Hazardous Waste*. **NOTE:** while there is some overlap with the list of Particularly Hazardous Substances, such as the examples listed above, the extremely hazardous waste list is specific to the hazardous waste management program.

3. Biohazardous and Medical Waste

Please consult *SafetyNet #3 - Sharps Safety Guidelines*, as well as the *Medical* and the *Biological* Waste Management webpages for UC Davis information on medical and biological waste, and contact *EH&S Biosafety* for handling and disposal information.

[2] There are additional restrictions on the disposal of substances with a non-neutral pH; see the section on *Drain Disposal*.

4. Radiological Waste

Activities that produce or use radioactive materials may generate radioactive waste. Waste generated by research activities at UC Davis is typically low-level radioactive waste. Guidance regarding *radioactive waste management* is described on the EH&S website and in *SafetyNet #9 - Guidelines for Disposal of Radioactive Waste*. Please contact *EH&S Radiation Safety* for additional information.

C. Proper Hazardous Waste Management

1. Training

All personnel who are responsible for handling, managing or disposing hazardous waste must attend training **prior** to working with these materials. *Hazardous Waste Management and Minimization* training is available from EH&S, and includes instruction on the *container labeling program*. Additionally, videos outlining a variety of WASTe functions are available on the *WASTe* website. Each laboratory must also complete annual training on their lab-specific spill response procedures (see *SafetyNet #13*) and the *CUPA self-audit*.

2. Waste Identification

All the chemical constituents in each hazardous waste stream must be accurately identified by laboratory personnel, even those components present at trace levels. This is a critical safety issue for both laboratory personnel and hazardous waste technicians 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 personnel must consult the PI/Laboratory Supervisor, the *CHO*, or the *Hazardous Materials Manager*. 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 commercial chemical products, and also the chemical, physical, and toxicological properties of the ingredients. SDSs for hazardous chemicals is available from the *UC SDS website*, with additional SDS resources available on the *Safety Services website*.

3. Labeling

Comprehensive *UC Davis hazardous waste labeling information* is provided on the EH&S website and an *online system for generating hazardous waste labels (WASTe)* is also provided. An example of a completed WASTe tag is shown in **Figure X-I**. Additional information is available from *SafetyNet #110 – Guidelines for Completing the Chemical Waste Label*. Refer to these resources as **all** hazardous waste must be appropriately labeled.

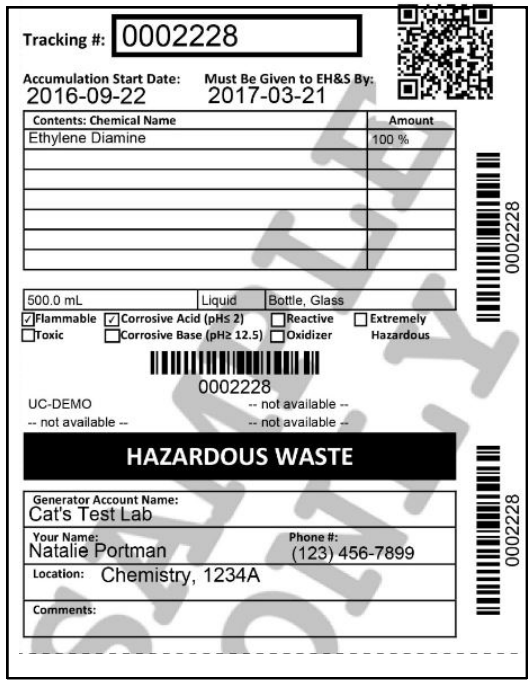


Figure X-I. Sample label generated from WASTe

4. Storage

The hazardous waste storage area in each laboratory is considered a Satellite Accumulation Area (*SAA*) by the EPA. According to EPA requirements, this area must remain under the control of the persons producing the waste. This means the SAA should be located in an area that is supervised and not accessible to the public. The chosen SAA within the laboratory should be properly labeled and located in such a place as to minimally impact normal laboratory activities. Other SAA requirements include the following:

1. Hazardous waste containers must be labeled at all times.
2. Waste must be collected and stored at or near the point of generation.
3. According to State law, the maximum amount of waste that can be stored in a SAA is *55 gallons of a hazardous waste or one liter of extremely hazardous waste.* If you reach these volumes for a specific waste stream, you must dispose of the waste within **three days**.
4. The maximum amount of flammable solvents allowed to be stored in a laboratory outside a flammable storage cabinet, safety can, or approved refrigerator/freezer is 10 gallons; this limit also includes waste solvents.
5. Hazardous waste streams must have compatible constituents and must be compatible with the containers with which they are stored.
6. Hazardous waste containers must be in good condition with leak proof lids.
7. All hazardous waste containers in the laboratory must be kept closed when not in use.
8. Oxidizing inorganic acid waste (e.g., nitric acid, chromic acid, perchloric acid) or pressure generating wastes (e.g., from use of piranha solution, also known as piranha etch, or use of aqua regia) must be stored with vented or pressure-relief caps.
9. Hazardous waste containers must be stored in secondary containment at all times.
10. Containers must be less than 90% full.
11. Dry wastes must be double-bagged in clear, three-mil plastic bags.

5. Segregation

All hazardous waste must be managed in a manner that prevents spills and unexpected reactions. Additionally, proper waste segregation can help reduce disposal costs. Whenever possible, recommended segregation approaches include:

- Segregate:
  - acids from bases
  - oxidizers from organics
  - cyanides from acids
  - halogenated solvents from non-halogenated solvents
  - radioactive waste from chemical waste
- Exclude metals from solvent wastes.

Refer to *SafetyNet #43 – Identification and Segregation of Chemical Waste* for additional guidance on chemical waste segregation.

6. 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 cause catastrophic container failure, resulting in serious injury and property damage. All chemical constituents and their waste byproducts must be compatible for each waste container generated. Waste labels must be immediately updated when a new constituent is added to a waste container, so personnel in the laboratory will be aware and manage the container and waste accordingly.

One example of a common incompatible waste stream is oxidizing acids and flammable solvents. Oxidizers added to any fuel can create an exothermic reaction and may cause catastrophic container failure. Ensuring appropriate segregation of the waste containers and strategic use of a vented cap can help to avoid container failure should inadvertent mixing of these incompatible waste streams occur.

Piranha etch solution is a reactive mixture that contains sulfuric acid and hydrogen peroxide and this is often still fuming during disposal. For this waste stream, and other reactive mixtures like it, vented caps are mandatory.

US EPA has provided guidance on the *compatibility of hazardous wastes*.

7. Accumulation Time

Hazardous waste may not accumulate anywhere on campus for more than one year. This one-year period includes the 60-90 days EH&S may need to store the waste prior to shipment. As a result, hazardous wastes must not be accumulated in laboratories for more than 270 days (9 months) after the accumulation start date.

> Hazardous wastes must be removed from laboratories no more than nine months after the accumulation start date.

One major exception to the one-year maximum accumulation period pertains to *extremely hazardous wastes*. Extremely hazardous wastes (e.g., hydrofluoric acid, arsenic or bromine-containing wastes) may not be accumulated for more than 90 days if certain volume limits are exceeded. For this reason, EH&S advises removal of all hazardous waste as soon as containers are full or at least every 90 days.

8. Waste Which Requires Special Handling

a. Sharps

Syringes, glass pipettes, and other sharps contaminated with hazardous materials (chemicals, radioactive, or biological) must be placed in a specially designed rigid container. Do NOT use red medical waste containers for non-medical waste sharps unless the biohazard symbol has been defaced.

EH&S will pick up sharps waste containers on request for disposal. Autoclaved sharps containers of medical waste must be disposed through EH&S or an approved medical waste disposal company; contact *EH&S Biosafety* for more information. Additional guidance for disposal of sharps and broken glassware is available in *SafetyNet #3 - Sharps Safety Guidelines.*

b. 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." Do <u>not mix</u> unknowns in order to minimize disposal costs.

c. Peroxide-Forming Chemicals

If old containers of peroxide forming chemicals are discovered in the laboratory, (greater than five years past the expiration date or if the date of the container is unknown), **do not handle the container**. If crystallization, visible discoloration, multiple layers, or liquid stratification is present in or on the exterior of a container, **do not handle the container** and contact **EH&S at (530) 752-1493 immediately.** Secure the immediate area and restrict access to the container until it can be evaluated by EH&S personnel.

<u>**Do not handle the container if:**</u>

- Old containers of peroxide-forming chemicals are discovered in the laboratory, (greater than five years past the expiration date or if the date of the container is unknown),
- Crystallization is present in or on the exterior of a container, or
- Discoloration, multiple layers, or liquid stratification is visible.

Secure the immediate area and restrict access to the container until it can be evaluated by EH&S personnel. Contact **EH&S at (530) 752-1493** or *hazwaste@ucdavis.edu* for inspection, pick-up, and disposal.

d. Dry Picric Acid

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 the **EH&S at (530) 752-1493 immediately**. Secure the immediate area and restrict access to the container until it can be evaluated by EH&S personnel.

SafetyNet #104 - Safe Use and Management of Picric Acid provides additional information related to picric acid.

e. Explosive Compounds with Shipping Restrictions

A variety of other compounds classified as explosives or water or air reactive are used in research laboratories. These compounds often have shipping restrictions and special packaging requirements. When disposing these compounds, employees must ensure they are stored appropriately for transport. Flammable metals must be completely submerged in oil before they are offered for 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 *Chemical Hygiene Officer* and the *Hazardous Waste group* for disposal considerations of these compounds.

f. Chemotherapy Waste

Containers or items which still contain scrapable or pourable amounts of chemotherapeutic material are considered bulk chemotherapy waste and must be disposed of according to the *Medical Waste Management Plan* and *SafetyNet #124*. Pourable chemotherapy/oncology chemicals should be left in their original containers and offered for hazardous waste pick-up through the EH&S *WASTe* program.

Any waste that is contaminated through contact with, or having previously contained, chemotherapeutic agents, including, but not limited to, gloves, disposable gowns, pipette tips, paper towels, or syringes, may be considered *trace chemotherapy waste* and must be sent for incineration by a contracted vendor in accordance with the *UC Davis Medical Waste Management Plan.* Trace chemotherapy needles should be collected in a dedicated chemotherapeutics sharps container, either labeled as such by the manufacturer or a sharps container with the words "Chemotherapy Waste" or "CHEMO." Full sharps containers can be placed directly inside the trace chemotherapy waste barrel if they have a sealed gasket around the lid, otherwise they must be placed in a compliant biohazard bag before being placed in the chemotherapy waste barrel.

g. Animals

Animal carcasses not contaminated with chemicals or radioactive materials are disposed through individual Department contracted service providers. For animal carcasses which have chemical or radioactive material contamination, contact EH&S at (530) 752-1493 or *hazwaste@ucdavis.edu* for guidance on the needed disposal method.

9. Managing Empty Containers

Empty containers that held *Extremely Hazardous or Acutely Hazardous material* must be managed as hazardous waste following the standard hazardous waste disposal procedures. **Do not rinse** or reuse these containers.

All other empty hazardous chemical containers, if they are less than, or equal to 5 gallons in size, should either be reused for hazardous waste collection, recycled, or discarded. The labels should be completely defaced (remove it or mark it out completely), and the cap removed. Dispose or recycle empty plastic or glass containers as regular trash or in a campus recycling bin.

Empty containers greater than 5 gallons can be reused as a waste container or recycled through Environmental Stewardship and Sustainability. The container must be marked with the date it was emptied, and the container reused or recycled within one year of that date. *EH&S SafetyNet #124 - Empty Container Management*, provides additional information related to empty container management at UC Davis.

10. Laboratory Clean-Outs

Laboratory clean-outs and disposal of high hazard compounds must be scheduled in advance. The PI/Laboratory Supervisor is responsible for coordinating the disposal of all chemicals from their laboratories and the decontamination of all potentially contaminated laboratory surfaces, including fume hoods. Laboratory clean-out typically involves the removal and disposal of excess chemicals when a laboratory is closing, moving, or when legacy chemicals have been accumulated. Chemicals should be stored in the original manufacturer container (in good condition) with the original label. Departments must establish processes to ensure laboratory clean-outs are completed. In cases where an abandoned hazardous materials or equipment are identified, the department is responsible for coordinating the decommissioning and any costs associated with the process. EH&S will assist with the completion of a laboratory clean-out. Please contact *hazwaste@ucdavis.edu* for consultation and guidance. Laboratory closeout guidance is available on the *EH&S website*. Keep in mind that some close-out steps require significant lead time.

D. Hazardous Waste Minimization

UC Davis is a large quantity generator of hazardous waste and is committed to minimizing the costs, health hazards, and environmental impacts associated with the disposal of hazardous waste. Additional information and training on *Hazardous Waste Management and Minimization* is available on the EH&S website.

1. Administrative Controls

In order to reduce the amount of chemicals that become waste, administrative and operational waste minimization controls can be implemented. Usage of chemicals in the laboratory areas should be reviewed to identify practices which can be modified to reduce the amount of hazardous waste generated.

Purchasing: When ordering chemicals, be aware of any properties precluding long term storage, and order only exact volumes to be used. Using suppliers who can provide quick delivery of small quantities can assist with reducing surplus chemical inventory and associated risk. Purchase the minimum quantity needed, and no more than can be consumed within a year.

Inventory: Rotate chemical stock to keep chemicals from becoming outdated, and implement the "first in, first out" approach to stock chemicals. Locate surplus/unused chemicals and attempt to redistribute these to other users, investigate returning unused chemicals to the vendor, or dispose of surplus/unwanted material as hazardous waste through *EH&S*.

Operational Controls: Review your experimental protocol to ensure chemical usage is minimized. Reduce total volumes used in experiments; 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. Reuse solvents if possible. Spent solvents can also be used for initial cleaning, using fresh solvent only for final rinse. Use less hazardous or non-hazardous substitutes when feasible. Some examples include:

- Specialty detergents can be substituted for sulfuric acid/chromic acid cleaning solutions (see *SafetyNet #152 – Corrosive Bath Safety*).
- SYBR Safe Gel Green and Gel Red are recommended in place of ethidium bromide.

Ideas for ways to reduce disposal costs are provided in *SafetyNet #72 – Chemical Substitutes*, and *SafetyNet #34 – Managing Chemical Waste Streams to Reduce Disposal Cost.*

2. Drain Disposal

UC Davis does not permit drain disposal of chemical wastes, 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, EPA hazardous waste definitions specify that materials with a pH between 2 and 12.5 are not hazardous wastes. However, drain disposal of these materials is still not permitted, because local industrial waste water discharge requirements have more restrictive pH thresholds ($pH < 5$ and $pH > 11$ are prohibited). In addition, acid and base neutralization may be considered waste treatment, a process strictly regulated by the EPA (see "Bench Top Treatment" below). Additional information on drain disposal of materials can be found in *SafetyNet #6 - Drain Disposal Guidelines*, *Sewer Disposal Policy*, and on the *numerical Local Limits* webpage. Contact *local_limits@ucdavis.edu* for additional questions about drain disposal variances.

Drain disposal of properly disinfected infectious or biohazardous liquids is acceptable, if disinfection is conducted as specified by the *EH&S Biological Safety Program*, and the liquids disposed contain no other hazardous constituents.

3. Bench Top Treatment

EPA regulations allow some limited bench top treatment of certain chemical waste streams in laboratories provided 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. The EPA requirements for treating hazardous waste in laboratories generally follow the *National Research Council "Prudent Practices in the Laboratory" 2011, Chapter 8* procedures, or other peer-reviewed scientific publications. The quantity of waste treated in one batch cannot exceed 5 gallons of liquid or 18 kilograms of solid/semi-solid waste. As treatment may result in residuals which may have to be managed as hazardous waste, all residual hazardous waste must be handled according to *UC Davis Hazardous Waste Program requirements*.

E. Transportation and Disposal

It is a violation of DOT regulations to transport hazardous waste in personal vehicles. As a result, EH&S provides pick-up services for all hazardous waste generators. These recurring waste pick-ups are for routinely generated research wastes. Hazardous waste disposal requests can be initiated using *WASTe*.

Frequent disposal will ensure that waste accumulation areas in labs are managed properly, and that maximum storage volumes are not exceeded. Once a waste container is 90% full or it is near the *accumulation time* limit, it should be scheduled for pick-up by EH&S. Once an experiment or process is completed, all containers, including those that are partially filled, should be scheduled for EH&S pick-up. *SafetyNet #8 – Guidelines for Disposal of Chemical Waste* provides related information.

Prior to EH&S pick up, please inspect all containers to make sure they are safe to transport. Verify each container has an accurate waste label, and the containers are clean and free of residue and do not show any signs of bulging, fuming, or bubbling. EH&S may refuse to pick up waste that is not properly prepared.

- Hazardous waste pick-ups can be initiated at the *WASTe website.*
- Radioactive wastes – related information is available at the *EH&S Radioactive Waste Management website.*
- Biohazardous waste (medical waste, infectious materials or biohazardous agents) – contact *Biosafety Program personnel* and review related information on the *EH&S Biological Waste Management website.*
- Controlled Substances – requests for controlled substance disposal can be initiated through the *Controlled Substance Usage Log Management System.*

XI. CHEMICAL AND LABORATORY SECURITY

A. Motivation

Laboratories and university research activities can become a target of malicious actions with intent of inflicting harm to individuals or pursuant to criminal activity. Implementation of a laboratory security plan can help to mitigate risks of these malicious actions while being complementary to existing laboratory safety policies and procedures. Guidance on the elements of a laboratory security plan is available within *Prudent Practices* (see Chapter 10). Current campus laboratory security guidance can be found in *SafetyNet #118 - Laboratory Security Tips for Hazardous Materials Users* and *PPM 390-60.* ACS has developed a *security vulnerability checklist*; it is recommended all laboratories complete this self-assessment.

It is critical that chemicals be secured to prevent theft from campus laboratories. Numerous federal agencies are involved in the maintenance of laboratory security, including the *Drug Enforcement Agency*, *Federal Bureau of Investigations*, and the *Department of Homeland Security*. Access to hazardous chemicals, including toxic and corrosive substances, should be restricted at all times (*PPM 390-60*). All hazardous chemicals must be recorded in the *chemical inventory system* including any amount of carcinogens or *Chemicals of Interest* (COI) as identified in the *Chemical Facility Anti-Terrorism Standard* (CFATS). 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 tax-free alcohol (see *PPM 350-20*), *select toxins*, and *controlled substances*. For guidance on recommended locked storage requirements, please contact the EH&S office at 530-752-1493 or *ehs-help@ucdavis.edu.*

Initial onboarding of laboratory personnel should include training on entry procedures, provisioning of appropriate access, and inventory of any materials issued or acquired.

On termination or transfer of laboratory personnel, all related hazardous materials should be properly disposed of or transferred to the laboratory supervisor or a designee. It is each laboratory's responsibility to prevent and report any theft of chemicals from their laboratory. Laboratory, building, or facility access must also be modified to prevent terminated or transferred laboratory personnel from gaining access. A laboratory supervisor, or designee, must retrieve all metal keys, disable electronic access, and/or change any PIN access codes.

B. Security Vulnerability Assessment

Laboratories are encouraged to conduct a *Security Vulnerability Assessment* (SVA): assistance conducting a SVA is available from the *UC Davis Police Department*. Aspects that should be covered in a SVA include:

- Existing threats, based on the history of the institution (e.g., theft of laboratory materials, sabotage, data security breaches, protests);
- The attractiveness of the institution as a target, and the potential impact of an incident;

- Chemicals, biological agents, radioactive materials, or other laboratory equipment or materials with dual use potential;
- Sensitive data or computerized systems;
- Animal care facilities;
- Infrastructure vulnerabilities (e.g., accessible power lines, poor lighting);
- Security systems in place (e.g., access control, cameras, intrusion detection);
- Access controls for laboratory personnel (e.g., background checks, authorization procedures, badges, key controls, escorted access);
- Institutional procedures and culture (e.g., tailgating, open laboratories, no questioning of visitors);
- Security plans in place; and
- Training and awareness of laboratory personnel.

Labs can increase their security by simply keeping lab doors closed and locked when unoccupied, maintaining a current and accurate chemical inventory, training personnel on security procedures, and controlling laboratory access through regular audits of metal keys and access control systems. Personnel should know each laboratory user: if unable to do so, personnel should wear identification badges, along with signing in and out visitors. Labs should immediately report any facility concerns related to lighting, door and lock hardware, or equipment function to *Facilities Management* or *PO&M*. Labs should immediately report any suspicious activity, information security breaches or loss to the *UC Davis Police Department* and the PI/Laboratory Supervisor; if intellectual property is also affected, the *Information Security Office* must also be notified.

C. Contact Information

In the event of an emergency or urgent situation, call 9-1-1. Non-emergency questions can be directed to 530-752-1230 (UC Davis campus) or 916-734-2555 (UC Davis Health campus). If off-campus, contact the local law enforcement agency.

XII. ACCIDENTS AND CHEMICAL SPILLS

A. Regulatory Requirements

The necessary work practices, procedures, and policies outlined in this chapter are required by the following:

- *8 CCR §342*, "Reporting Work-Connected Injuries"
- *8 CCR §3220*, "Emergency Action Plan"
- *8 CCR §3221*, "Fire Prevention Plan"
- *8 CCR §5162*, "Emergency Eyewash and Shower Equipment"
- *8 CCR §5192*, "Hazardous Waste Operations and Emergency Response"

B. Overview

Laboratory emergencies may result from a variety of factors, including serious injuries; fires and explosions; spills and exposures; and natural disasters. All laboratory employees should be familiar with and aware of the location of their laboratory's or department's Emergency Action Plan and safety manuals. **Before beginning any laboratory task**, know what to do in the event of an emergency situation. Identify the location of safety equipment, including first aid kits, eye washes, safety showers, fire extinguishers, fire alarm pull stations, and spill kits. Plan ahead and know the location of the closest fire alarms, exits, and telephones in your laboratory. **Table XII-I** outlines some common accident prevention methods. Additional information is available including:

- Campus emergency management policy (*PPM 390-10*).
- *UC Davis Campus Emergency Management Plan*.
- *Emergency Response Guide for the UC Davis campus* provides an overview of emergency response procedures. A separate *UC Davis Health Sacramento Campus Emergency Response Guide* is available for activities at the Sacramento campus. The applicable guide should be posted in each laboratory.

For all incidents requiring emergency response, call 9-1-1.

The *UC Center for Laboratory Safety* maintains a *website of Lessons Learned* from previous research-related incidents and injuries. UC Davis Safety Services also maintains a website of *Lessons Learned*. *Researchsafety@ucdavis.edu* welcomes the opportunity to discuss any previous incidents, corresponding root cause analyses, and efforts to support dissemination of anonymous Incident and Near-Miss information. By sharing this information at UC Davis, and throughout the UC system, we can aim to learn from previous events with the goal of preventing future recurrence.

Table XII-I. Accident prevention methods

Always:	Never:
✓ wear appropriate eye protection. ✓ wear appropriate laboratory coat. ✓ wear appropriate gloves. ✓ wear closed-toe/closed-heel shoes and full-length pants. ✓ confine long hair and loose clothing. ✓ use the appropriate safety controls (e.g., certified fume hoods). ✓ label and store chemicals properly. ✓ keep the work area clean and uncluttered.	✗ enter a laboratory wearing inappropriate clothing (e.g., open-toe shoes and shorts). ✗ work alone on procedures involving hazardous chemicals, biological agents, or other physical hazards unless approved by the PI/Laboratory Supervisor. ✗ eat, drink, chew gum or tobacco, smoke, manipulate contact lenses or apply cosmetics in the laboratory. ✗ use damaged glassware or other equipment.

C. Accidents

In the event of an injury or illness:

1. Seek medical attention if needed. Have the SDS available to aid in treatment.
2. Notify the PI/Laboratory Supervisor immediately.
3. File a Worker's Compensation claim through the *Employee Injury and Illness Reporting* (EIIR) system.

PIs/Laboratory Supervisors are responsible for ensuring that their employees receive appropriate medical attention in the event of an occupational injury or illness. All accidents and injuries requiring medical care must be reported to EH&S. At a minimum, each laboratory should have the following preparations in place:

1. Access to a first aid kit.
2. Posting of *emergency telephone numbers and locations of emergency treatment facilities*, including Occupational Health Services. This information should be reviewed and updated if needed at least annually.
3. Training of adequate number of staff in *basic first aid*. *Basic CPR training* is also strongly recommended.
4. Training of staff to arrange an escort for injured personnel to the medical treatment site when possible and to provide medical personnel with copies of SDS(s) for the chemical(s) involved in the incident. For non-emergencies, you may use a personal vehicle instead of taking an ambulance.

Serious occupational injuries, illnesses, and exposures to hazardous substances, including those that occur at an off-site location, must be reported to EH&S within eight hours at (530) 752-1493 during normal business hours or (530) 752-1230 after hours. EH&S will report the event to Cal/OSHA, investigate the accident, and complete exposure monitoring if necessary. Serious injuries include those that result in permanent impairment or disfigurement or require hospitalization. Examples include, but are not limited to, amputations, lacerations with severe bleeding, burns, concussions, fractures, and crush injuries. As soon as PIs/Laboratory Supervisors are aware of a potentially *serious injury*, they must contact EH&S. It is better to over-report injuries than it is to not report at all.

If laboratory personnel experience a severe or life-threatening injury, or any other medical emergency, call **9-1-1** for emergency response. When treatment at an Emergency Room is needed (e.g., burns, large lacerations, etc.) the two most applicable locations are:

1. *Sutter Davis Hospital Emergency Room*, (530) 756-6440, 2000 Sutter Place, Davis, CA 95616.
2. *UC Davis Medical Center (UCDMC) Emergency Department*, (916) 734-2011, 2315 Stockton Boulevard, Sacramento, CA 95817.

Personnel with minor injuries should be treated with first aid kits as appropriate, and receive further evaluation and treatment, when necessary, at:

1. *Occupational Health Services*, (530) 752-6051, in the Cowell Building, UC Davis campus.
2. *Student Health Services*, (530) 752-2300, in Student Health and Wellness Center, UC Davis campus.
3. *Employee Health Services*, (916) 734-3572, at 2221 Stockton Boulevard, Cypress Building, Suite A, UCDH.

After normal business hours, treatment can be obtained at *designated medical centers and emergency rooms*. If the injury is work-related, please follow the instructions for *Worker's Compensation Injury Reporting*. Please note that neither Occupational Health Services, Student Health Services, nor Employee Health Services offer emergency medical care. All acute emergencies should contact **9-1-1** or seek care at the nearest emergency room.

If your work environment is not in close proximity to Davis, CA (main campus) or Sacramento, CA (UCDH), the PI is responsible to provide laboratory personnel with guidance on the location and contact information for the most appropriate medical treatment facility to your location. This information shall be contained in: A) laboratory-specific *SOPs*, B) laboratory-specific *Laboratory Safety Plan*, or C) *Field Safety Plan*.

D. Laboratory Safety Equipment

New personnel must be instructed in the location of fire extinguishers, emergency eyewashes, safety showers, and other safety equipment *before* they begin work in the laboratory. This training is considered part of the laboratory-specific training all lab personnel must complete, and is outlined in the *Site-Specific Safety Orientation and Training Checklist for New Laboratory Personnel*. Existing equivalent checklists are also acceptable.

1. Fire Extinguishers

All laboratories working with combustible or flammable chemicals must be outfitted with appropriate fire extinguishers. All extinguishers must be mounted on a wall in an area free of clutter or stored in a fire extinguisher cabinet. Personnel should be familiar with the location, use, and classification of the extinguishers in their laboratory. A helpful overview video on laboratory fires and fire extinguishers is available from the *Dow Chemical Company* and *training on the proper operation of a fire extinguisher* is available from Fire Prevention.

It is important to use the right kind of fire extinguisher for a given fire, as not all extinguishers can be safely used on all types of fires. At UC Davis, the following classes of fire extinguishers are most common:

- **A** - Ordinary combustible solids including paper, wood, coal, rubber, and textiles.
- **B** - Flammable and combustible liquids including gasoline, diesel fuel, alcohol, motor oil, grease, and flammable solvents.
- **C** - Electrical equipment.

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).
- Appropriate training has been received.
- It is safe to do so.
- The person wishes to do so and is capable.

Any time a fire occurs, or a fire extinguisher is used, no matter for how brief a period, the PI/Laboratory Supervisor, or most senior laboratory personnel present at the time of the incident, must immediately report the incident to the UC Davis Fire Department at 9-1-1.

2. Safety Showers and Eyewash Stations

Immediate access to emergency eyewash stations and safety showers is required where the risk of chemical exposure can cause:

- eye damage.
- severe irritation.
- permanent tissue damage.
- toxicity by absorption.

Access must be available in **10 seconds** or less for a potentially injured individual and access routes must be kept clear. The installation locations of emergency eyewashes and safety showers shall follow *8 CCR §5162* and the relevant sections of ANSI Z358.1 incorporated by reference. Safety showers must always have a minimum clearance of 16 inches from the centerline of the spray pattern in all directions: this means that no objects should be stored or left within this distance of the safety shower. Water hoses, sink faucets, or showers are not acceptable eyewash facilities. Additionally, portable keg-type shower/eyewash systems are only acceptable as a temporary solution and are not intended to replace plumbed emergency safety showers/eyewash stations.

In the event of contact with a chemical or substance, immediately irrigate the eyes and/or other parts of the body for 15 minutes. Individuals using the emergency eyewash and/or safety shower should be assisted by an uninjured person who can aid in decontamination and to encourage the individual to use the eyewash and/or shower for the full 15 minutes. Clothing that has been in contact with hazardous materials must be removed. Fire blankets and clean lab coats may be used to cover the injured person for warmth and modesty. Medical attention must be sought immediately, and the event reported to the PI/Laboratory Supervisor and EH&S (530) 752-1493. Call Facilities for assistance with clean-up (530) 752-1655.

Safety shower/eyewash combination units are tested according to *SafetyNet #66 – Emergency Eyewash and Shower Testing and Use*.

3. Fire Doors

Many areas of research buildings contain critical fire doors as part of the building design. These doors are an important element of the fire containment system and shall remain closed unless they are held open by an electromagnetic releasing system integrated with the building fire detection system. Fire doors typically include hallway laboratory and office doors, which must be kept closed. See *SafetyNet #513- Fire Door Regulations* for more information.

E. Fire-Related Emergencies

If you encounter a fire, or a fire-related emergency (e.g., abnormal heating, smoke, burning odor), immediately follow these instructions:

1. Pull the closest fire alarm pull station **and call 9-1-1** to notify the Fire Department.
2. Evacuate and isolate the area:
   - Use portable fire extinguishers to facilitate evacuation and/or control a small fire (i.e., size of a small trash can), if safe to do so.
   - If possible, shut off equipment before leaving.
   - Close doors.
3. Remain safely outside the affected area to provide details to emergency responders.
4. Evacuate the building when the alarm sounds. **It is against state law to remain in the building when the alarm is sounding.** If the alarm sounds due to a false alarm or drill, you will be allowed to re-enter the building as soon as the Fire Department determines that it is safe to do so. **Do not go back in the building until the alarm stops and you are cleared to reenter by Fire Department personnel.**

If your clothing catches on fire, go to the nearest emergency shower immediately and activate the water flow. If a shower is not immediately available, stop, drop, and roll; then proceed the nearest safety shower to cool off. A fire extinguisher may be used to extinguish a fire on someone's person. Report any burn injuries to the supervisor immediately and seek medical treatment. Report every fire (even if extinguished), explosion, and all situations having fire or explosion potential to **9-1-1**, as required by *Fire Safety* (*PPM 390-40*). Contact UC Davis Fire Prevention at 530-752-4268 or 530-752-2059 immediately every time a fire extinguisher is discharged. Information on fire extinguisher training, or to request a new fire extinguisher can be obtained from *UC Davis Fire Prevention*.

Immediately report any fire or fire extinguisher discharge, even if the fire is extinguished, to the Fire Department and the PI/Laboratory Supervisor.

F. Chemical Spills

Chemical spills, or release of gas, chemical smoke, or vapor, can result in chemical exposures and contaminations. *SafetyNet #13 – Guidelines for Chemical Spill Control* provides helpful information and should be posted in all laboratories. Additional guidance related to mercury spills is provided in *SafetyNet #16 – Guidelines for Mercury Spill Control*. These incidents 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 personnel cannot safely manage the hazard.
- The material is too hazardous, or the quantity is too large to safely manage without professional assistance (see **Table XII-II**).

Effective emergency response to these situations is imperative to mitigate or minimize adverse reactions when chemical incidents occur. After emergency procedures are completed, all personnel involved in the incident should follow UC Davis chemical exposure procedures as appropriate (see *Hazard Assessment and Chemical Exposure Monitoring*).

Table XII-II. Highly toxic chemical spill response

All spills of these materials require emergency response. Do not try to clean up spills of any size of:		
• Aromatic amines	• Hydrazine	• Cyanides
• Bromines	• Nitriles	• Carbon disulfide
• Nitro-compounds	• Ethers	• Organic halides

Before beginning the clean-up of any spill, several factors should be evaluated to ensure the safety of all involved. Some of the factors to consider are outlined in **Table XII-III**. 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. Remember to wear appropriate PPE before helping others. For a non-emergency chemical ingestion, inhalation, or dermal exposure contact the *California Poison Control System* at 1-800-222-1222 immediately for assistance, and seek medical care as instructed. PIs/Laboratory Supervisors 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.

1. **Spill location.** Is the spill in a well-ventilated area? In a fume hood or outside the fume hood?
2. **Size of spill area/chemical quantity.** How big is the spill? Is it a solid or liquid?
3. **Toxicity.** How toxic is the chemical? Is it a chemical that should not be handled outside of ventilation control?
4. **Volatility.** How volatile is the chemical? Will it evaporate quickly?
5. **Flammability and presence of ignition sources.** Is the spilled material flammable? What is the potential for it to ignite? Are there open flames or other sources of ignition present in the laboratory?
6. **Availability of spill cleanup materials, including proper PPE.** Does the lab have the proper materials, including the proper PPE for all who will participate, to clean up a spill?
7. **Training of responders.** Are the responders familiar with the hazards of the material?

Table XII-III. Factors to consider before initiating spill clean-up

1. What to Do: Small Chemical Spill (< 0.5 liter)

- Evacuate all non-essential persons from the spill area.
- If needed, call for medical assistance by dialing 9-1-1.
- Help anyone who may have been contaminated. Use emergency eyewashes/showers by flushing the skin or eyes for *at least 15 minutes*. Seek medical attention following use of the eyewash/safety shower. Bring the appropriate SDS to aid in treatment.
- Post someone just outside the spill area to keep people from entering. Avoid walking through contaminated areas.
- Confine the spill to a small area. Do not let it spread.
- Turn off potential ignition sources (e.g., open flames, electrical heaters, and other electrical equipment), and close valves on compressed gas cylinders if the chemical is flammable.
- Before attempting to clean-up a spill, you must have the proper protective equipment (including safety goggles, gloves and a laboratory coat or other protective garment) and appropriate clean-up materials. Check the chemical-specific SDS (available *online*) for spill clean-up procedures or call EH&S at (530) 752-1493 for guidance.

- 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 provide HazMat response.
- Work with another person to clean-up the spill. Do not clean-up a spill alone.
- DO NOT ADD WATER TO THE SPILL.
- Use an appropriate chemical spill kit to neutralize and absorb inorganic acids and bases. For other chemicals, use the appropriate spill kit or absorb the chemical with sorbent pads, paper towels, vermiculite, dry sand, or diatomaceous earth.
- Collect the residue and place it in a clear plastic bag. Double bag the waste and label the bag with a properly completed *Hazardous Waste label*.

Note, solid spills are not typically emergencies. If the chemical is toxic, wear the appropriate PPE and use damp paper towels to transfer it into plastic bags. DO NOT dry sweep. Double bag and label as hazardous waste as described above.

2. What to Do: Large Chemical Spill (> 0.5 liter)

Large chemical spills require emergency response. Call 9-1-1. If the spill presents a situation that is 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 at a safe distance from the spill area to keep people from entering the spill area.
    - Confine the spill area if possible and safe to do so.
    - Leave on or initiate 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.

G. Earthquake

In the event of an earthquake, please take the following precautions:

1. Take cover under a desk or strong doorframe during the shaking.
2. Remain under cover indoors until the shaking subsides. Evacuate the building only once the shaking has ceased.
3. Report any injuries or broken utility services to 9-1-1.

4. Assist any injured individuals with receiving medical attention.
5. Be prepared for these events. Know your department's Emergency Action Plan

ACKNOWLEDGEMENTS & REFERENCES

UC Davis acknowledges the assistance of the UCLA Office of Environment, Health & Safety. The UCLA Laboratory Safety Manual and Chemical Hygiene Plan served as a base reference for much of the content and was augmented and adapted for applicability to UC Davis.

Supporting and cited materials are referenced electronically via hyperlink throughout the document whenever possible. The following publications served as substantive information references.

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APPENDICES

A. Glossary

ACCIDENT - an undesired event that results in personal injury or property damage, as defined by the *National Safety Council*.

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 (AL) - 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.

BULK CHEMOTHERAPY WASTE - Bulk chemotherapy waste is generated from the use and handling of hazardous drugs that are classified as chemotherapeutic agents *and* do not meet the definition of *empty* or are containers or items which still contain scrapable or pourable amounts of chemotherapeutic material. Bulk chemotherapy waste is described in the *Medical Waste Management Plan*, *SafetyNet #124*, and the *Hazardous Drugs SOP*.

"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

Cal/OSHA has an additional definition for *Select Carcinogens*.

CHEMICAL HYGIENE OFFICER (CHO) - An EH&S employee who is qualified by training or experience to provide technical guidance in the development and implementation of the provisions of the Chemical Hygiene Plan and Standard Operating Procedures.

CHEMICAL HYGIENE PLAN (CHP) - 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*.

CLASS 1A FLAMMABLE LIQUID - Any liquid with a closed-cup flash point below 73°F (23°C) AND with a boiling point below 100°F (38°C). Examples include diethyl ether, pentane, heptane, and petroleum ether.

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-323-72.

CORROSIVE - A substance that, according to the U.S. Department of Transportation (*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.

EMPTY - California has specific definitions of empty that can be found at the Department of Toxic Substances Control (*DTSC*). Essentially a container of pourable liquids is defined as empty when there is no longer a continuous stream of material coming from the opening when the container is held in any orientation. If the material is not pourable, the container is empty if no hazardous material remains in the container that can feasibly be removed by physical methods, including scraping and chipping, but not rinsing. This applies to materials that pour slowly or don't pour at all from the container, including, but not limited to, viscous materials, solids which have "caked up" inside the container, and non-pourable sludges.

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.

FLAMMABILITY LIMITS - The range of concentrations where a gas or vapor (from a liquid) as a mixture in air will propagate a flame and cause an explosion. The concentration range spans the lower flammability limit (lower explosive limit) for the minimum concentration to the upper flammability limit (upper explosive limit) for the maximum concentration. Note that these limits vary according to temperature, oxygen levels, and the presence of other chemicals.

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 in *29 CFR §1910.109(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*.
2. *Pensky-Martens Closed Tester*.
3. *Small Scale Closed-Cup Tester*.

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, or where fire or explosion hazards are generated close to sources of ignition (see *Local Exhaust Ventilation*).

HAZARD ASSESSMENT - A formal procedure undertaken by the Principal Investigator or designee 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 available 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 CHEMICAL - Any chemical which is classified as a physical hazard, or a health hazard, a simple asphyxiant, combustible dust, pyrophoric gas, a hazard not otherwise classified, or is included in the List of Hazardous Substances prepared by the Director pursuant to Labor

Code 6382 (*8 CCR §339*). 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 (TLVs) for Chemical Substances and Physical Agents and Biological Exposure Indices (BEIs)*, ACGIH (latest edition).
3. *The Registry of Toxic Effects of Chemical Substances*, NIOSH (latest edition).

HAZARDOUS MATERIAL – As defined by the Department of Transportation, 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, and water-reactive material.

HEALTH HAZARD - From *8 CCR §5194*, 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. 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. The criteria for determining whether a chemical is classified as a health hazard are detailed in *GHS Purple Book*, which incorporates by reference *29 CFR 1910.1200 Appendix A*.

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.
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.

INCIDENT - An unplanned, undesired event that adversely affects completion of a task.

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.

IMMEDIATELY DANGEROUS TO LIFE OR HEALTH (IDLH)- a threat of exposure to airborne contaminants when that exposure is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment.

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 SCALE - Work with substances in which the containers used for reactions, transfers, and other handling of substances are designed to be easily and safely manipulated by one person. "Laboratory scale" excludes those workplaces whose function is to produce commercial quantities of materials.

LABORATORY 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.
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.

NEAR-MISS - As defined by *OSHA*, refers to incidents where no property was damaged and no personal injury sustained, but where, given a slight shift in time or position, damage and/or injury easily could have occurred. General examples of near-misses include:

- Any non-compliance that could have led to an accident.
- Observation of unsafe conditions such as fire risks, faulty equipment, or failure to use appropriate PPE.
- Falling or flying objects that do not make contact with individuals nor cause any significant property damage.
- Waste going into the wrong waste stream.
- Failure of any equipment or associated systems that are in place to protect health and safety (e.g., fume hoods, glove boxes).
- Unexpected failure of building facilities systems which may compromise laboratory activities (e.g., water supply, HVAC system).

Some specific examples of near-misses that have occurred in academic research include:

a. A vacuum pump leaking oil creates a slick floor surface where someone slips but does not fall nor is injured.
b. A centrifuge tube breaks but not all of the broken glass is removed from the rotor. Someone reaches into the rotor and is poked by a residual piece of broken glass, but no laceration occurs.
c. Incompatible material is added to a hazardous waste container. The waste container pressurizes and ruptures while the lab is unoccupied. No equipment damage or chemical exposure occurs.

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. 704, "*Standard System for the Identification of the Hazards of Materials for Emergency Response*." 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. (Note: The GHS system uses a numerical severity rating that is opposite.)

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 - A substance that gives up oxygen easily to stimulate combustion of organic material.

PARTICULARLY HAZARDOUS SUBSTANCES (PHS) - Substances that pose significant threats to human health including acute toxins, reproductive toxins, and carcinogens. Special provisions must be documented in laboratory SOPs to prevent the exposure of laboratory personnel to particularly hazardous substances.

PERMISSIBLE EXPOSURE LIMIT (PEL) - An exposure, inhalation or dermal permissible exposure limit specified in *8 CCR §5155*. PELs may be either a time-weighted average (TWA) exposure limit (8-hour), a 15-minute short-term limit (STEL), or a ceiling (C).

PERSONAL PROTECTIVE EQUIPMENT (PPE) - Any devices or clothing worn by the worker to protect against hazards in the environment. Examples are 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 SDS.

RECOMMENDED EXPOSURE LIMIT (REL) - NIOSH maximum recommended concentration to which workers can be exposed for time-weighted average (TWA) for up to a 10-hour workday during a 40-hour work week. The recommendations are proposed for adoption as PELs by OSHA.

REPRODUCTIVE TOXINS - Chemicals which negatively affect the reproductive capabilities including fertility, chromosomal damage (mutagenesis), 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*.

SATELLITE ACCUMULATION AREA (SAA) - Places where wastes are generated in the industrial process or the laboratory and where those wastes must initially accumulate prior to removal to a central area.

SECONDARY CONTAINER - Container used to hold/store chemicals that is not the manufacturer's original container.

SECONDARY CONTAINMENT - A device used to prevent the release of hazardous materials in the event of a spill. Examples include plastic bins, plastic bags, sealable storage containers, etc. Secondary containment must be able to hold 100% of the volume of the largest container or 10% of the combined volume of all container contents (for multiple containers), whichever is greater.

SELECT AGENT TOXINS - Select agents are biological agents and toxins that have been determined to have the potential to pose a severe threat to public health and safety, to animal and plant health, or to animal or plant products.

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

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

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.

SERIOUS INJURY OR ILLNESS - Any injury or illness occurring in a place of employment or in connection with any employment which requires inpatient hospitalization for a period in excess of 24 hours for other than medical observation or in which an employee suffers a loss of any member of the body or suffers any serious degree of permanent disfigurement, but does not include any injury or illness or death caused by a Penal Code violation, except the violation of Section 385 of the Penal Code, or an accident on a public street or highway.

SHORT-TERM EXPOSURE LIMIT (STEL) - 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. The daily TLV-TWA must also not be exceeded.

SIMPLE ASPHYXIANT - A substance or mixture that displaces oxygen in the ambient atmosphere and can thus cause oxygen deprivation in those who are exposed, leading to unconsciousness and death.

SOLVENT - A substance, commonly water, but in industry often an organic liquid, which dissolves another substance.

SPECIFIC TARGET ORGAN TOXICITY (STOT) - Adverse, non-lethal organ-specific health effects of a toxic substance that manifest following a single exposure.

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) that 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).

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.

TRACE CHEMOTHERAPY WASTE - Trace chemotherapy hazardous waste is generated from the use and handling of hazardous drugs that are classified as chemotherapeutic agents *and* are considered *empty*. Any waste that is contaminated through contact with, or having previously contained, chemotherapeutic agents, including, but not limited to, gloves, disposable gowns, pipette tips, paper towels, or syringes must be must be sent for incineration by a contracted vendor in accordance with the *Medical Waste Management Plan*.

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.

B. General Rules for Laboratory Work with Chemicals

1. Prudent Laboratory Practices

Few laboratory chemicals are without hazards, and general precautions for handling all laboratory chemicals should be adopted, in addition to specific guidelines for particular chemicals. Exposure should be minimized even for substances of no known significant hazard and special precautions should be taken for work with substances that present special hazards. One should assume that any mixture will be more toxic than its most toxic component and that all substances of unknown toxicity are toxic.

Avoid inadvertent exposures to hazardous chemicals by developing and encouraging safe habits and thereby promoting a strong safety culture.

2. Safe Laboratory Habits

a. Personal Protective Equipment

- Wear closed-toe/closed-heel shoes and full-length pants, or equivalent, at all times when in the laboratory (i.e., no exposed skin from waist to toes).
- Utilize appropriate PPE while in the laboratory and while performing procedures that involve the use of hazardous chemicals or materials. These items may include laboratory coats, gloves, and safety glasses or goggles. (See *UC Davis 290-50, Protective Clothing and Equipment*.)
- Confine long hair and loose clothing.
- Wear appropriate gloves when the potential for contact with toxic materials exists; inspect the gloves before each use and replace them often. Remember that latex gloves provide little to no protection from solvents and strong corrosives. Do not reuse disposable gloves.
- 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. Contact lens wearers should review the NIOSH publication *Contact Lens Use in a Chemical Environment* for more information.
- Ensure that appropriate PPE is worn by all persons, including visitors, where chemicals are stored or handled.
- Use appropriate respiratory equipment when air contaminant concentrations are not sufficiently restricted by engineering controls, inspecting the respirator before use. Respirator requirements are summarized in *SafetyNet #88 – The Respiratory Protection Program*.
- 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 stations.

b. Chemical Handling

- Before using any chemical know its characteristics (*SDSs* are an excellent source of information) including:
    - Quantity that is toxic or hazardous,
    - Route(s) of exposure,
    - Type of hazard,
    - Method of chemical action in the body,
    - Symptoms of exposure,
    - Physical properties of the chemical, and
    - Chemical compatibility.
- Use only those chemicals for which the quality of the available ventilation system is appropriate.
- Vent apparatus which may discharge toxic chemicals (vacuum pumps, distillation columns, etc.) into local exhaust devices.
- Properly label and store all chemicals.
- Keep chemical containers tightly closed when not in use.
- Segregate chemicals in storage to keep adequate separation between incompatible materials. Use appropriate secondary containment.
- **Do not** store chemicals in alphabetic order.
- Avoid smelling chemicals.
- Deposit chemical waste in appropriately labeled receptacles and follow all other waste disposal procedures in this campus Chemical Hygiene Plan.
- In the case of an accident or spill, refer to the emergency response procedures for the specific material. These procedures should be readily available to all personnel. Information on minor chemical spill mitigation may also be referenced in *SafetyNet #13 - Guidelines for Chemical Spill Control*. For general guidance, the following situations should be addressed:
    - **Eye Contact**: flush eyes with water for a prolonged period (15 minutes) and seek medical attention.
    - **Skin Contact**: flush the affected area with water and remove any contaminated clothing. If symptoms persist after washing, seek medical attention.
    - **Clean-up**: promptly clean up spills, using appropriate protective apparel and equipment, and proper disposal.

c. Equipment Storage and Handling

- Use equipment only for its designed purpose.
- 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 hood closed at all times, except when adjustments within the hood are being made.

- Leave the fume hood "on" even when it is not in active use if toxic substances are in the fume hood or if it is uncertain whether adequate general laboratory ventilation will be maintained when it is "off."

d. 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/Laboratory Supervisor, 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).
- Vacuum lines must be protected with traps to prevent contamination.
- Be alert to unsafe conditions and ensure that they are corrected when detected.
- Use of headphones in the laboratory, for non-research purposes is strongly discouraged: some of the risks are highlighted in a *video from Cornell*. If headphones are used in the laboratory for non-research purposes leave one ear unobstructed to be able to hear any sounds and language of any emergency events.
- If personal electronic devices (e.g., laptop, cellular phone, MP3 player, etc.) are used in the laboratory, take precautions to prevent contamination with hazardous materials.
- Know the locations of fire extinguishers, alarm pull stations, eyewashes, and emergency showers, and know how they operate, including activation and deactivation.
- Immediately report any fires or fire extinguisher discharge to the PI/Laboratory Supervisor and Fire Prevention.

e. Hazardous Waste

- Call EH&S with any problem concerning hazardous waste and its disposal.
- Completely fill out and attach hazardous waste labels before waste accumulation starts.
- Date containers when the first drop of waste is added to the container.
- Use only screw-top containers that can be securely closed.
- Keep containers closed except when being filled.
- Leave headspace in containers for expansion (do not fill over 90% full).
- Store waste containers in *secondary containment* and properly labeled.
- Substitute less hazardous chemicals whenever possible.

3. Unsafe Laboratory Habits

a. Personal Protective Equipment

- Do not enter the laboratory without wearing appropriate clothing, including closed-toe/closed-heel shoes and full-length pants, or equivalent (i.e., no exposed skin from waist to toes).
- Do not wear laboratory coats or gloves outside of the laboratory area.

b. Chemical Handling

- Do not smell or taste chemicals.
- Do not allow release of toxic substances or fumes into cold or warm rooms, as these types of areas typically involve re-circulated atmospheres.
- Never use mouth suction for pipetting or starting a siphon.
- Do not dispose any hazardous chemicals through the sewer system. These substances might interfere with the biological activity of waste-water treatment plants, create fire or explosion hazards, cause structural damage, or obstruct flow.

c. Equipment Storage and Handling

- Do not use damaged glassware or other equipment, under any circumstances. The use of damaged glassware increases the risks of implosion, explosion, spills, and other accidents.
- Do not use uncertified fume hoods or glove boxes for hazardous chemical handling.
- Avoid storing materials in hoods and do not allow them to block vents or air flow.

d. Laboratory Operations

- Never work alone on procedures involving hazardous chemicals, biological agents, or other physical hazards unless you have received prior approval from the PI/Laboratory Supervisor.
- Avoid unattended operations, if at all possible. Unattended operations require prior approval from the PI/Laboratory Supervisor.
- Do not engage in distracting behavior such as practical joke playing in the laboratory. This type of conduct may confuse, startle, or distract another worker.

e. Hazardous Waste

- Do not mix chemical waste streams, e.g., halogens, metals, solvents, etc.
- Never put chemical hazardous waste in red or biohazard bags.
- Do not place sharps, pipettes, or broken glass in plastic bags (use an appropriate sharps container).
- Do not leave waste containers open.
- Never guess at the contents of an unknown container.

f. Food/Drink

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

C. Chemical and Workspace Labeling

1. Primary Container Labeling

Most manufacturer labels provide safety information to inform about chemical hazards and to help workers protect themselves. This information may include protective measures and/or protective clothing to be used, first aid instructions, storage information, and emergency procedures.

The label on original manufacturer containers must not be removed or defaced in any way until the container is emptied of its original contents. Incoming containers must be inspected to make sure the label is in good condition. Date new chemicals when they are received in the laboratory, as well as the initials of the responsible person. Time-sensitive peroxide forming chemicals should be labeled with the date received and date opened.

2. Secondary Container Labeling

The appropriate labeling of chemical *secondary containers* (i.e., containers used for storing commercial chemicals that are not the original manufacturer packaging) or laboratory-prepared solutions/dilutions is important to laboratory safety. With the exception of transient containers that will contain chemicals for immediate use and will not be left unattended, **all containers of chemicals being used or generated in UC Davis research laboratories should be labeled sufficiently to indicate the contents of the container, including those containing non-hazardous materials**. Many chemicals lack a unique identification property (e.g., color, odor, etc.), and are thus impossible to distinguish based on sensory assessment. Following a consistent and comprehensive chemical labeling approach in the laboratory has many advantages including, but not limited to the following:

- to help prevent hazardous reactions resulting from the accidental combination of incompatible chemicals.
- to give workers the “right to know” regarding hazardous chemical exposure.
- to minimize the high costs associated with the disposal of unknown chemicals.
- to facilitate the proper storage and segregation of chemicals.
- to enable a quick response in the event of a chemical spill or other emergency.

Appropriate labeling impacts the safety of various stakeholders in the laboratory. Improperly labeled or unlabeled chemicals can be dangerous for safety and support personnel including, but not limited to:

- Laboratory personnel
- Laboratory Safety Officers/Laboratory Managers
- Custodial personnel
- Hazardous waste disposal personnel
- Facilities and Maintenance and Design and Construction Management personnel
- School/College/Departmental Safety Coordinators/Safety Officers
- Laboratory Safety Professionals
- Contractors
- Emergency Responders

- Regulatory Officials (e.g., California Safety and Health Administrations (Cal/OSHA), California Department of Public Health Representatives (CDPH), Department of Toxic Substances and Control (DTSC), California Unified Program Agency (CUPA), etc.

Although experienced laboratory personnel may have learned and adapted to a prescribed labeling convention, new or inexperienced personnel may have difficulties understanding the labeling conventions used in a new laboratory setting. Standardized laboratory chemical labeling conventions are important to avoid confusion. Labels containing the proper chemical name, in English, can eliminate the confusion that may be caused when acronyms are used. Some examples of potentially confusing acronyms/abbreviations are:

- ABS: Acrylonitrile Butadiene Styrene *or* Alkyl Benzene Sulfonate
- ACN: Acetonitrile *or* Acrylonitrile
- BHA: Beta Hydroxy Acid *or* Butylated Hydroxyanisole
- DBA: 4-(Dimethylamino)azobenzene *or* 3,3'-Diaminobenzidine *or* 1,4-Diaminobutane
- IPA: Isopropyl Alcohol *or* India Pale Ale
- PAN: Phosphorus, Acetic and Nitric Acids *or* Peroxyacetyl Nitrate
- PGA: PhosphoGlisaric Acid *or* PhosphoGlyceric Acid *or* PolyGlycolic Acid
- TEA: Triethylamine *or* Triethanolamine

At a **minimum**, the following information must be provided on a hazardous chemical container:

1. **The name of the chemical written in legible English**:
   a. Acronyms or abbreviations may be used so long as the corresponding definitions are posted in a prominent location and available to all laboratory occupants.
   b. <u>Any</u> acronyms/abbreviations being used in the laboratory must be legible, located on a conspicuous area of the container, and included in the definitions posting.
2. **The hazard(s) associated with the chemical**. Any of the following hazard-labeling systems may be used:
   a. Word(s) that explain the hazard:
      i. The warning may be a single word (e.g., "Danger", "Caution", "Warning") or <u>preferably</u> identifies the hazard(s), including both physical (e.g., "Water-Reactive", "Flammable" or "Explosive") and health (e.g., "Carcinogen", "Corrosive", "Irritant", etc.), such as what is found on the NFPA diamond and in hazard warnings on the manufacturer label or SDS.
      ii. The use of acronyms or abbreviations for the hazard statement is strongly discouraged.
   b. Globally Harmonized System (GHS) hazard *pictograms.*
   c. National Fire Prevention Association *diamond.*
3. ***Chemicals prone to peroxide formation*** must also have:
   a. Date Received.
   b. Date Opened.

Additionally, the following information <u>should</u> be provided on a hazardous chemical container:

4. The **name** of the person responsible for the chemical.
5. The **date** the chemical was synthesized or transferred from the original container.

Containers of non-toxic and normally harmless chemicals should also be labeled with content information, including containers such as squirt bottles containing water or containers of buffer solutions. This helps to minimize the inadvertent combination of incompatible materials.

There are a few other laboratory labeling situations that occur frequently:

1. Small vials can be grouped into one secondary container which is labeled with the above listed information.
2. Novel chemicals need to be labeled based upon knowledge of the chemical and physical properties. If these properties are unknown, the materials should be treated similarly to *Particularly Hazardous Substances* and labeled as "Toxic."
3. Temporary flasks must be labeled following the above requirements whenever they are left unattended.

Chemical Labeling – What are Laboratory Personnel Responsible for?

- Inspecting incoming containers to be sure that labels are attached and are in good condition and contain the information outlined above.
- Reading the container label each time a newly purchased chemical is used. It is possible that the manufacturer may have added new hazard information or reformulated the product since the last purchase.
- Ensuring that chemical container labels are not removed or defaced, except when containers are empty.
- Labeling any secondary containers used in the laboratory, to prevent unknown chemicals or inadvertent reaction.
- Verifying that chemical waste containers have complete and accurate chemical waste labels.

3. Labeling Resources and Options

Labels should be durable and water, solvent and fade resistant.

Inexpensive commercially manufactured squeeze bottles printed with NFPA triangle and/or GHS hazard labels are available for commonly used solvents. These are optimal because solvents tend to erode labels over time. *ThermoFisher Scientific* and other laboratory equipment vendors offer a wide variety of options.

Pre-Printed Solvent Squirt Bottles

a. Label Makers

Commercial label makers are available starting at prices as low as $20 and can be used to make simple text labels. *Brother* manufactures many options, which can be used in conjunction with *Brother TZe tape* that adheres to glass, metal and plastic and resists fading, water and solvents.

Labels pre-printed with the applicable GHS hazard pictograms can be used to identify hazards. *Brady*, *Labelmaster*, and other vendors offer options for hazard symbol labels, and some even offer a *variety pack of hazard labels*.

Pre-printed Labels/Pictograms

b. Ink-Jet/Laser-Jet Printer Labels

Avery and other manufacturers offer a multitude of adhesive labels and document templates to assist the creation of laboratory labels. This includes a series of products intended for *chemical and GHS labels*. By using printed text, a large amount of information can be placed legibly into a smaller area than would be possible by hand-written ink. One great application of this type of label is for ampules. Once the printed label has been adhered to the container surface it can be further covered by clear tape to improve the label's durability.

4. Workspace Labeling

It is good laboratory practice to label one's workspace to convey information regarding the activities and hazards to other laboratory occupants. Workspaces **must** be labeled under the following conditions:

1. In areas where radioactive materials are used or stored;
2. In areas where *Particularly Hazardous Substances* are used or stored, including:
    a. Acutely Toxic Materials;
    b. Carcinogens; and
    c. Reproductive Toxins;
3. When a reaction is left unattended; and
4. When a reaction is left overnight.

For more information on labeling, see *Chapter 6* (Inventory, Labeling, Storage, and Transport) and *SafetyNet #42 - General Guidelines for Storage and Management of Laboratory Chemicals*.

D. Globally Harmonized System (GHS) Pictograms and Hazards

GHS Hazard Pictograms and Related Hazard Classes			
Pictogram & Description	 Exploding bomb	 Flame	 Flame over circle
Hazards	Unstable explosives; Self-reactive substances & mixtures; Organic peroxides; Fire or projection hazard; May mass explode in fire.	Flammable gases, aerosols, liquids & solids; Self-reactive substances & mixtures; Pyrophoric liquids & solids; Self-heating substances & mixtures; Substances & mixtures in contact with water emit flammable gases; Organic peroxides.	Oxidizing gases & liquids.
Pictogram & Description	 Gas cylinder	 Corrosion	 Skull and crossbones
Hazards	Gases under pressure, including Compressed gases, Liquefied gases, Refrigerated Liquefied gases, & Dissolved gases.	Corrosive to metals; Skin corrosion; Serious eye damage.	Acute toxicity (oral, dermal, inhalation).
Pictogram & Description	 Exclamation mark	 Health hazard	 Environment
Hazards	Acute toxicity (oral, dermal, inhalation); Skin irritation; Eye irritation; Skin sensitization; Specific Target Organ Toxicity (single exposure).	Respiratory sensitization; Germ cell mutagenicity; Carcinogenicity; Reproductive toxicity; Specific Target Organ Toxicity (single exposure); Specific Target Organ Toxicity (repeated exposure).	Hazardous to the aquatic environment including acute hazard & chronic hazard.

E. Particularly Hazardous Substances – Supplemental Information

1. Particularly Hazardous Substances Definitions

Particularly hazardous substances fall into the following three major categories: acute toxins, reproductive toxins, and carcinogens.

a. Acute Toxins

Substances that have a high degree of acute toxicity are substances that may be fatal or cause damage to target organs as the result of a single exposure or exposures of short duration. They can be defined as:

1. A chemical with a median lethal dose (LD50) of 50 mg or less per kg of body weight when administered orally to albino rats weighing between 200 and 300 grams each.
2. A chemical with a median lethal dose (LD50) of 200 mg or less per kg of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between 2 and 3 kg each.
3. A chemical that has a median lethal concentration (LC50) in air of 5000 ppm by volume or less of gas or vapor, or 50 mg per liter or less of mist, fume, or dust, when administered by continuous inhalation for 1 hour (or less if death occurs within 1 hour) to albino rats weighing between 200 and 300 grams each.

b. Reproductive Toxins

Reproductive toxins include any chemical which may affect the reproductive health of men and women including fertility, chromosomal damage (mutagenesis), and developmental effects on embryos or fetuses (teratogenesis). A list of reproductive toxins is maintained online by the *California Office of Environmental Health Hazard Assessment*.

c. Carcinogens

Carcinogens are chemical or physical agents that are capable of causing 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. Comprehensive UC Davis requirements are outlined in the *Carcinogens SOP*. Please contact *EH&S* with any questions you may on the safety expectations for carcinogen use.

F. Segregation of Incompatible Chemicals

Table F1 contains a list of incompatible chemicals. The following chemicals, listed in the left column, should not be used with chemicals listed in the right column, except under specially controlled conditions. Chemicals in the left column should not be stored in the immediate area with chemicals in the right column. Incompatible chemicals should **always** be handled, stored, or packed so that they cannot accidentally come into contact with one another. This list is representative of chemical incompatibilities and is not complete, nor are all incompatibilities shown.

Table F1 – Incompatible chemicals

Chemical	Keep Out of Contact with:
Alkaline metals, (powdered aluminum, magnesium, sodium, potassium, etc.)	Carbon tetrachloride or other chlorinated hydrocarbons, carbon dioxide and water
Acetic Acid	Chromic acid, nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides, and permanganates
Acetylene	Chlorine, bromine, copper, fluorine, silver, and mercury
Ammonia	Mercury, chlorine, calcium hypochlorite, iodine, bromine, and hydrofluoric acid
Ammonium nitrate	Acids, metal powders, flammable liquids, chlorates, nitrites, sulfur, finely divided organic or combustible materials
Carbon, activated	Calcium hypochlorite
Copper	Acetylene and hydrogen peroxide
Chromic acid	Acetic acid, naphthalene, camphor, glycerin, turpentine, alcohol, and flammable liquids
Chlorine	Ammonia, acetylene, butadiene, butane, methane, propane, hydrogen, sodium carbide, turpentine, benzene, and finely divided metals
Cyanides	Acids - organic or inorganic
Hydrogen peroxide	Copper, chromium, iron, most metals, alcohols, acetone, organic materials, aniline, nitromethane, flammable liquids, and combustible materials
Hydrogen sulfide	Fuming nitric acid and oxidizing gases
Hydrocarbons (butane, propane, benzene, gasoline, turpentine, etc.)	Fluorine, chlorine, bromine, chromic acid, and sodium peroxide
Iodine	Acetylene, ammonia, and hydrogen
Nitric acid	Acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids, flammable gases, copper, brass, and any heavy metals
Perchloric acid	Acetic anhydride, bismuth and its alloys, alcohol, paper, wood, ether, oils, and grease
Phosphorous	Oxidizing agents, oxygen, strong bases
Potassium chlorate	Sulfuric and other acids
Potassium permanganate	Glycerin, ethylene glycol, benzaldehyde, and sulfuric acid
Sodium	Carbon tetrachloride, carbon dioxide, and water
Sodium nitrite	Ammonium nitrate and other ammonium salts
Sodium peroxide	Ethyl or methyl alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerin, ethylene glycol, ethyl acetate, methyl acetate, and furfural
Sulfides, inorganic	Acids, sulfuric acid, potassium chlorate, potassium perchlorate, and potassium permanganate

Special Segregation of Incompatible Chemicals

In addition to the segregation noted in **Table F1**, dangerously incompatible substances, even in small quantities, should not be stored next to each other on shelves or in such a position that accidental rupture of containers may allow mixing. **Table F2** contains examples of dangerously incompatible substances. **Table F3** contains examples of incompatible oxidizing agents and reducing agents. Unlike **Tables F1** and **F2**, *all* oxidizing agents are incompatible with *all* reducing agents.

Table F2 – Dangerously incompatible substances

Chemical	Keep out of contact with:
Chlorine	Acetylene
Chromic acid	Ethyl alcohol
Oxygen (compressed, liquefied)	Propane
Sodium	Chloroform and aqueous solutions
Nitrocellulose (wet, dry)	Phosphorous
Potassium permanganate	Sulfuric acid
Perchloric acid	Acetic acid
Sodium chlorate	Sulfur in bulk

Table F3 – Incompatible oxidizing agents and reducing agents

Oxidizing Agents	Reducing Agents
Chlorates	Ammonia
Chromates	Carbon
Dichromates	Metals
Chromium trioxide	Metal hydrides
Halogens	Organic Compounds
Halogenating agents	Phosphorus
Hydrogen peroxide	Silicon
Nitric acid	Sulfur
Nitrates	
Perchlorates	
Peroxides	
Permanganates	
Persulfates	

G. Summary of Revisions

The following are brief descriptions of revisions to v2.0 of the UC Davis Laboratory Safety Manual that were approved by the CLSC (bookmarks provided where possible). A complete list of revisions starting from version 1.0 is available upon request from *chem-safety@ucdavis.edu*.

1. Updated Safety Memo, "*A Commitment to Safety in Research*."
2. Updated links throughout.
3. Added responsibility of PIs/Laboratory Supervisors to ensure users know how *to properly use and store PPE*.
4. Added link to *SafetyNet #5 - Eye and Face Safety Protection for Laboratory Workers*.
5. Added link to new *SafetyNet #155 - Body Protection for Laboratory Workers*.
6. Added additional information on the *proper storage of PPE*.
7. Added language to include training on *activation and deactivation of eyewashes and/or safety showers*.
8. Added guidance to have the *appropriate SDS available when seeking medical attention*.
9. Added link to *SafetyNet #154 - Guidelines for Working with Silica*.
10. Added additional examples of *waste-like containers*.
11. Added guidance for *storing compressed gas cylinders outside*.
12. Changed language regarding *transporting hazardous materials* in university vehicles.
13. Added language regarding *transportation of cryogens and simple asphyxiants*.
14. Added information about *transporting cryogens in an elevator* and linked SafetyNet #58.
15. Added language regarding *transporting compressed gas cylinders safely in a vehicle*.
16. Added guidance to *contact EH&S when transporting hazardous materials* in a vehicle on campus.
17. Added "*strongly recommended*."
18. Added guidance to have the *appropriate SDS available when seeking medical attention*.
19. Included *contact information for Facilities to assist with clean-up* after an eyewash and/or safety shower has been activated.
20. Added guidance to have the *appropriate SDS available when seeking medical attention*.
21. Added language to include training on *activation and deactivation of emergency equipment*.