LABORATORY SAFETY MANUAL

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

Environment, Health & Safety
1120 Estes Drive Extension
CB# 1650

TABLE OF CONTENTS

INTRODUCTION

This manual is a safety reference document for laboratory personnel at the University of North Carolina at Chapel Hill. The University's Department of Environment, Health & Safety prepared this manual, followed by review and approval from both the University's Laboratory and Chemical Safety Committee (LCSC) and the University Safety and Security Committee (USSC). This manual provides basic information about hazards that you may encounter in the laboratory and safety precautions to prevent laboratory accidents and minimize exposure to hazardous chemicals. The Laboratory Safety Manual is part of the University's "Chemical Hygiene Plan" required by the U.S. Department of Labor's Occupational Safety and Health Administration (http://www.osha.gov) in its "Occupational Exposures to Hazardous Chemicals in Laboratories" Standard (29 CFR 1910.1450).

Each laboratory that uses hazardous materials must have a printed copy of this manual readily available to employees in the laboratory, along with certain other materials described in Chapter 1. Each laboratory worker must be familiar with the contents that pertain to his or her workplace and the procedures for obtaining additional safety information needed to perform his or her duties safely.

In order to keep the contents of this manual up-to-date with current regulations and best practices, EHS may periodically rewrite, add, or delete sections. EHS will notify the Principal Investigator and Safety Supervisor listserv and post the changes to the EHS website when this occurs. The message will prompt you to add, replace, or discard particular pages as needed. EHS will maintain a log of the additions, deletions, and replacements to the Laboratory Safety Manual on the Laboratory Safety page: http://ehs.unc.edu/ih/lab/.

Comments and suggestions for improving the manual are welcome and encouraged. Please send comments to:

Director
Environment, Health & Safety
1120 Estes Drive Extension, CB# 1650
(p) 962-5507
(f) 962-0227
email: dehs@unc.edu

EMERGENCY TELEPHONE NUMBERS

	PHONE	HOURS
Environment, Health and Safety (EHS)	962-5507*	8:00 am- 5:00 pm
Work-Related Injuries (normal work hours)	966-9119	8:30 am - 4:30 pm
Work-Related Injuries (after hours)	966-7890	After hours
University Police	911	24 hours
Fire or Smoke	911	24 hours
Medical Emergencies	911	24 hours
N.C. Poison Control Center	1-800-84 TOXIN (1-800-848-6946)	24 hours

*University Police contacts EHS during non-business hours.

SPECIAL INCIDENT REPORTING

Gas Leaks or Odors: EHS - 962-5507

Chemical Spills: EHS - 962-5507

EHS - SCOPE OF SERVICE

EHS employs a staff of professionals trained in the field of occupational and environmental health and safety to provide support for University activities and to assure a safe and healthful environment for employees, students and visitors. The Department's program areas are:

Radiation Safety

The radiation safety program includes inventory and purchase control of radiation sources, use application review, monitoring, radiation safety surveys, training and consultation.

The Radiation Safety Manual describes the radiation safety program in detail: http://ehs.unc.edu/manuals/index.shtml.

Fire Safety

EHS' fire safety section is responsible for enforcing the North Carolina Building and Fire Codes, investigating fire incidents, developing evacuation procedures, implementing the Egress and Life Safety Policy, maintaining fire alarm and extinguishing systems, and serving as liaison to the State Department of Insurance. EHS reviews construction, renovation and maintenance projects to ensure compliance with safety standards. Direct any concerns relating to fire or life safety to the Campus Fire Marshal.

Regular health and safety inspections of University physical facilities (buildings, offices, laboratories, classrooms and shops) identify safety deficiencies and potential hazards.

Industrial Hygiene and Biological Safety

The industrial hygiene and biological safety program inspects University work environments to anticipate, recognize, evaluate, and control personnel exposures to chemical, physical and biological hazards. IHBS provides consultative services to laboratory personnel on proper handling and storage of hazardous chemicals and infectious agents, ventilation and other engineering controls, safety equipment and personal protective clothing. The industrial hygiene section investigates and evaluates potential health hazards encountered by University personnel. This section also conducts performance testing of chemical hoods, provides employee safety training, and reviews proposed plans for new or renovated laboratory facilities.

IHBS operates an asbestos program that surveys campus buildings for asbestos, collects air samples in buildings with asbestos, and inspects asbestos abatement contractors for compliance with state regulations.

Environmental Affairs – Hazardous Waste Management

The hazardous waste management program assists University departments in properly disposing of hazardous materials used in their support and research operations. A major goal of the program is to encourage researchers to incorporate waste minimization procedures in their research protocols.

Safety Training

Safety training programs available to University personnel provide a review of safe practices and provide an orientation to University policies and state and federal regulations. Programs are available in the following areas:

- laboratory safety (required for all laboratory personnel)
- radiation safety
- use of fire extinguishers
- compliance with the OSHA standard for Occupational Exposure to Hazardous Chemicals in Laboratories, also known as the "OSHA Laboratory Standard"
- compressed gas cylinder safety
- biological safety
- hazardous waste
- animal handler training (available through the Office of Animal Care and Use)

Contact EHS for a schedule of classes or arrange a presentation for your laboratory.

EHS Website

You can obtain additional information regarding EHS by accessing the EHS website at http://ehs.unc.edu. The website includes Health and Safety forms that one can download (MS Word format), Laboratory Safety Data Sheets, several self-study modules, access to employee training history, training schedules, annual reports, guidelines for recombinant DNA use, links to Material Safety Data Sheet sites, and much more and EHS continually updates it.

Condensed Laboratory Safety Information for New Research Personnel

(Adapted from *Responsible Conduct of Research 2005*, Office of Vice Chancellor for Research & Economic Development)

Safe use of hazardous materials requires knowledge of risks to the researcher, campus community, and environment. Researchers learn to handle hazardous materials safely during their scientific training and experience, as well as through information and training provided by their supervisors and the University's Department of Environment, Health, and Safety (EHS). This section summarizes some key requirements, and the subsequent chapters of this Laboratory Safety Manual expand on these requirements.

Through campus committees, the University has established environment, health, and safety policies and procedures to minimize risk and comply with state and federal laws. These policies and procedures are in this Laboratory Safety Manual, the Radiation and Biological Safety Manuals, as well as the EHS web site (http://ehs.unc.edu/). All laboratory personnel are welcome to participate in University environment, health, and safety committees. Although many of these policies and procedures are directed at laboratories, any research involving hazardous materials must comply. Principal Investigators (PIs) must ensure that their research complies with these policies and procedures and that their personnel receive appropriate safety information and training.

Laboratories Must Have a Lab Safety Plan

State and federal laws require that each laboratory have a Chemical Hygiene Plan. At the University, this consists of the Laboratory Safety Manual (LSM) and a Laboratory Safety Plan (LSP). The LSM covers general policies and procedures for laboratories, while each principal investigator prepares a Laboratory Safety Plan to address the hazards and precautions specific to his or her laboratory. The Laboratory Safety Plan identifies hazards and describes procedures for emergencies, special hazards, and handling hazardous materials. The Plan includes laboratory locations, personnel, procedures, engineering controls, personal protective equipment, and safe work practices. Chapter 2 of this Laboratory Safety Manual includes instructions for the preparation of a Laboratory Safety Plan. PIs must update location and personnel information when changes occur, but at least annually.

Requirements for New Laboratory Personnel

Orientation training is mandatory for all new laboratory personnel. They must attend EHS orientation training as soon as possible after joining the lab or take the online class offered at the EHS website. EHS offers training in laboratory safety, radiation safety, blood-borne pathogens, formaldehyde use, shipping of hazardous materials, and other topics. Before beginning work in a laboratory, all personnel should take time to identify the nearest fire alarm, fire extinguisher, safety shower, eyewash station, and spill kit.

Laboratory personnel forward a completed, signed copy of the Worker Registration Form (or submit an online Worker Registration Form: https://s4.its.unc.edu/LabRadWorker/) to EHS when they start working in a laboratory.

Personal Protective Equipment

The University uses several methods to control exposures to hazardous materials. Widely used methods on campus include engineering controls such as chemical laboratory hoods, biological safety cabinets, and local exhaust ventilation. University environment, health, and safety policies and procedures and the Laboratory Safety Plan describe work-practice controls. Personal protective equipment (PPE) is also an important way to minimize exposure by preventing absorption, inhalation, and physical contact. PPE includes gloves, safety glasses, and lab coats. The Laboratory Safety Plan describes appropriate PPE.

Proper selection and use of PPE is critical to protection; laboratory personnel should contact EHS for advice. The PI is responsible for providing all laboratory personnel with appropriate PPE, which should be designed for the task and should fit the employee well. Some guidelines:

- University policy requires eye protection for all experimental procedures. Safety glasses with side shields offer minimal protection; splash goggles and face shields offer greater protection for procedures involving liquids. EHS encourages laboratory personnel to wear eye protection at all times when in a laboratory.

- Gloves offer a degree of protection from hazardous materials and hot or cold materials. The type of hazardous material determines the type of glove that you wear. Laboratory personnel should consult the Laboratory Safety Manual (Chapter 5) and the manufacturer for proper selection and use of gloves. Disposable gloves are single use; throw them away after each use.

- Latex gloves are common, but the University discourages their use because of the possibility of allergic reactions to the natural proteins found in them. Many alternatives to latex are available. When using latex gloves, the University Latex Allergy Policy advises laboratory personnel to wear the powder-free type and to wash hands frequently.

- Do not wear sandals and open-toed shoes in University laboratories.

- Do not take lab coats home and clean. Departments should use cleaning services for lab coats.

- Use of respirators (including N95 or "dust/mist" masks) requires evaluation of the work site by EHS and annual medical evaluation, training, and fit testing.

Other Requirements for Research Involving Hazardous Materials

Laws and University safety policies impose additional requirements for the use of radioactive materials, biohazardous agents, bloodborne pathogens, controlled substances, carcinogens, reproductive toxins, and substances with a high degree of acute toxicity.

- Minimize the amount of and safely store flammable, pyrophoric, corrosive, and reactive chemicals when not in use. Laboratory personnel should contact EHS to dispose of excess chemicals.

- OSHA law includes additional requirements for carcinogens, reproductive toxins, and substances with a high degree of acute toxicity. Examples of each of these are included in the appendices to Chapter 7 of this Laboratory Safety Manual. Researchers who use such chemicals must consider special containment devices, decontamination procedures, and restriction of use to designated areas.

- PIs must review radioactive material ordering, receipt, storage, use, and disposal responsibilities with each member of the laboratory. See the UNC Radiation Safety Manual for more information.

- PIs who use or possess a select agent (one with significant potential for use by terrorists) must notify EHS and follow additional security requirements. For more information, see Chapter 8 of this Laboratory Safety Manual.

- PIs whose research involves blood and other potentially infectious materials must prepare an Exposure Control Plan. Potentially exposed employees must receive additional training and be offered vaccines at no charge. See the UNC Biological Safety Manual for more information.

- The University Employee Occupational Health Clinic (UEOHC) provides vaccinations and other occupational health services to University employees. Employees with non-emergency hazardous material exposures and injuries should contact the UEOHC.

- Faculty, staff, and students who are pregnant, think they may be pregnant, or are planning a family, and may potentially be exposed to chemical reproductive toxins, radioactive material, or other ionizing radiation, may voluntarily contact EHS for counseling, evaluation, and exposure monitoring.

- The U.S. Department of Transportation and the Federal Aviation Administration require training for employees preparing hazardous materials for shipment. EHS offers this training. Regulated hazardous materials include radioactive material, infectious substances, fixed tissue, biologicals in alcohol solutions, dry ice, formalin, unknowns, and other chemicals.

- Hazardous materials must have appropriate security to prevent accidental exposure, unauthorized access, and theft. Radioactive materials, select agents, controlled substances, and drug precursors require additional security controls. Keep these substances in locked storage. Lock laboratories when not occupied. Laboratory personnel should keep an inventory of these materials so unauthorized removal can be detected. Notify the Department of Public Safety of theft or the presence of unfamiliar or unauthorized personnel.

- EHS' orientation training, safety manuals, and web site provide waste management and disposal procedures for chemical, biological, and radioactive laboratory wastes. Laboratory personnel should contact EHS for removal of chemical and radioactive waste from the laboratory at no charge to them. Federal, state, and local laws severely restrict disposal in the normal trash or sewer. PI support is critical for waste procedure compliance. Contact EHS with further questions.

Environment, Health and Safety Surveys

As required by state and federal law, EHS inspects and surveys all campus laboratories annually, and sometimes more frequently. These surveys are comprehensive and address record keeping, fire safety, egress, engineering controls, personal protective equipment, work practices, and where appropriate, chemical, biological, and radiation safety. EHS sends survey findings to the PI and are available to all laboratory personnel. Previous EHS survey findings are a good measure of laboratory risks. Contact EHS with questions about survey findings or environment, health, and safety policies and procedures.

Summary of Documents on File in Your Laboratory

The following documents must be available to all laboratory personnel at all times. Review these with all new staff before working in the laboratory and annually thereafter, and document these reviews.

1. Laboratory Safety Plan.

2. Laboratory Safety Manual.

3. Worker Registration Forms. All new laboratory personnel must complete a "Lab/Radiation Worker Registration Form" even if they have previously worked for a different PI. Laboratory personnel must provide a copy of the form to EHS. When these forms are submitted online, print out a copy to keep with other printed laboratory documents.

4. Training Documentation. Documentation of each laboratory employee's orientation training, other applicable EHS training, and the Laboratory Safety Plan and Manual annual review are required.

5. Material Safety Data Sheets (MSDS) for those chemicals used routinely. Researchers should consult the MSDS when using a particular compound for the first time. Researchers should keep their files or binders up to date by requesting the latest MSDS when placing orders and keeping MSDSs that arrive with incoming chemicals. The University permits electronic access or storage, but there must be no immediate barriers to employee access when a MSDS is needed.

If applicable, the Principal Investigator must keep the following documents on file in the laboratory:

6. Radiation Safety Manual (a hard copy no longer required in lab). This manual explains the principles of radiation protection, survey requirements, personnel monitoring, and emergency procedures. It contains web links to important forms that are required by the Radiation Safety Manual procedures.

7. Biological Safety Manual. This manual describes safe handling procedures for pathogens. It includes procedures and forms for registering recombinant DNA experiments with the Institutional Biosafety Committee.

8. Exposure Control Plan. This plan contains procedures for the safe handling of human blood and other potentially infectious substances, as well as personnel training requirements and vaccination options.

EHS highly recommends that each laboratory obtain a copy of *Prudent Practices in the Laboratory: Handling and Disposal of Chemicals* (National Academy Press) and *Safety in Academic Chemistry Laboratories* (available free from the American Chemical Society at http://membership.acs.org/c/ccs/pubs/SACL_faculty.pdf).

EHS' website (http://ehs.unc.edu) includes manuals, training schedules, material safety data sheets, registration forms, and other safety information. The Laboratory Safety Plan templates are also available on the website. Please contact EHS at 962-5507 for more information on the safe handling of hazardous substances.

CHAPTER 1

LABORATORY SAFETY AT THE UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL

Overview

This chapter outlines some of the basic regulations that govern laboratory safety, services offered by EHS, how to report injuries and incidents, laboratory self-inspections, and how to respond to fires and chemical spills.

This chapter outlines the responsibilities for laboratory safety and health that are borne and/or shared by the Principal Investigator, laboratory personnel, the academic department that houses your research group, and EHS. This chapter also describes the EHS Collaborative Laboratory Inspection Program (CLIP), key compliance issues that arise from laboratory inspections, and enforcement policies for non-compliance.

Table of Contents

This page intentionally left blank.

CHAPTER 1

LABORATORY SAFETY AT THE UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL

I. Commitment to Safety

The University of North Carolina at Chapel Hill (UNC) is committed to providing a safe and healthful environment for all persons associated with the institution, including staff, students, visitors, and the community. Personnel conduct a vast array of research utilizing hazardous materials on the campus. Cooperation of all parties involved is required to ensure that the University conducts research safely with regard to workers, the community, and the environment. Environment, Health & Safety (EHS) has administrative responsibility for assisting laboratory personnel in developing safe work practices and for compliance with federal, State, and local regulations.

II. The OSHA Laboratory Standard and the Chemical Hygiene Plan

The Occupational Safety and Health Administration (OSHA) administers the workplace safety and health regulations in the United States. The OSHA regulation entitled "Occupational Exposure to Hazardous Chemicals in Laboratories" (29 CFR 1910.1450, commonly referred to as the "Laboratory Standard") supersedes most general industry health standards for UNC laboratories. The Laboratory Standard requires the development of a "Chemical Hygiene Plan" which states how the University will implement the requirements of the Laboratory Standard to provide a safe and healthful work environment for its employees. The Laboratory Standard provides additional recommendations in its non-mandatory appendices extracted from *Prudent Practices in the Laboratory: Handling and Disposal of Chemicals*. OSHA cites this book because members of the laboratory community prepared it through sponsorship of the National Research Council, and it is widely distributed and accepted.

Although the Laboratory Standard provides some compliance flexibility, the Chemical Hygiene Plan must address specific areas. These areas include exposure monitoring, employee information and training, medical consultations and examinations, hazard identification, use of personal protective equipment, and recordkeeping.

To comply with the Laboratory Standard, your lab must have a copy of this Laboratory Safety Manual within the lab space, as well as a Laboratory Safety Plan that is specific for your lab operations. Chapter 2 provides detailed instructions for creating a Laboratory Safety Plan. The Laboratory Safety Plan plus the Laboratory Safety Manual equals the Chemical Hygiene Plan required by OSHA.

III. Cooperation

Though the University of North Carolina at Chapel Hill is committed to providing a safe and healthful environment for all persons associated with the institution, this cannot occur unilaterally. A top-down approach to safety and health is ultimately less likely to succeed than a cooperative effort from all affected parties. This chapter details the responsibilities that help ensure this necessary cooperation occurs. Your cooperation is also required to ensure that UNC-Chapel Hill stays compliant with applicable federal, state, and local regulations related to safety and health in the workplace environment and the natural environment.

IV. Responsibilities

Principal Investigators, laboratory personnel, your department, and EHS all share responsibility for laboratory safety. Specific duties of each include the following:

A. Department Chair

1. Ensure the department's compliance with health and safety standards.

2. Provide timely notification to EHS upon termination of faculty who used hazardous materials, to expedite clearance of the laboratory for the next investigator.

3. Consider appointment of a safety committee from a cross-section of the department's employees to address departmental safety concerns.

B. Principal Investigator

1. Prepare a Laboratory Safety Plan (LSP) as described in Chapter 2, to complement the Laboratory Safety Manual (LSM). These documents constitute your Chemical Hygiene Plan as required by OSHA.

2. Ensure that laboratory personnel meet the training requirements of the Laboratory Standard, including chemical hazard information, safety rules and good work practices.

3. Provide **initial** training to laboratory personnel, upon employment, on the contents of the Chemical Hygiene Plan. Document this training on the form provided (Appendix 1-D) or similar. Maintain training records for one year in the laboratory safety notebook.

4. Provide **annual** training to all laboratory employees on the contents of the Chemical Hygiene Plan. Document this training on the form provided (Appendix 1-D) or similar. Maintain training records for one year in the laboratory safety notebook.

5. Ensure that staff and visitors observe safety rules.

6. Ensure that proper safety supplies and equipment, such as gloves, safety glasses and/or goggles, lab coats, and respirators* are available for all people in the laboratory. *Note:

if respirators are required, the PI is also responsible for the cost of medical and/or pulmonary function tests that may be required for respirator use.

7. Obtain material safety data sheets (MSDSs) for hazardous chemicals used in the laboratory and make these available to the laboratory staff.

8. Post appropriate hazard information signs within the laboratory.

9. Provide information to EHS in a timely manner so that it may post appropriate signage at laboratory entrances.

10. Conduct an "exit interview" with laboratory workers prior to their departure to ensure that they have properly labeled and prepared hazardous materials for disposal by EHS or use by other workers.

11. Notify EHS prior to vacating laboratory space when moving on campus and notify department chair and EHS of planned departure from UNC or discontinuance of the use of hazardous materials. Decontaminate laboratory surfaces and prepare hazardous materials for disposal by EHS or use by other laboratories. Refer to EHS guidelines on vacating laboratory space.

C. Laboratory Workers

1. Study the Laboratory Safety Plan, the chapters of the Laboratory Safety Manual relevant to your research, and other information provided by your supervisor.

2. Complete appropriate training and orientation programs provided by EHS.

3. Complete and submit a Laboratory/Radiation Worker Registration Form (online at https://s4.its.unc.edu/LabRadWorker/) to EHS whenever there is a change in work location or laboratory assignment. See Appendix 1-A for instructions on how to fill out this form.

4. Follow safety guidelines when handling hazardous materials, including the proper use of personal protective equipment.

5. Notify EHS of accidents, spills, or conditions that may warrant further investigation and/or monitoring.

6. Review laboratory materials to ensure that you have properly labeled and prepared all hazardous materials for disposal by EHS or use by other workers before you leave the research group.

D. Environment, Health & Safety

1. Provide training and orientation programs for laboratory personnel.

2. Inspect laboratories regularly for safety and health hazards and for compliance with State and Federal regulations.

3. Investigate potential safety and health hazards identified by laboratory employees.

4. Monitor personnel for over-exposures to chemical, biological, physical, and radioactive hazards.

5. Advise laboratory personnel on proper disposal of waste chemicals and other hazardous materials.

6. Consult with faculty, staff, students, and departmental safety committees on safety matters.

7. Assist safety committees in organizing committee meetings.

8. Post appropriate signage at laboratory entrances.

V. The Collaborative Laboratory Inspection Program

As one if its key responsibilities, EHS is required to inspect all research groups at least annually. To maximize program effectiveness, EHS developed the Collaborative Laboratory Inspection Program (CLIP), which includes three types of inspections: key-indicator reviews, referral inspections, and announced inspections. EHS personnel perform the key-indicator reviews annually and unannounced to get a snapshot of laboratory safety and compliance. EHS presumes that if a research group complies with the items on the key-indicator list, it has an effective safety program in place. Referral inspections are used to follow-up on issues when key-indicator reviews identify significant non-compliance or unsafe and unhealthy conditions. EHS conducts announced inspections to "audit" specific items, such as inventories of radioactive materials.

EHS sends inspection reports to the Principal Investigator within two weeks of the laboratory inspection. Principal Investigators are to correct all non-compliant issues or unsafe or unhealthy conditions identified during the inspections in a timely manner. Some citation items will require a written response in which the PI required to outline what he or she did to correct the variances and what steps he or she will take to prevent a recurrence.

VI. Compliance with Laboratory Safety Standards

A. Compliance Issues

The health and safety of workers and building occupants is the most important factor to consider in laboratory work. In addition to these health and safety concerns, compliance with

OSHA, Radiation Protection, and EPA regulations is also important because of the severe financial consequences, especially related to EPA hazardous waste regulations. Fines for seemingly minor violations, e.g., improper labeling, lids not screwed-on tight, etc., may run into the tens of thousands of dollars; therefore compliance with these regulations must receive special attention.

B. Safety Standards

Sources of health and safety standards and key compliance issues include:

Standard	Key Compliance Issues
OSHA Laboratory Standard	Laboratory Safety Plan, training of staff, MSDSs, emergency plan, secure compressed gas cylinders, outdated peroxide-formers
EPA/State Hazardous Waste regulations	Lids, labels, mixing incompatibles, secondary containment, location
Radiation Protection regulations	Radiation source control, dose limits, waste, training, personnel monitoring, labeling, and hazard information signs
Fire/Life Safety Codes	10 gallon open storage flammables limit, clear laboratory egress, hallway storage
University policies	Training, prevention of injuries, personnel policies, grant proposal review
Consensus standards of good laboratory practice	Hazardous material inventory minimization and storage compatibility, housekeeping, appropriate attire, food & drink within designated area

C. Violation Severity Classifications

The University uses the following categories of violations:

- Imminent danger
  - A process, action, or condition that constitutes an immediate threat to life or serious injury if not abated. The University has authorized EHS personnel to 'shut-down' any operation in this category.

- Serious violation
  - A process, action, or condition where there is substantial probability that death, serious physical harm, or significant exposure to biological or physical agents could result.

- Willful
  - An intentional and knowing violation of safety standards (as contrasted with inadvertent violation).

- Repeated
  - Violations of the same type found upon re-inspection of a laboratory.

- Non-serious violation
  - An action or condition that has a direct relationship to workplace health and safety but probably would not cause death or serious physical harm. Related non-serious violations may result in a serious violation where in combination they present a substantial probability of exposure, injury, or physical harm.

- *De minimus* violation
  - A condition that has no direct or immediate relationship to workplace health and safety.

- Non-conforming use/condition
  - A violation created by a process, action, or condition due to a facility deficiency.

- Not adhering to standards of good laboratory practice
  - Inadequate hygiene, lab practices, or housekeeping.

D. Enforcement Policies

- Imminent danger
  - EHS notifies laboratory personnel to cease operations immediately and close the laboratory, then notifies the EHS Director who in turn notifies the department head of the affected PI to request assistance in abatement of the problem. The EHS Director also notifies the Associate Vice Chancellor for Auxiliary Services and Public Safety to secure the area if necessary. EHS will perform follow-up inspections to ensure compliance.

- Serious violation
  - EHS notifies laboratory personnel and PI, if available, of the violation and sets a deadline for abatement, and may recommend that the PI shut down the operation until abated. Follow-up notification, in writing, goes to the PI, department head (requesting assistance to assure compliance), the Laboratory and Chemical Safety Committee and/or the Radiation Safety Committee, as appropriate. EHS will perform follow-up inspections to ensure compliance.

- Non-serious violation
  - EHS notifies laboratory personnel of the violation and requests abatement as soon as practicable. EHS sends follow-up notification in writing to the PI. EHS sends a summary report of all inspected PIs to respective department heads monthly.

- *De minimus* violation and not adhering to standards of good laboratory practice
  - EHS notifies laboratory personnel of the violations and recommends improvements, and sends inspection reports to the PI. EHS will not perform on-site follow-up inspection.

- Willful and/or repeated violations
  - EHS Director notifies the PI and/or the department head of violation(s) and recommends that the affected department take disciplinary action in accordance with University HR/Health & Safety policies. EHS may suspend authorization to use radioactive materials if the violation(s) affect the safe use or management of radioactive materials. Depending on the nature of the violation(s), EHS may move to shut down the laboratory until the PI demonstrates the ability to operate the laboratory safely. If the violations only involve radioactive materials or radiation producing devices, the Radiation Safety Officer will handle notifications, in accordance with the Radiation Safety Committee procedures.

E. Notification of Granting Agencies

For some laboratories, EHS has signed a "Certificate of Environmental and Safety Compliance", a requirement for some granting agencies. This certification requires EHS to notify the granting agency if that laboratory is in violation of any applicable environmental or safety law or regulation.

F. Reports to Department Heads and Laboratory & Chemical Safety Committee

EHS will send monthly reports to the department head summarizing inspection activities within his or her department. The reports will list the serious, willful, and repeated violations for each PI and render a general assessment of Outstanding, Excellent, Good, Poor, or Unacceptable. EHS will also report these findings at meetings of the Laboratory & Chemical Safety and Radiation Safety Committees, as appropriate.

VII. The Most Important Laboratory Safety Factor

Many factors can contribute to establishing a safer laboratory environment. The chapters of this Manual outline several of them. The most important of these factors is **you**.

Most laboratory injuries and incidents are not the result of "someone else's actions", though of course the exceptions can be dramatic. Most injuries and incidents involve the laboratory worker who is directly working with the apparatus, chemical, needle, animal, etc. Therefore, the most important way for you to have a safer laboratory environment is to perform all your tasks in the safest manner possible.

The resources in this Manual plus other guidebooks such as *Prudent Practices in the Laboratory: Handling and Disposal of Chemicals* (National Academy Press) and *Safety in Academic Chemistry Laboratories* (available free from the American Chemical Society at http://membership.acs.org/c/ccs/pubs/SACL_faculty.pdf) can guide you in how to do your laboratory work safely. Please contact EHS at 962-5507 if you have any questions or concerns about laboratory safety, the contents of this Manual, or suggestions for improving laboratory safety.

VIII. How Safe is Your Lab? Laboratory Self-Assessment

Several factors, many of them unintentional, can affect laboratory safety. Hazards can emerge due to complacency and familiarity, tediousness, or distraction. The requirements and recommendations of this manual and the Laboratory Safety Plan will not fully protect you unless you exercise diligence in your daily work, or at least stop periodically to assess your environment.

Step back and look carefully at your laboratory environment, looking at it as a first-time visitor would. Does it look safe, neat, and orderly? Are chemicals stored properly? Are you and other personnel taking appropriate precautions? Can you see ways to make the lab safer? You are strongly encouraged to conduct at least an annual (and preferably more frequent) assessment of your laboratory's safety practices. Appendix 1-E at the end of this Chapter is a laboratory self-audit form that can assist with this. The items on this checklist are some of the most frequent causes of preventable laboratory accidents, and frequently cited by EHS during lab inspections. Contact EHS with any special concerns that arise from these self-audits, and repeat audits frequently in order to track whether your lab is making improvements.

Figure 1.1 –

When you stop to look closely at your lab environment, what potential hazards do you see?

Use the self-inspection checklist (Appendix 1-E) for periodic assessments.

IX. Request for Hazard Investigation

The Occupational Safety and Health Act of North Carolina makes provisions for employees to request an inspection or evaluation of conditions that they believe may constitute a health or safety hazard. University employees are encouraged to report such conditions to EHS and to request a special investigation into the need for corrective action. University employees who are aware of a health hazard or unsafe condition should notify EHS, 1120 Estes Drive Extension, CB# 1650 or call 962-5507. Persons requesting an inspection by EHS (or the Department of Labor) may request confidentiality, and by law their name will not appear on any record published, released, or made available to the public, their immediate supervisor, or department head.

UNC also offers a resource called the Compliance Line. The Compliance Line is an option for making confidential reports using either the internet or a telephone line, to report compliance concerns about EHS issues. You can also use this resource for concerns related to finances, research, or HIPAA (the Health Insurance Portability and Accountability Act). This resource is not maintained on UNC's systems, or by UNC employees. EthicsPoint, based in Portland, Oregon, is the commercial service provider for the Compliance Line. You can file reports anonymously, and the reports are held securely and confidentially on the external systems. The Compliance Line internet access is at http://www.ethicspoint.com (Click on "File a New Report or Follow-up on a Report"). Compliance Line telephone access: 1-866-294-8688.

After EHS has concluded its investigation, results are communicated, in writing, to the party requesting the investigation and other appropriate University personnel, with due consideration to anonymity requests. EHS will initiate corrective action if there are reasonable grounds to believe that a violation or danger exists. If EHS cannot implement corrective action within a reasonable period, EHS may terminate the operations pending corrective action.

X. Exposure Monitoring

The greatest potential for over-exposure generally occurs during transfer operations involving concentrated chemicals. Conduct these operations in a laboratory hood to minimize the potential for over-exposure. Refer to Chapter 17: Laboratory Hoods for more information.

EHS will perform monitoring upon request, or if there is reason to believe that exposure levels for a substance routinely exceed the OSHA-defined Permissible Exposure Limit (PEL) or action level. Any employee may request monitoring and be notified of the results, in writing, within 15 days of the receipt of the results. To file a formal request for monitoring, complete Appendix 1-B and send, or deliver, to EHS. EHS also responds to telephone requests for evaluation of exposure to chemicals and provides monitoring if appropriate.

XI. Reporting Injuries and Illnesses

Report all personal injuries and accidents that occur on the job to EHS. EHS may take corrective action to minimize the probability of recurrences in your lab and others. Types of injuries may include animal bites, needlesticks, cuts from broken glass, exposure to biological agents, etc. Fill out the Employee Incident Report Form (located at http://ehs.unc.edu/ehs/docs/h2-01-a.doc) and send to EHS.

Send formal reports of accidents, injuries, or occupational illnesses to students, staff, faculty and visitors while on University property, or in the course of University employment or activity, to EHS on the Industrial Commission Form 19 (http://www.comp.state.nc.us/ncic/pages/form19.pdf). Report accidents resulting in death or hospitalization to the Director of EHS immediately. Report accidents resulting in lost work time to EHS (962-5507) as soon as practicable during regular work hours (8:00 am to 5:00 pm Monday-Friday).

It is your responsibility to notify your supervisor immediately of any job-related injury or illness. If unable to do so, a co-worker should notify your supervisor as soon as possible.

Supervisors must ensure that employees receive prompt treatment of the injury by obtaining first aid or assistance to medical treatment. If the treatment requires more than first aid, the supervisor or another person must accompany the injured person en route to treatment; do not send injured employees unescorted to seek medical attention. Take the injured employee to the University Employee Occupational Health Clinic (UEOHC) located on the first floor of the Ambulatory Care Center on Mason Farm Road. Students who are also employees, such as graduate students doing research and work-study students, should go to the UEOHC to seek treatment for a work-related illness or injury. Students who do not have a work-related illness or injury should go to the UNC Campus Health Service. For severe or life-threatening injuries, go to the UNC Hospitals Emergency Room, located at the NC Neurosciences Hospital.

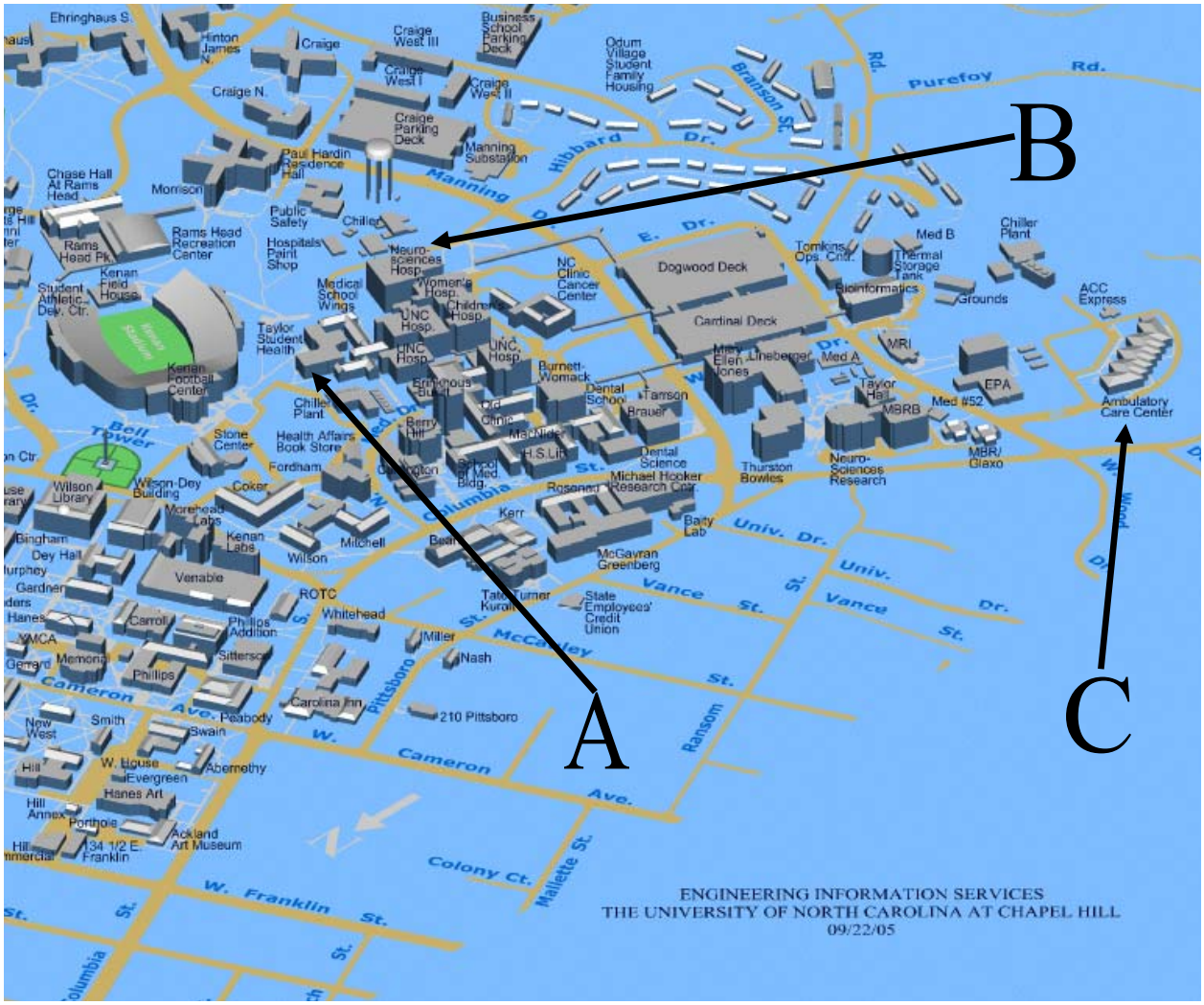


Figure 1.2 – Campus map showing health care locations in case of injury:

A – Campus Health Services (formerly Student Health)
B – UNC Hospitals Emergency Department
C – University Employee Occupational Health Clinic

XII. Medical Consultations and Examinations

If you work with hazardous chemicals, UNC will provide the opportunity for medical consultations and/or medical examinations. Complete the "Request" form, Appendix 1-C, and mail or deliver to EHS under the following circumstances:

- You develop signs or symptoms associated with a hazardous chemical to which you might have been exposed in the laboratory;
- Exposure monitoring reveals an exposure level routinely above the Permissible Exposure Limit (PEL) or action level, if applicable, for an OSHA regulated substance, as prescribed by the regulations for the particular substance; and,
- An exposure to a hazardous chemical is likely because of a spill, leak, explosion, or other release.

The UEOHC will provide you with consultation/examination as soon as practicable following notification, and a written opinion to you and EHS that includes:

- Recommendations for follow up;
- The results of the examination and any associated tests;
- Any revealed medical conditions that may place you at increased risk, and
- A statement that UEOHC consulted you on medical conditions that may require further examination or treatment. The written report will not reveal medical findings unrelated to occupational exposure.

XIII. Information and Training

The Laboratory Standard requires that your employer advise you of chemical hazards at the time of initial assignment, and whenever new exposure situations occur. This information must cover:

- The contents of the Laboratory Standard;
- The location and availability of the chemical hygiene plan;
- The PELs of OSHA regulated substances and recommended exposure limits to non-regulated substances;
- Physical and health hazards of chemicals in the workplace;

- The signs and symptoms associated with exposures to hazardous chemicals used;

- The location and availability of known reference material, including material safety data sheets (MSDS), on the hazards, safe handling, storage, and disposal of hazardous chemicals, and

- Measures employees can take to protect themselves, including emergency procedures and personal protective equipment.

EHS provides periodic safety orientations on the Laboratory Standard and general chemical safety. The Laboratory Standard training is also available online at http://ehs.unc.edu/training/index.shtml, as are several other training modules. Successful completion of the Laboratory Safety/Managing Hazardous Waste course (either in person or online) is required of all laboratory employees to meet a portion of the Laboratory Standard's training requirement.

XIV. Obtaining Material Safety Data Sheets

If you do not receive an MSDS with the chemicals you purchase, you can (1) contact the chemical manufacturer, (2) contact EHS, or (3) visit the EHS website (http://ehs.unc.edu) for several online MSDS resources. The University subscribes to the Canadian Centre for Occupational Health & Safety MSDS database, which includes over 200,000 continuously updated MSDSs. This site is accessible from any computer connected to the UNC TCP/IP network and is located on the EHS Chemical Safety Page, or directly at http://ccinfoweb.ccohs.ca/msds/search.html. The EHS Chemical Safety and Workplace Safety web pages contain additional MSDS resources that are accessible off the UNC TCP/IP network.

XV. Recordkeeping

OSHA regulations require maintenance of monitoring and medical records for a period of thirty years following termination of employment. The records that EHS maintain include:

- Copies of Laboratory Safety Plans
- Laboratory worker biographical data and laboratories in which they work (PI and dates)
- Monitoring results
- Medical examination and consultation records
- Reports and investigations of accidents in laboratories

XVI. Planning for Emergencies

It is the responsibility of each laboratory unit to establish emergency plans in the events of fire, chemical spills or other emergencies resulting from accidents within their laboratories. You also need to be familiar with the emergency plans and evacuation routes for your building. Plans may vary slightly, depending on the design of the building, but generally will incorporate the following features:

A. Fire Emergency Procedures

Purpose: How you react in the event of fire depends on how well you have prepared for a fire emergency. Therefore, departments should ensure that all employees are familiar with the procedure to follow in the event of an emergency as outlined in the University's Emergency Plan.

Procedure to follow: Departments that need a special fire emergency procedure due to unique operations should contact the Fire Safety Section for assistance. Most departments can follow the basic building evacuation procedure outlined below.

In the event of an alarm, remember **RACE**.

- **R**: Remove anyone from immediate danger
- **A**: Activate the building fire alarm system and call 911.
- **C**: Confine the fire by closing all windows and doors.
- **E**: Evacuate and leave the building.

Extinguish the fire, if you can do it safely and have received training from EHS. You are NOT required to use fire extinguishers; however, you are required to receive fire extinguisher training from EHS if you want to use fire extinguishers in the event of an incipient-stage fire in your lab. See Chapter 10: Fire Safety for more information.

How to Survive a Building Fire

- Crawl, if there is smoke.
- Feel doors before opening.
- Go to the nearest exit.
- Always use an exit stair, not an elevator.
- Close doors.
- Use a fire extinguisher if the fire is very small and you know how to use it safely.
- If you are on fire - Stop, Drop and Roll.
- If you get trapped:
    - Close the door.
    - Seal cracks.
    - Open the windows if safe.
    - Signal for help and phone 911.
    - Do not jump.
    - The fire department will reach you.

If You are Physically Impaired:

If you are disabled (even temporarily), you should do the following:

- Learn about fire safety.
- Plan for fire emergencies.
- Be aware of your own capabilities and limitations.

Look for "areas of refuge" like stair enclosures or other side of corridor fire doors. Elevators are not safe during fires. Sometimes it may be safer to stay in your room. If there is an immediate threat to safety, ask others near you for assistance. If no help is available, seek refuge in a room with a window or stairway. If possible, call 911 to report your location and receive instructions from the Emergency Operator.

B. Emergency Response to Chemical Spills

Many laboratory spills are of limited hazard potential, and laboratory personnel can clean up safely. Your laboratory should be equipped to handle small low-hazard spills. You should call EHS (2-5507) if a spill situation involves any of the following:

- spills that present a respiratory hazard;
- spills that pose a threat of fire or explosion;
- more than 100 mL of an OSHA regulated chemical carcinogen or a highly toxic chemical (see appendices to Chapter 7);
- more than 1 liter of a volatile or flammable solvent;
- more than 1 liter of a corrosive (acid or base) liquid;
- elemental (liquid) mercury spills; refer to section C below.

Chemical Spill Response Kit

Your laboratory should be equipped with protective clothing and spill cleanup materials to respond to small low-hazard chemical spills. Specialized chemical and corrosives spill kits are commercially available. In addition, you may obtain these materials to make your own spill kit.

Description

- 1 Pail, Plastic, 2.5 Gallon
- 2 Oil Dri, Bentonite Clay, 5LB Bag
- 2 Plastic Bags, Black, 3ml 23x20x48
- 1 Dust Pan with Brush, Polypropylene
- 4 Bags, Zip-lock
- 1 pair Disposable, Nitrile Gloves (Large)
- 2 Tags with Ties for Bags
- 2 pairs of Shoe Covers, Disposable Tyvek
- 1 Label (sticker) "Chemical Spill Kit" for bucket
- 1 Sign "Spill Area - Keep Out"
- 1 Instruction sheet "Clean up of Laboratory Spills"

Optional Items (Not Included in Kit)

- 1 Goggles Safety
- 2 pair Gloves Neoprene 11", Long
- 2 Coveralls Tyvek, Large

Response Steps for Chemical Spills

Step 1: Leave and Control Spill Area:

- Evacuate personnel from the immediate spill area.
- Block off immediate spill area- close corridor doors, use lab carts, wastebaskets, etc.
- Eliminate any fire hazard, especially if spill is flammable or combustible- turn off burners, electrical equipment, etc.
- Post sign, "Spill Area - Keep Out".
- Alert other personnel in laboratory and adjacent areas of a chemical spill including the PI or Instructor.

Step 2: Help Injured Personnel:

- Take care of injured personnel- move from spill, remove contaminated clothing, flush skin with water, use eyewash and/or safety shower, etc. If there is a chemical splash to the eyes and/or there are burns or respiratory problems, seek medical attention.

Step 3: Evaluate Hazard:

- Make preliminary evaluation of hazard and identification of risks and decide whether you should call EHS. If it can be handled without respiratory protection, continue with clean up.

Step 4: Clean Up Spill:

- Contain the spill using absorbent clay to stop spill from spreading under refrigerators, cabinets, equipment, drains, or corridors. Then spread clay around the perimeter, damming the spill.
- Use the clay to absorb the rest of the liquid.
- Scoop the clay/absorbed chemical mixture into a plastic pail lined with a plastic bag.
- Seal plastic bag and containerize for disposal.
- Wash and deactivate the spill surfaces of trace amounts of the spilled chemical. Contact EHS for advice.
- Fill out Electronic Hazardous Material Pick-Up Request (https://s4.its.unc.edu/HazMat_Pickup/) for collected spill material or call EHS for disposal instructions.
- Replace used materials in spill kit.

Step 5: Review Incident:

- Review incident to prevent further spills and improve response procedures.

C. Mercury Spills

If your lab uses any devices that contain liquid elemental mercury, such as thermometers, manometers, or sphygmomanometers, you must have a small mercury spill kit available to contain the spill. The example below (Figure 1.3) is available from Fisher Scientific, catalog #19021910. Use the contents of the mercury spill kit for initial containment.

Contact EHS for assistance during or immediately after completing initial containment. Prior to EHS arrival, seal off the immediate spill area so that no one can walk on spilled mercury.

Figure 1.3 –

Mercury spill kit. Contents include mercury-absorbing sponges, amalgamating powder, and containment bags.

D. Requesting Assistance for Chemical Spills

Some spills may be more hazardous and laboratory personnel should not attempt clean up. As stated earlier, call EHS if the spill is more than 100 mL of an OSHA regulated chemical carcinogen or a highly toxic chemical; more than 1 liter of a volatile or flammable solvent; or, more than 1 liter of a corrosive (acid or base) liquid. In such cases, evacuate the room and call EHS immediately.

These more hazardous spills may only involve the EHS Spill Response Team, or the UNC Emergency Response Plan might need to be activated which involves the Chapel Hill Fire Department, UNC Public Safety, local hazmat teams, and North Carolina Regional Response Team #4. In the event of major uncontrolled incidents such as fire, major releases of hazardous chemicals to the environment, or life threatening injuries, call 911 immediately.

Communication between the laboratory, department, EHS, and other response personnel is very important. The Principal Investigator and other laboratory personnel who know the hazardous materials involved and/or the particular circumstances of the accident must be present at the incident command site. Obtain material safety data sheets for the chemicals involved to bring to the incident command site.

This page intentionally left blank.

APPENDIX 1-A

COMPLETING THE LABORATORY / RADIATION WORKER REGISTRATION FORM

The Laboratory/Radiation Worker Registration Form is required for all personnel who work in a laboratory environment, regardless of whether they actually handle hazardous materials.

The Form can be completed and submitted online, https://s4.its.unc.edu/LabRadWorker/. Follow the instructions below to fill out the form.

Login

If you have an ONYEN and password, use these to login. If you do not have an ONYEN and password, or cannot remember it, click on the indicated field to log on with your PID# and date of birth.

Registration Type

If you do not have an existing form in the system, the next screen will ask you for the type of registration sought: Laboratory Only, Laboratory and Radiation, or Radiation Only. Choose the registration option corresponding to your anticipated work within UNC laboratories or UNC Hospitals.

Registration Menu

If you already have a form in the system, you are taken to the Registration Menu screen after login.

- Select VIEW to view and/or print your current registration information.
- If you wish to edit the information on your current registration, select EDIT. After confirming your choice, you go to the Registration Type screen described above*.
- To delete your current registration form, select DELETE. This places a request to EHS for deletion.
- To enter a new registration (with a different Principal Investigator), select either TRANSFER PI or NEW REGISTRATION FORM. Both of these choices lead to the Registration Type screen*.

*Though three different fields (Edit, Transfer PI, and New Registration Form) lead to the Registration Type screen and the subsequent Demographic Information screen described below, you cannot change the Principal Investigator field in the Demographic Information screen if you choose Edit. This can only be changed by selecting Transfer PI or New Registration Form in the Registration Menu.

Demographic Information

- Employer: Select your appropriate employer category from this list of five. You can only select one per form. If you select Contract Agency or Other, use the text box to describe this entity.
- Department Name: It is better to select this from the drop-down menu to ensure the correct name and spelling. However, you can also type your department name directly into the text box below.
- Campus Box Number: Use the look-up link to the right if you do not know your campus box number.
- Phone Number: This is a contact number for your laboratory. For campus numbers, you must enter all seven digits after the area code. If your laboratory suite does not have a land line phone, you can enter a mobile phone or pager number. The default area code is 919; you must erase this if your laboratory contact number is out of the 919 area code.
- Principal Investigator: This field cannot be changed if you selected EDIT on the Registration Menu. Select your PI from the drop-down menu. If your PI is not on this menu (or you are the PI and your name is not on this menu), contact EHS for further information. New PIs cannot be added to the EHS data system until they complete and submit a Laboratory Safety Plan (see Chapter 2 for information and instructions).

Registration Page Two

- Supervisor is not PI: Complete these if your supervisor is not the Principal Investigator listed in the previous section.
- Work Will Involve: Select all that apply to your work, or that could apply. Contents of this section vary, based on what option you selected (Lab Only, Lab/Rad, Rad Only) on the Registration Type screen. Use the links if you have questions about animal handlers or the requirements for bloodborne pathogen training.
- If you work in a production laboratory or shop that produces hazardous waste, select the Hazardous Waste box at the end of the form. DO NOT select this if you work in a research laboratory.

Click on CONTINUE when finished. If you are registering as a laboratory worker only, this completes the registration.

If you are registering as a radiation worker, you will go through additional screens. These screens require you to list the radionuclides or radiation-producing equipment you will work with, your previous experience with radiation, dominant hand, and previous employment with radiation exposure.

Contact EHS at 962-5507 if you have any problems or questions about completing the Laboratory/Radiation Worker Registration Form.

APPENDIX 1-B

REQUEST FOR MONITORING

Name: _____ PID No: _____

Title: _____ Phone No: _____

Department: _____ CB#: _____

Lab Building: _____ Lab Room No: _____

Principal Investigator: _____

Employed by UNC Since: _____ In this laboratory: _____

Chemical(s) for which monitoring is requested: _____

Describe how chemical is used in laboratory: _____

Describe operations for which monitoring is requested: _____

When (date and time) will operations be performed for which monitoring is requested:

_____

Other Comments: _____

Please mail, deliver, fax, or e-mail this form to Environment, Health & Safety. Results will be sent within 15 days after monitoring results have been received.

Environment, Health & Safety
1120 Estes Drive Extension, CB# 1650
(p) 962-5507
(f) 962-0227
email: dehs@unc.edu

APPENDIX 1-C

REQUEST FOR MEDICAL CONSULTATION OR EXAMINATION

Name: _____ PID No: _____

Title: _____ Phone No: _____

Department: _____ CB#: _____

Lab Building: _____ Lab Room No: _____

Principal Investigator: _____

Employed by UNC Since: _____ In this laboratory: _____

Reason for request for medical consultations or examination:

_____

1) Name of chemical to which employee was or may have been exposed:

_____

2) Description of the conditions under which exposure occurred, dates, and exposure dates, if available:

_____

3) Description of signs and symptoms experienced:

_____

Please mail, deliver, fax, or e-mail this form to Environment, Health & Safety.

Environment, Health & Safety
1120 Estes Drive Extension, CB# 1650
(p) 962-5507
(f) 962-0227
email: dehs@unc.edu

APPENDIX 1 - D

Laboratory Safety Plan – Annual Training and Documentation Form

Information communicated by the Principal Investigator:

_____ contents of the Laboratory Safety Plan;

_____ contents of applicable portions of the UNC Laboratory Safety Manual;

Specify applicable chapters: _____

_____ Location of material safety data sheets (MSDSs); and

_____ information from MSDS and other sources on specific hazards in the laboratory;

_____ other, specify:

I _____ have been instructed in the above information on (date) _____/_____/_____, I understand the safety procedures described, and I am responsible for following them at all times.

_____ _____

Employee Principal Investigator

This form is to document that the items noted above have been communicated to the employees during an in-house training session given by the Principal Investigator or Laboratory Safety Supervisor.

Please file this form in your laboratory safety notebook.

APPENDIX 1-E:

UNC-Chapel Hill Laboratory Safety Self-Audit Form

Building Name: _____ Department: _____

Room Number/PI Name: _____ Auditor Name and Date of Inspection: _____

ITEM (Mark Y, N, or N/A as appropriate)	**ITEM** (Mark Y, N, or N/A as appropriate)
1. LAB SIGNS & DOCUMENTS	**7. LABORATORY REFRIGERATOR/FREEZER**
a. Primary contacts & emergency numbers posted	a. "No Food or Drink" sign posted on door
b. Warning/restriction signs (rad, carcinogen, biohaz -if needed)	b. Food/drink not stored in unit
c. Lab Safety Manual accessible	c. Flammables stored in approved safety refrigerator
d. Lab Safety Plan accessible and up-to-date	**8. CHEMICAL STORAGE**
2. SAFETY EQUIPMENT	a. Chemicals stored by Compatibility Group
a. Fire extinguisher available (within max 75 ft)	b. Incompatible chemicals physically separated
1. Unobstructed & mounted at designated location (40" top)	c. Chemicals properly labeled (original or secondary label in place)
2. Extinguisher has annual inspection, sealed, and charged	1. Secondary containers w/ labels (name, hazard warnings)
3. Appropriate extinguisher for hazard (Class A, B, C, or D)	2. Storage areas labeled with compatibilty group
b. MSDS's available in lab or other central location	d. Special labels & storage (carcinogens, biohaz or acute toxics)
c. Safety shower present (within 75 ft or 10 sec travel)	e. No excess chems on bench tops/in hoods/under sinks
1. Unobstructed	f. Flammable storage: <10 gallon (38L) outside flammable cabinet
2. Checked/tested by Facilities Services (inspection tag)	g. Controlled substances in sturdy, locked storage
d. Eyewash present (within 75 ft or 10 sec travel)	**9. UNSTABLES-REACTIVES-EXPLOSIVES**
1. Unobstructed	a. Marked with date received & date opened
2. Checked/tested by lab within past month (inspection tag)	b. Peroxide formers marked with date to be discarded/tested
e. First Aid kit (if applicable) stocked and up-to-date	**10. WASTE CHEMICALS**
f. Exit signs & emergency lighting operating (if needed)	a. Timely waste pick-up requests (no build-up of waste in lab)
3. PROTECTIVE CLOTHING (PPE)	b. Containers have tightly-closed lids that do not leak
a. PPE (eyewear, gloves, coats) available and used in lab	c. Secondary containment for glass bottles ≤4L, or stored on floor
b. Proper eye protection use (safety glasses/goggles/face shield)	d. Waste containers are at or near the point of generation
c. Visitor glasses readily available (if visitors permitted)	e. Containers labeled for chemical contents (no abbreviations)
d. Proper chemical resistant/heat resistant/cryogenic gloves	**11. VENTILATION – HOODS & BIOSAFETY CABINETS**
e. Closed shoes (no open toe or canvas shoes) worn	a. Exhaust hood & alarm working properly
f. Rubber apron available (if concentrated acid/base use)	1. Annual inspection sticker within past year (80-120 fpm)
4. GENERAL HAZARDS	2. Sash kept at or below marked height except for set-up
a. Corridors & exit doors unobstructed	b. Biosafety cabinets certified within past year
b. Adequate lighting for tasks	c. Hood housekeeping - properly maintained, no excess storage
c. Excess trash, boxes, & paper removed promptly	**12. MECHANICAL**
d. No eating/drinking/food storage in lab (exc. designated areas)	a. Belts, pulleys, rotating parts guarded (esp. vacuum pumps)
e. Handwashing facility (with liquid soap) available	b. Stop switches easily accessible
f. Proper disposal of needles and sharp objects (metal cans)	c. Equipment is secured (i.e., bolted to floor)
g. Proper disposal of broken glass waste (lined cardboard box)	d. Electrical disconnect unobstructed
5. SPILL PROCEDURE	e. Unattended operating equipment labeled/posted
a. Spill kit available - proper size & type	**13. GAS CYLINDERS**
b. Spill procedures written in Lab Safety Plan & available	a. Properly secured (individual chain/cable recommended)
6. ELECTRICAL	b. Storage bottle with empty or full labels
a. Proper power cord use (good housekeeping, no trip hazard)	c. Cylinder labeled as to contents
1. Extension cords- temp. use, single only (no daisy chains)	d. Caps on cylinders not in use
2. Powerstrips (w/surge protection)- computer equip. only	**14. TRAINING**
3. No cording through walls, floors or ceiling	a. Lab Safety Plan training for all lab members on annual basis
b. Electrical cords not frayed & good insulation	b. Signed copies of Appendix 1-D to verify training
c. 3-pronged plugs not altered; grounding pins in place	c. Lab Safety/Managing Hazwaste training for ALL lab members
d. Ground Fault Circuit Interruptors on outlets in wet locations	d. Annual Bloodborne Training (if approp.) – documentation
e. Electrical panel boxes and disconnects unobstructed	e. Other training (radiation, laser, formaldehyde, etc.) if needed

Additional Observations and Notes: _____

Facilities Services maintenance requests: 962-3456 EHS: 962-5507; http://ehs.unc.edu

CHAPTER 2

LABORATORY SAFETY PLAN

Overview

This chapter provides detailed instructions for completing and updating the various schedules of a Laboratory Safety Plan. The Laboratory Safety Plan is a required document that outlines specific conditions, hazards, and controls in your laboratory spaces.

Table of Contents

This page intentionally left blank.

CHAPTER 2

LABORATORY SAFETY PLAN

Laboratory Safety Plans are a key element of the Chemical Hygiene Plan. The purpose of the Laboratory Safety Plan (LSP) is to provide you with safety information specific to the laboratory in which you work. Annual communication of LSP contents to laboratory personnel by the Principal Investigator provides the minimum specific training required by the Laboratory Standard. Use Appendix 1-D to document this annual training.

This chapter describes the required information to include in an LSP. You can download electronic templates (MS Word format) of LSP Schedules from the EHS website at http://ehs.unc.edu/ih/lab/lsp.shtml.

In the future, Principal Investigators will be able to submit his or her LSP online, rather than printing out a copy and mailing to EHS. This method of submittal will not change the basic steps outlined below for preparing a LSP.

Type information in the spaces provided. **Handwritten plans are not accepted.** Once the PI has completed the LSP:

- Print it,
- Sign and date it,
- File a copy in the laboratory safety notebook,
- Mail a copy to EHS, CB# 1650.

The copy filed in the "Laboratory Safety Notebook" is to be available to laboratory employees at all times.

Instructions for Preparing a Laboratory Safety Plan

Each Principal Investigator is required to prepare a Laboratory Safety Plan to supplement the Laboratory Safety Manual. Complete a separate LSP for each building in which you have laboratory space. Laboratory space is considered any location in which you use or store hazardous materials. This could include common areas that you might share with other research groups. Pages 2-4 through 2-8 cover the items that are to be included in the Laboratory Safety Plan.

Instructions for Updating a Laboratory Safety Plan

Each Principal Investigator is required to update the Laboratory Safety Plan at least **annually** or more often if changes occur. Changes include but are not limited to addition/deletion of personnel, rooms, and research processes. A PI only needs to complete Schedule A, Sections I-III for personnel changes.

Schedule A - LABORATORY PROJECT INFORMATION

Section I: Demographic Data. Provide pertinent demographic information about the Principal Investigator, including name, PID, department, CB#, location, campus phone number, after hours phone number, person responsible for safety in absence of PI, his/her campus address, campus phone number, after hours phone number, and email addresses.

The after hours number can be a home phone number, cell phone number, or pager. EHS includes this number on the laboratory entrance signs that it prepares and posts. First responders (EHS, UNC Public Safety, and Chapel Hill Fire Department) will use it to contact the PI or the Safety Supervisor in the event of an emergency after hours or on weekends.

Do not use Social Security Numbers on these forms.

Section II: Descriptions of Research, Types of Hazards, and Locations. Provide a short title of research activity covered by the plan and grant number if funded. In Table 1, indicate the schedules attached (if this is an updated plan, you only have to attach schedules that you have updated):

Schedule B: Hazardous Chemicals
Schedule C: Radioactive Materials
Schedule D: X-Ray Equipment
Schedule E: Lasers
Schedule F: Biological Hazards
Schedule G: Recombinant DNA
Schedule H: Use of Transgenic Animals or Plants

In the table, identify the room numbers covered by the plan and check under the room number which schedules or type of operation occur in that room. Schedules A and B are required for all new plans, and for updated plans where rooms are added/deleted or processed changed.

Section III: Laboratory Personnel

In Table 2, list all workers under your jurisdiction that use, or work in close proximity to, hazardous materials in the laboratory. Provide his/her PID number and employment status, and identify which types of hazardous materials each employee uses, by checking the box on the row beside the name of the employee and under the hazard type column. Each person working in the laboratory must complete a Laboratory/Radiation Worker Registration form (see Appendix 1-A for instructions).

Section IV: Employee Information and Training

The OSHA Laboratory Standard requires that supervisors advise employees of chemical hazards at the time of initial assignment and whenever new exposure situations occur. Keep a laboratory safety notebook as a reference for laboratory personnel. Indicate the location of this information

in Table 3. The Laboratory Standard requires communicating the following information to employees:

- Location and availability of the Chemical Hygiene Plan (Laboratory Safety Manual and Laboratory Safety Plan).
- Location and availability of known reference material (including material safety data sheets) on the hazards, safe handling, storage, and disposal of hazardous chemicals.
- Permissible Exposure Limits (PELs) for OSHA regulated substances and recommended exposure limits for non-regulated substances.
- Physical hazards and health hazards of chemicals in the workplace.
- Signs and symptoms associated with exposures to hazardous chemicals used.
- Documentation that each employee has received training from EHS on the OSHA Laboratory Standard.
- Documented annual review of the Laboratory Safety Plan (Appendix 1-D) for each person.

Section V: Personal Protective Equipment (PPE)

Identify the personal protective equipment required for laboratory procedures. Consult Chapter 5 of this manual for additional information and complete Table 4 in the LSP form using the following procedure:

- Conduct a walk-through survey of laboratory to identify hazards for which eye, face, and hand PPE are required.
- Identify specific work areas, materials or chemicals in the space provided under "Laboratory Operation".
- In the space under "Hazard" describe the potential hazards for which PPE is required.
- Under "PPE Required" describe the specific PPE to be worn when performing that work activity.

Section VI: Emergency Procedures

General emergency procedures are contained in Chapter 1 of this manual. Prepare specific procedures for each laboratory in the event of an emergency arising outside of the laboratory as well as those that might arise within the laboratory. These procedures should include:

- Actions to prevent damage to equipment;
- Actions to prevent loss of experiments in progress;
- Actions to secure hazardous material in use at the time an emergency is sounded;
- Chemical spill response procedures.

Section VII: Floor Plans

Prepare a floor plan for each laboratory room covered by the LSP, showing the location of hazardous materials (including wastes), benches, desks, laboratory hoods, fire extinguishers, spill

control supplies, compressed gas cylinders, and any other items that could be of concern to emergency response personnel.

Schedule B - HAZARDOUS CHEMICALS

Section I: Hazard Identification

Each research group must prepare a summary of the types of hazardous materials stored in the laboratory, to provide information to laboratory and emergency response personnel. Indicate the total quantity of each hazard/compatibility class (*Chapter 4: Proper Storage of Chemicals in Laboratories*). For most hazard/compatibility classes, detailed inventories are not required at this time. Detailed inventories are required for select carcinogens, highly toxic chemicals, and compressed gases. Refer to the Appendices to *Chapter 7: Highly Toxic Chemicals and Select Carcinogens* for examples of commonly used select carcinogens and highly toxic chemicals. Also, list biohazardous agents and the nuclides and possession limits for radioactive materials authorized for use in the laboratory.

An online Chemical Inventory System (CIS) will be available in the future, as part of the online Laboratory Safety Plan. This system will include several of the most common chemicals used in the laboratory in a drop-down menu format, each already placed in the appropriate hazard/compatibility class. Please contact EHS if you have any questions about proper classification of chemicals before the online CIS is completed, or for chemicals that are not included in the CIS.

Section II: Laboratory Safety Rules and Procedures

The UNC Laboratory Safety Manual provides basic safety protocols. Each Principal Investigator must supplement the LSM with safe handling procedures, research protocols, and other safety procedures that are specific to his or her research group. Items you are to address include:

- Detailed procedures for handling toxic chemicals and "select carcinogens" (Chapter 7) that are used in the laboratory, including designation of the work area and entry restrictions;
- Identification of materials and procedures that are to be restricted to laboratory hoods and biological safety cabinets;
- Designation of areas where eating or drinking is allowed, if any (also indicate areas on the floor plan, Section 7).

Section III: Hazardous Waste Disposal

Prepare procedures to ensure proper segregation, containment and storage of wastes. Give special attention to avoid mixing of incompatible wastes, and to ensure proper segregation to minimize disposal costs. Refer to *Chapter 12: Management of Laboratory Wastes* for detailed information on waste disposal.

Schedules C & D - RADIOACTIVE MATERIALS & X-RAY EQUIPMENT

Submit Schedule C (or Schedule D) and an updated Schedule A to EHS if this is an amendment to an existing Laboratory Safety Plan. To obtain authorization to procure and use radiation sources, a prospective Authorized User must forward Schedules C and/or D, as applicable, to the Radiation Safety Officer in EHS. The Radiation Safety Officer will review the application and schedule an interview with the prospective user to evaluate the facilities available, the training and experience of the applicant and staff for the proposed use, and the details of the proposed research using radioactive materials or x-rays.

The procedures described in the application, as modified by the Radiation Safety Officer and/or the Radiation Safety Committee, become the conditions under which they authorize a researcher and his/her personnel to use radiation sources. The Radiation Safety Officer must review any subsequent change in procedure regarding the use, storage or disposal of sources prior to instituting the change. Please read the UNC Radiation Safety Manual for more information.

Schedule E - LASERS

If this is an amendment to an existing Laboratory Safety Plan, submit Schedule E and an updated Schedule A to EHS. Provide information on the laser as requested on the form: location, laser type, manufacturer, beam characteristics, maximum output, frequency, aperture diameter, divergence, focal length, access controls, and emergency switch. List the names of the operators, and training requirements. You can revise the attached list of laser safety operating conditions to fit the specific conditions in the laboratory.

Schedule F - BIOLOGICAL HAZARDS

Provide a list of pathogens used in the laboratory, their biosafety level, and a summary of the diseases and symptoms caused by the agents in the table. Provide the following information: use of human blood, tissues, cell lines, etc. in the laboratory; potential risks for laboratory workers; whether vaccinations are to be provided or periodic serum samples taken; specific safety precautions; waste disposal; and emergency procedures.

List specific rooms in which you will conduct BSL-2 or BSL-3 work.

Schedule G - RECOMBINANT DNA

Use Schedule G to submit applications to use Recombinant DNA to the Institutional Biosafety Committee (IBC). The types of experiments that require reporting to the IBC or obtaining prior approval from the IBC include:

- Those using human or animal pathogens as host-vector systems;
- Cloning DNA from human or animal pathogens into a non pathogen host-vector system; and,
- Experiments involving whole animals and plants, including transgenic species.

The third page of Schedule G requests additional information for gene transfer experiments involving whole animals or plants. The information provided must be in sufficient detail to allow for an informed review by the committee. As with other LSP Schedules, you must type Schedule G.

List specific rooms in which you will conduct recombinant DNA work.

Schedule H - USE OF TRANSGENIC ANIMALS OR PLANTS

Use this form to submit applications to the IBC for the use of transgenic animals or plants that are imported from other labs or institutions. For transgenic animals that your laboratory prepares, use Schedule G. For Schedules G and H, you must fully describe the genetic alterations and/or foreign gene expression.

CHAPTER 3

GENERAL SAFETY PRINCIPLES AND PRACTICES

Overview

This chapter lists and describes several major categories of hazardous materials and/or hazardous operations that you could work with in your lab. For each category, the chapter includes recommended safe work practices and regulatory requirements (if applicable).

Table of Contents

This page intentionally left blank.

CHAPTER 3

GENERAL SAFETY PRINCIPLES AND PRACTICES

I. Safety Awareness

Everyone involved in laboratory operations - from the highest administrative level to the individual workers - must be safety minded. Safety awareness can become part of everyone's habits only if senior and responsible staff demonstrates a sincere and continuing interest in safety, and discusses it repeatedly. Over-familiarity with a particular laboratory operation may result in overlooking or underrating its hazards. This attitude can lead to a false sense of security, which frequently results in carelessness. Be alert to unsafe conditions and actions and call attention to them so that one can make corrections as soon as possible. Every laboratory worker has a basic responsibility to himself/herself and colleagues to plan and execute laboratory operations in a safe manner.

II. Unattended Operations

Frequently, laboratory operations must run continuously or overnight. Equipment and experiments that run unattended during the day or overnight can cause significant problems and harm to personnel, facilities, and equipment. If unattended operations are necessary, it is essential to plan for potential interruptions in utility services such as electricity, water and inert gas. Make sure you perform a hazard analysis to identify potential consequences of failures in utility services or equipment. Design operations to be "fail-safe", so that one malfunction will not cause a propagation of additional failures.

If necessary, arrange for routine inspection of the operation. If appropriate, leave laboratory lights on during unattended operations, and place a sign on the entrance door. Appendix 3-C is an example sign for unattended operations. You can use this design, or a similar type, to convey critical information to personnel (such as other lab personnel, maintenance, housekeepers, or incident responders) who could encounter your unattended operation. Contact EHS if you have any questions.

A. Frequently Asked Questions about Unattended Operations:

1. What is meant by "unattended operation"?

For the purposes of this section, an unattended operation is any unmonitored lab activity that has the potential to release water, gas, chemical substances, electrical energy, or chemical energy during foreseeable failures of equipment or utility services.

2. Which types of unattended operations would require door signage?

Any unattended operation which could potentially harm personnel (such as maintenance workers or housekeepers) due to contact during normal operation or failure; or which could cause substantial damage to property or the environment during failures.

Example: Soxhlet extractor (Figure 3.1)

- Should stay attended, but would certainly require a door sign if unattended.
- The hot plate could burn to the touch.
- In the event of flask breakage, a fire could start if a flammable solvent such as hexane or petroleum ether is in use.
- A rupture of the condenser water line could flood the lab or rooms below.

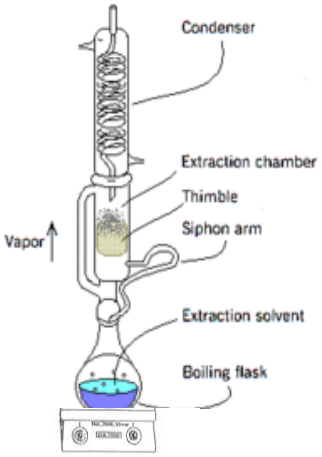


Figure 3.1 –
Soxhlet Extractor

3. What are some examples of "fail-safe" designs?

Fail-safe designs help ensure that a failure will leave the experiment unaffected, or convert it to a state that minimizes injury or damage. Examples include:

- Water flow monitors and solenoid valves that shut off water to a condenser in the event of water line rupture;
- Temperature-sensing monitors that turn off power to hot plates or vessels if the temperature exceeds a pre-set limit for any reason;
- Automatic gas shutoff valves that shut off gas flow in the event of a power outage, leak, or significant seismic event.

III. Eating, Drinking and Smoking

Contamination of food, drink, tobacco products, and cosmetics is a potential route for ingestion of a hazardous substance. University policy prohibits smoking in University buildings. Store, handle, and consume food and drink items in areas free of hazardous substances. Consider designating non-laboratory areas, such as nearby break rooms, lounges or conference rooms, as food storage and eating areas for laboratory personnel.

When you establish food areas within laboratory spaces, observe the following rules:

1. Establish well-defined, fully outlined areas (including desks, cabinets, microwaves and refrigerators) within the lab space.

2. Clearly post a sign designating the food item area(s) and instructing that no radioactive, chemical, or infectious materials are permitted. Example sign is available at http://ehs.unc.edu/ih/lab/labels/docs/food_area.pdf.

3. Food item areas must be at least three feet from a laboratory work area or chemical storage area. In some instances, EHS may permit, upon evaluation, less than three feet if an appropriate barrier is in place. In other cases, three feet may be inadequate to prevent contamination of food items, i.e., laboratory operations with a high potential for aerosolization and volatilization of chemicals, radioactive materials, or biological materials.

4. EHS does not permit food areas in rooms with such operations. The design of some laboratories may not allow for the designation of food areas.

5. Wash food containers, dishes, and utensils only in sinks exclusively designated for food utensils. Wash laboratory glassware or equipment in separate sinks. Do not use glassware or utensils used for laboratory operations for food or beverages.

6. Do not use laboratory refrigerators, ice chests, and cold rooms for food storage. Use separate, dedicated equipment with prominent labels that state "Food/Drink Use Only" or similar wording (http://ehs.unc.edu/ih/lab/labels/docs/food_use_only.pdf is an example).

7. Designated food item areas must be free from all research-related items, including personal protective equipment (e.g. lab coats, gloves, safety glasses).

8. Do not allow any chemical, radioactive, or biological materials storage above a designated food item area.

IV. Housekeeping

Safety performance and orderliness in the laboratory are related. When housekeeping standards fall, safety performance inevitably deteriorates. Keep work areas clean, and properly label and store chemicals and equipment. Cleanup should follow the completion of any operation or at the end of each day. Deposit wastes in appropriately labeled receptacles, and clearly mark temporary holding containers. Do not accumulate unneeded chemicals. Stairways and hallways cannot be storage areas. Maintain free, unobstructed access to exits and emergency equipment, such as eyewash stations and emergency showers.

V. Working Alone

Avoid performing experiments alone in a laboratory building. Arrange with individuals working in separate laboratories outside of working hours to cross check periodically. Alternatively, UNC Police can check on laboratory workers. Do not undertake experiments known to be hazardous when alone in a laboratory.

Under unusual conditions, special instructions may be necessary. The Principal Investigator must determine whether the work requires special safety precautions, such as having two persons in the same room during a particular operation.

VI. Hazard Information Signs and Placards

Post laboratory areas that have special or unusual hazards with hazard information signs and labels. Standard signs and symbols exist for a number of special situations, such as radioactive materials, radiation hazards, biological hazards, fire hazards and laser operations. Other signs shall be posted to show the locations of safety showers, eyewash stations, exits and fire extinguishers. Fire extinguishers are to be labeled to show the type of fire for which they are intended. A green on white placard must be posted to designate emergency eyewash and shower facilities. Waste containers must be labeled for the type of waste for which they are intended. The safety- and hazard- sign systems in the laboratory should enable a person unfamiliar with the usual routine of the laboratory to escape in an emergency (or help combat it, if appropriate). The EHS Safety Labels page is located at http://ehs.unc.edu/ih/lab/labels/.

EHS provides signage for laboratory entrances, based on information provided by the laboratories. Contact EHS if you have any questions or concerns about signage within the laboratory, or entrance signs.

VII. Labels on Chemical Containers

Label all containers of hazardous materials to identify the contents. University labeling requirements and guidelines include the following:

- Inspect incoming containers of hazardous chemicals to ensure that containers have legible labels.

- If you receive a new chemical (one not previously used in your laboratory), retain the Material Safety Data Sheet (MSDS) for the laboratory file, unless your lab prefers to maintain MSDSs electronically. Inform laboratory personnel about the hazards of the chemical. See Chapter 1 of this Manual for information on obtaining MSDSs.

- If the composition of a chemical produced in the lab is unknown, assume it is hazardous.

- If you produce a chemical for another user outside the lab, you must comply with the provisions of 29 CFR 1910.1200, including preparation of an MSDS. Contact EHS for assistance.

- Clearly spell out the name of the chemical on the label any time you transfer substances from original containers to secondary containers, or when synthesizing/mixing new substances, if the substances are not for the immediate use of the handler or preparer. Do not use molecular formulas as sole identification. For example, do not write H_2SO_4 only on a label to identify the contents as sulfuric acid. The label must read "Sulfuric Acid".

- In the case of buffer solutions, it is appropriate to identify the contents as "Buffer Solution" and include the type of buffer in its abbreviated form (e.g. "Buffer Solution - Tris"). Consult the EHS Safety Labels Page for examples.

VIII. Eyewash and Safety Shower Facilities

Emergency eyewash and safety showers are required in buildings within 10 seconds travel distance and not more than 75 feet from where toxic chemicals are used. These facilities must be on the same level as the chemical area; there can be no stairs or ramps between the hazard and the eyewash and/or safety shower. Units must be plumbed units that meet the ANSI Standard Z358.1-2004 (Figure 3.2).

Some field operations and other locations where plumbing connections are not available might require a non-plumbed unit (Figures 3.3a and 3.3b). Do not use these non-plumbed units in areas where plumbed units can be installed. Non-plumbed units are available that meet the ANSI requirements for flow and duration (1.5 liters/0.4 gallons per minute for 15 minutes). However, non-plumbed units are more difficult to maintain. Their solutions require frequent changing per manufacturer's instructions. Because most non-plumbed units do not have a significant reserve capacity, you must refill them after every use or test to ensure they maintain the required minimum flow and duration.

Figure 3.2 – Plumbed Eyewash Stations.
Pictured are common variations of plumbed eyewash stations that meet ANSI requirements.
Note that all have a single-motion activation method.

a **b** **c**

Figure 3.3 – Non-Plumbed Eyewash Stations (a, b) and Eye Flush Squeeze Bottle (c).
Eye flush squeeze bottles cannot substitute for approved eyewash due to insufficient water delivery capability.

Hand held drench hoses in laboratories are a supplement, but not a substitute, for an eyewash and safety shower. Personal eye flush squeeze bottles (Figure 3.3c) do not meet ANSI requirements, because they cannot deliver the required minimum flow rate and duration. EHS discourages the presence of these bottles in your lab because they have a limited shelf life, are prone to contamination, and are ineffective at dual-eye or eye-face irrigation.

Because some chemicals, even in small amounts, can irritate or damage skin upon contact, flush affected areas with water as soon as possible. Remove personal protective equipment and clothing in the areas of chemical contact once you or your co-workers have activated the shower. Fellow workers may need to help remove contaminated clothing. Call 911 if immediate medical attention is necessary. Contact the University Employee Occupational Health Clinic (6-9119) immediately. Remain in the shower or continue flushing the eyes for no less than 15 minutes.

Each research group is responsible for ensuring that emergency eyewash facilities, both within its laboratory space and in nearby common areas, remain operational and accessible. Check the system at least once a month. A quick (~5 second) activation of the eyewash verifies water pressure, and flushes rust, scale, and other debris out of the system. Perform these checks on all eyewash facilities that your research group might use, even if the facilities are located in common areas outside the group's lab room(s). Verify monthly eyewash checks by filling out inspection tags located on or near the units. If the eyewash does not have an inspection tag, contact EHS. After performing the monthly check, make sure that water does not remain on the floor to create a slip hazard for personnel. This is an especially important consideration for eyewash facilities located in common corridors and that lack floor drains. For these facilities, use buckets, secondary containment trays, or other collection devices to prevent discharge of water directly onto the floor.

Facilities Services checks safety showers and has the equipment necessary to contain, collect, and cleanup the large volume of water discharged by a safety shower test.

IX. Maintenance Personnel

Laboratory research may also expose maintenance, housekeeping, and other support personnel to potential physical and chemical hazards in the laboratories. You can keep their exposure risk to a minimum by proper labeling of waste containers (refer to LSM Chapter 12) and decontaminating equipment before servicing. Before requesting service of laboratory equipment by maintenance personnel complete and attach a Safety Clearance Form (Appendix 3-A) to the equipment.

When you surplus laboratory equipment you must affix the "Surplus Property" version of the Safety Clearance Form. This is an orange sticker with the same information as the paper version but it will not fall off in transit. Call EHS (2-5507) to request these stickers. The University will pick up surplus property; however, personnel will not pick up laboratory equipment without the proper "Surplus Property" sticker. Check with your business office for current surplus procedures.

X. Equipment Decontamination

The following are some general decontamination guidelines. Refer to the Radiation Safety Manual for questions concerning radioactive contamination. Refer to the Biological Safety Manual for questions concerning biological contamination. Contact EHS if you have additional questions about equipment decontamination.

- Safely remove, drain, or discharge chemicals from the equipment, collecting the chemicals for re-use or hazardous waste disposal.

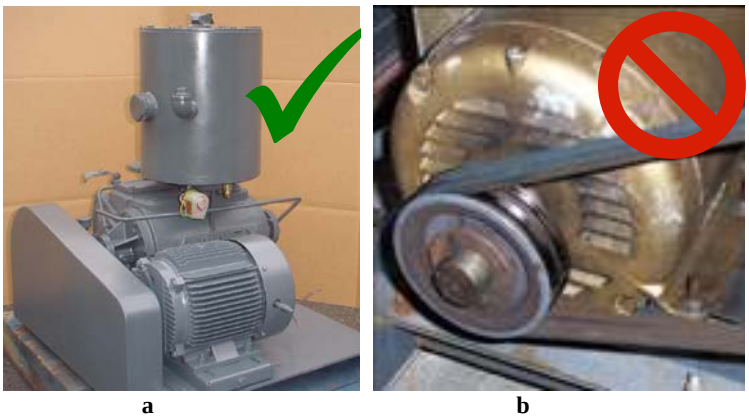
- If applicable, use an inert gas or liquid to purge the chemical residues. In some cases, the rinsate might require disposal as hazardous waste.

- For equipment with non-permeable surfaces, decontaminate by scrubbing with warm, soapy water.

- For equipment that also might contain biological contamination, follow the soapy water wash with a 1:10 bleach solution soak. Rinse the equipment after at least 10 minutes contact time with the bleach.

XI. Machine Guarding

All mechanical equipment must be equipped with guards that prevent access to electrical connections or moving parts (such as the belts and pulleys of a vacuum pump). Inspect equipment before use to ensure that the guards are in place and functioning. Careful design of guards is vital. An ineffective guard can be worse than no guard at all, because it may give a false sense of security. Emergency shutoff devices might be necessary, in addition to electrical and mechanical guarding. Contact EHS if you have questions or concerns about guarding.



a **b**

Figure 3.4a - Vacuum pump with proper guard over the belt and sheaves.
Figure 3.4b - Missing guard, causing dangerous nip points.

XII. Safety Shielding

Use safety shielding for any operation having the potential for explosion such as:

- When performing a reaction for the first time (use small quantities to minimize hazards),
- When a familiar reaction is carried out on a larger than usual scale (e.g., 5-10 times more material), and
- When you carry out operations under non-ambient conditions; place shields to protect all personnel in the area from the hazard.

XIII. Compressed Gases

The use of compressed gases on campus is to be in accordance with recommendations published by the Compressed Gas Association. The following rules summarize basic guidelines for the use and storage of compressed gases:

1. All compressed gas cylinders must bear labels that clearly identify the contents.
2. Compressed gas cylinders must be supported at all times, whether full or empty (Figure 3.5a). Acceptable methods of support include:

   a. wall-mounted or bench-mounted gas cylinder brackets;
   b. chains or belts anchored to walls or benches; and
   c. free standing dollies or carts designed for gas cylinders and equipped with safety chains or belts.

   Make sure that any chains, belts, or wall anchors supporting multiple cylinders have the strength to support the weight of the entire potential load. Do not overload support systems.

3. Gas cylinders must have the valve protection cap in place except when in use. A cylinder connected to a piece of equipment and properly supported is “in use”. Remove the pressure regulators and replace valve protection caps before moving cylinders, even if you have secured the cylinders to a dolly or hand truck. For example, do not transport acetylene and oxygen cylinders, used for cutting and brazing with regulators attached to the cylinders, except in the cylinder cart.
4. Post all hydrogen and/or acetylene storage and usage locations with permanent placards that read: "HYDROGEN/ACETYLENE - FLAMMABLE GAS - NO SMOKING - NO OPEN FLAMES."
5. Gas cylinders must be in an upright position and clamped securely at all times. Because of the extreme hazards created by using certain cylinders in a horizontal position (e.g., acetylene), you must consult EHS before using cylinders in any position other than vertical, with the valve up.

a

b

Figure 3.5:

(a) – Gas cylinders in storage with no method of support to prevent them from tipping over. Note that cylinders "in use" to the left do not require valve protection caps. However, ALL cylinders require support.

(b) – Properly supported cylinders.

6. Use appropriate dollies or hand trucks to move cylinders weighing more than 50 pounds. Do not move cylinders by spinning, sliding, rolling, etc. For movement within shops and laboratories, one may carry cylinders weighing less than 50 pounds, if desired.

7. Keep cylinders of all gases having a health hazard rating of three or four, such as ammonia, carbonyl sulfide, hydrogen cyanide, hydrogen sulfide, methylamine, and nitric oxide, in hoods or other enclosures that vent directly outside. Each hood or enclosure may not have more than three cylinders of this type. Provide appropriate and clearly marked first aid, antidote information, and supplies at room entrances. Material safety data sheets must be available, either in hard copy or electronic format.

8. Installed piping systems for flammable gases, toxic gases and oxygen must be in accordance with OSHA, NFPA, and ANSI standards and approved by EHS.

9. Pressure regulators and gauges must be compatible with the cylinder valves. You may not use "cheaters" (adapters) instead of the correct regulator and gauge.

10. All oxygen valves, gauges, regulators, pipes and fittings must be scrupulously free of oil, grease, graphite or any other oxidizable substance. For this reason, do not use soap-based leak detectors on oxygen cylinder regulators or fittings. Oxygen pipes, gauges, fittings, etc., must not reach elevated temperatures due to proximate welding operations, burners or other heat sources. Although oxygen is quite safe under normal temperatures and pressures, elevated temperatures and/or pressures (or contamination) may result in the rapid and violent oxidation of normally non-reactive materials. For example, a regulator used in oil-pumped nitrogen could produce a serious explosion if subsequently used for oxygen, due to the oil residue.

11. There are two general types of compressed gas cylinders: returnable (owned by the gas supplier, demurrage charged to the University) and non-returnable. Most suppliers will accept the return of their cylinders even if they are not empty (pressure approaching atmospheric). However, suppliers will not accept non-returnable cylinders under any circumstances. Disposal of non-returnable cylinders containing highly toxic or reactive gas can be very expensive. Therefore, purchase compressed gases in returnable cylinders if available. If non-returnable cylinders are the only alternative, be prepared to use all of the gas or pay for the cost of disposing of any leftover gas.

XIV. Systems Under Pressure

Do not carry out reactions in, or apply heat to, a closed system apparatus unless it is designed and tested to withstand pressure above atmospheric. Pressurized systems must be equipped with an appropriate relief device. If you cannot open the reaction directly to the air, use an inert gas purge and bubbler system to avoid pressure buildup.

XV. Cold Traps and Cryogenic Hazards

The primary hazard of cryogenic materials is their extremely low temperature. Cryogenic materials, and surfaces they cool, can cause severe burns if allowed to contact the skin. Wear gloves and a face shield when preparing or using cryogenic liquids. Do not use liquid nitrogen or liquid air to cool a flammable mixture in the presence of air, because oxygen can condense from the air and lead to an explosion hazard. Read Appendix 3-B (Cryogenic Hazards) for more information.

Use insulated gloves when handling dry ice. Add dry ice slowly to the liquid portion of the cooling bath to avoid foaming over. Avoid lowering your head into a dry ice chest: carbon dioxide is heavier than air, and suffocation can result. Do not store dry ice or liquid nitrogen in walk-in cold rooms; carbon dioxide or nitrogen can displace and thus lower the oxygen concentration in enclosed spaces.

XVI. Glassware

Accidents involving glassware are a leading cause of laboratory injuries. Use careful handling and storage procedures to avoid breaking glassware. When you use adequate hand protection when inserting glass tubing into rubber stoppers or corks or when placing rubber tubing on glass hose connections, you can prevent injuries. Tubing must be fire polished or rounded, and lubricated. Hold your hands close together to limit movement of glass should it break. Consider the use of plastic or metal connectors.

Do not attempt glass-blowing operations unless proper annealing facilities are available.

Handle vacuum-jacketed glass apparatus with extreme care to prevent implosions. Tape or shield equipment such as Dewar flasks. Only use glassware designed for vacuum work for that purpose.

Provide proper instruction in the use of glass equipment designed for specialized tasks, which can represent unusual risks for the first-time user. (For example, separator funnels containing volatile solvents can develop considerable pressure during use).

Glassware that is heated should be Pyrex or a similar heat-treated type. Use gloves, preferably leather, when picking up broken glass. Sweep up small pieces with a brush into a dustpan. Dispose broken glassware in a special container marked "CAUTION: GLASS AND SHARPS – Non-Hazardous Materials Only" (available on EHS Safety Labels page). Refer to the section in Chapter 12 entitled *Disposal to General Wastes - Sharps* for glass and sharps disposal policy.

Treat broken thermometers as hazardous waste. Refer to the mercury disposal and cleanup section in Chapter 1 for further information.

XVII. Needles and Sharps Safety

Needlestick injuries and cuts are frequent occurrences in laboratories. For needles contaminated with a toxic chemical or pathogenic organism, the consequences can be serious. You can reduce the likelihood of injuries by limiting the use of syringes and needles. Consider finding alternative procedures or use of a blunt needle. Other safety precautions include:

- Do not recap needles.
- If recapping is necessary, use a one-handed scoop method or a one-handed recapping device. EHS must approve the necessity and method used to recap needles, and you must document the procedures in your Laboratory Safety Plan.
- Do not remove needles from syringes.
- Do not bend, break, or otherwise manipulate needles.
- Discard in puncture resistant containers.

Razor blades are common in laboratories, and are another potential source of injury. Keep razor blades sheathed when not in use. If your lab uses blades that do not have sheaths, use a Styrofoam block, adhesive tack, or other material to prevent exposure to blades between uses. Do not store these blades unprotected on countertops, or in drawers where personnel could reach in and cut their hands. Dispose these blades in appropriate sharps containers; see Chapter 12: Management of Laboratory Wastes for further guidance.

XVIII. Electrical Safety

Electrical equipment now comprises a major part of the modern laboratory, thus posing a new set of possible laboratory hazards. Periodic laboratory inspections should pay particular attention to electrical safety. Incorporate electrical safety into the initial design and setup of laboratory equipment and apparatus. You must install and maintain all new electrical equipment, whether permanent or temporary, in accordance with the provisions of the National Electric Code (NEC). The latest edition of the NEC is NFPA 70 - 2005. Every replacement, modification, repair, or rehabilitation of any part of any electrical installation must comply with NEC standards.

1. **Proper Wiring:** Only Facilities Services may authorize modifications or changes to circuits or building equipment. All sources of electrical potential for either service or experiments must have adequate grounding and circuit breaking. University policy allows flexible extension cords only as temporary extension cords for portable equipment. Permanent wiring and receptacles are required for routinely used equipment or apparatus. Maintain all cords and plugs in a safe condition. You may use multi-outlet power strips for computer workstations, but not in any other part of the laboratory requiring multiple outlets. In this case, Facilities Services must install additional hard-wired outlets. A list of possible wiring hazard follows:

- spliced cords
- worn-out cords
- inadequate strain relief for plugs (causing cord to pull away from plug housing)
- tripping hazards from poorly positioned cords
- cords with missing ground pins
- cords draped near hot plates or open flames
- cords used near sinks or other wet locations unless protected with ground fault circuit interrupter (GFCI).

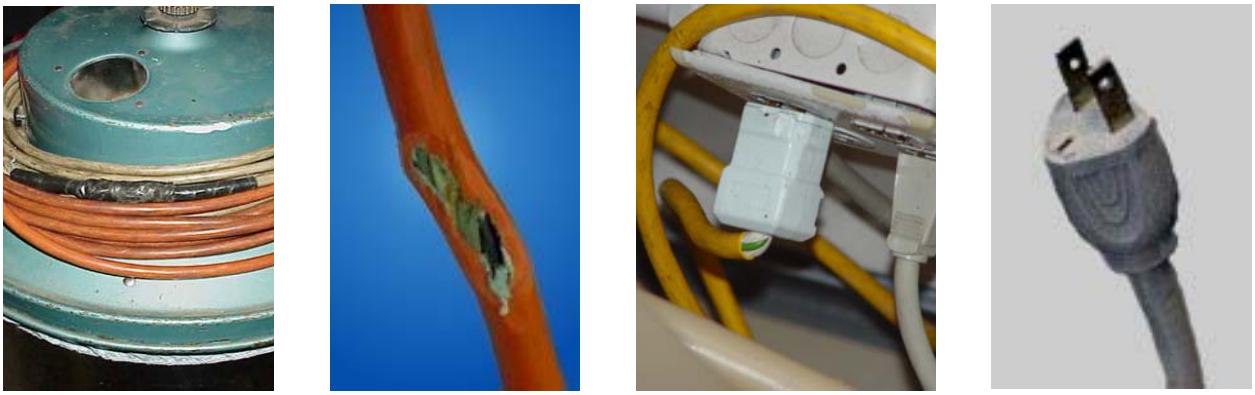


Figure 3.6 – Common Electrical Cord Hazards (left to right):
Spliced cords, worn-out or damaged insulation, inadequate strain relief, missing ground pin.

2. **Grounding and Bonding:** You must ground all exposed non-current-carry metal covers and other parts that are liable to energize. This includes the chassis of refrigerators, freezers, centrifuges, etc. When you transfer flammable liquids in metal containers, avoid static generated sparks by bonding between containers with the use of ground straps.

3. **Isolation:** Power sources must be isolated to prevent accidental contact, which could result in serious electrical shock. Take the following precautions to isolate power sources.

   a. Ensure a labeled switch is in a readily accessible location for shutting off the power to laboratory equipment or apparatus in case of emergency. Make sure that all switches are accessible and not blocked by other equipment or lab clutter.

   b. All electrical equipment or apparatus requiring frequent attention must be electrically isolated with a fused disconnect switch.

   c. Enclose all power supplies for experiments, so that accidental bodily contact with power circuits is impossible. Access doors must have interlocks. Even for temporary arrangements, enclosures are required.

   d. Use lockout and tagout on appropriate disconnect switches to de-energize electrical power to equipment being worked on. A lockout/tagout system makes it impossible to energize a

piece of equipment while the lock/tag is in place. Use a voltage tester to ensure the correct circuit is "dead."

You should never work alone around energized electrical equipment. Know the procedure for removing a person from contact with a live electrical conductor, and the emergency first-aid procedures for persons who receive a serious electric shock.

Ground Fault Circuit Interrupters (GFCI):
Additional Information

GFCI detect ground faults, also known as leakage currents, and in response open the circuit to halt the flow of electricity. GFCI can protect you if part of your body becomes a path for electrical current to ground. The leakage current threshold that "trips" a GFCI is typically five milliamps (5 mA). This is much lower than the threshold to trip a typical non-GFCI circuit breaker (usually at least 15 amps). GFCI can protect both equipment and personnel, whereas circuit breakers can only protect equipment.

Figure 3.7a – GFCI outlet

Figure 3.7b - non-GFCI outlet

Figure 3.7 c – GFCI adapter

Figure 3.7d – GFCI cord

GFCI outlets usually have two small buttons labeled "TEST" and "RESET" in the center (Figure 3.7a). Outlets located near sinks or other wet locations are to be GFCI outlets. Some circuits have GFCI protection at the circuit breaker, rather than the outlet; thus, the outlet might look like a non-GFCI version but the circuit is GFCI protected. Functional GFCI systems ensure that the worst result if one becomes a path to ground is a brief 5 mA shock, which is painful but not fatal.

Keep in mind that GFCI circuits trip more frequently than non-GFCI. De-energization of experimental apparatuses could damage equipment, destroy research, or even cause accidents (e.g. spills or releases). Consider the potential consequences of de-energization before using GFCI circuits, especially for operations you leave unattended. Fail-safe designs might be necessary.

Contact EHS if you have questions about areas that might require GFCI protection. Contact Facilities Services to have GFCI outlets installed, or to report GFCI outlets that trip frequently. Alternately, you can plug GFCI adapters (Figure 3.7c) or GFCI cords (Figure 3.7d) into non-GFCI outlets in wet locations. Note that flexible extension cords (including GFCI cords) are for short-term use with portable equipment, and are not a substitute for permanent wiring.

4. **Electrical Fires:** Poor contacts at electrical connections and overloaded circuits can cause fires. Poor contacts between plugs and receptacles can cause arcing, which could lead to serious fire hazards. Overloaded circuits can cause fire by overheating. Extension cords or cube taps can overload circuits. Multi-outlet boxes with built-in switches, pilot lights, circuit breaker, and reset provide better protection than cube taps.

Disconnect electrical soldering irons, hot plates, and other electrical heating equipment when not in use. Use fire- resistant metal sheets under heating equipment to protect work surfaces. Electric heating equipment should be equipped with a temperature-sensing device that turns off the electric power if temperature exceeds the preset limit.

Unattended overnight operations (see Section II) of electric heating devices, stills, etc. should incorporate fail-safe devices that sense temperature, flow, liquid level or electrical overload. You should only use hot plates for heating liquids with flash points above 100 ^{o}C. Steam baths are required for heating liquids with low flash points, e.g., ethyl ether.

You must plug all electrical equipment used in a laboratory hood into a receptacle outside the hood. Rheostats used to control equipment in a laboratory hood must be located outside the hood, as it is a spark-producing device that is not constructed to protect against liquid splashes or spills.

5. **Explosive Atmospheres**: Specially designed electrical equipment is necessary in areas where hazardous mixtures of explosive gases, vapor, or dusts are present (Article 500, National Electrical Code). Explosion-proof equipment, intrinsically safe circuits, purged enclosures, and positive-pressure ventilation are appropriate for operations in hazardous location. Some examples are:

   - Flammable liquid storage rooms
   - Flammable compressed gas storage rooms
   - Motors and stirrers for solvents and oil baths
   - Centrifuges using flammable liquids
   - Refrigerators for storing flammable liquids
   - Walk-in environmental chambers.

XIX. Storage in Buildings with Sprinkler Systems.

North Carolina Building Code and National Fire Protection Association (NFPA) standards require an 18-inch minimum clearance between the sprinkler head and the top of storage. The 18-inch requirement is not intended to limit the height of permanent shelving on a wall, if the shelving is incorporated into the building design and not directly below the sprinklers. Such shelving may extend above the 18-inch plane below the sprinkler. Shelving added to the building post-construction and any storage on the shelves may not extend above the plane 18 inches below the sprinkler head.

APPENDIX 3 – A

SAFETY CLEARANCE FORM

(For Surplus Property, use the sticker version of this form available by request at 962-5507.)

Principal Investigator: _____

Department: _____

Room Number: _____

Equipment: _____

Serial Number: _____

This is to certify that the laboratory equipment and/or room listed above is considered safe for maintenance work and/or occupancy. For Surplus Property, use the sticker version of this form available by request at 962-5507. All hazardous materials have been removed. All potentially contaminated surfaces have been decontaminated in accordance with Environment, Health & Safety requirements.

	circle
hazardous materials removed	yes / no
cleaned	yes / no
decontaminated	yes / no
rad safety survey conducted	yes / no
<600 dpm/100 cm^2	yes / no
<0.05 mR/hr or 500 cpm	yes / no
exceptions _____	
warning signs removed/covered	yes / no
inspected to verify above	yes / no

_____ _____

Signature, Principal Investigator Date

Surplus Property

For Surplus Property, use the sticker version of this form available by request at 962-5507.

APPENDIX 3 – B:

CRYOGENIC HAZARDS

(Post on cryogen tanks/Dewars).

Follow these necessary precautions:

- Know the first aid procedures for frostbite before using, handling, or storing a cryogenic liquid.
- Keep flammables and combustibles well away from liquefied oxidizing gases. For example, under suitable conditions, steel burns when in liquid oxygen.
- Avoid pouring a cryogenic liquid on or over the edge of a glass Dewar flask when filling or emptying the flask; the flask may break and implode.
- Do not put a cryogenic liquid into a household Thermos bottle or other insulated container ordinarily used to keep food or drinks cold.
- When using, handling, or storing cryogenic liquids, wear a laboratory coat without pockets (or at least without outside pockets) or wear a laboratory apron. Wear cuffless pants and high-topped leather shoes; to deflect any spills, the bottoms of the pants should cover the tops of the shoes. Remove watches, rings, and other jewelry.
- The eyes are particularly vulnerable to harm from exposure to cryogenic liquids. Wear both Type G, H, or K safety goggles and a Type N face shield when using, handling, or storing cryogenic liquids.
- If it is necessary to handle chilled parts of the apparatus, consider wearing insulating gloves. If the gloves become contaminated with an oxidizing cryogenic liquid, handle the gloves as though they are flammable for at least 24 hours.
- Avoid skin contact with cryogenic liquids. Even a very brief contact can result in severe frostbite and/or torn flesh.
- Laboratory workers who use, handle, or store toxic cryogenic liquids and all others in the area should wear appropriate respiratory equipment.
- Avoid inhaling air that has been cooled to near-cryogenic temperatures.
- The chilled vapors from evaporated cryogenic liquids tend to accumulate in pits and low-lying areas. These gases are of course invisible and have partially or completely displaced oxygen from the areas they occupy. Do not enter such areas without wearing an oxygen-supplying respirator.
- Never transport cryogenic liquids in an elevator. In the event of elevator malfunction, the resulting collection of evaporated gas in the elevator shaft from the cryogenic liquid could be disastrous.* Even a so-called closed Dewar has a pressure relief valve that can release evaporating vapors.
- Many solids become brittle and fragile at cryogenic temperatures. Before allowing an unfamiliar solid to be chilled to cryogenic temperatures, learn its properties at such temperatures.
- Immediately evacuate any area in which there is an uncontrolled release of a cryogenic liquid or vapor.

For more information, see Alaimo's *Handbook of Chemical Health and Safety* and the Compressed Gas Association's *Safe Handling of Cryogenic Liquids.*

Adapted from *Safety in Academic Chemistry Laboratories, American Chemical Society, 7th Ed.*

*If accumulated in an elevator shaft, nitrogen and other inert gases are asphyxiants; accumulations of oxygen and other oxidizing gases can cause spontaneous ignition and explosion; and accumulations of flammable gas are explosive.

APPENDIX 3 – C: UNATTENDED OPERATION EXAMPLE SIGN

NOTICE

UNATTENDED OPERATION

Type of Equipment/Experiment:

Location:

In case of emergency, contact:

This page intentionally left blank.

CHAPTER 4

PROPER STORAGE OF CHEMICALS IN LABORATORIES

Overview

This chapter instructs you how to interpret the labels on chemical containers, and how to safely store chemicals in the laboratory in a way that minimizes incompatible chemical reactions, spillage, breaking, or waste due to expiration.

Table of Contents

This page intentionally left blank.

CHAPTER 4

PROPER STORAGE OF CHEMICALS IN LABORATORIES

I. Inventory and Inspection

Each laboratory should maintain an inventory of the chemicals stored in the laboratory. Designate a storage place for each chemical, and return it to that place after each use. Store chemicals by hazard class, not the alphabet, and post storage areas to show the exact location of the chemical groups. Inspect chemical storage areas at least annually for outdated or unneeded items, illegible labels, leaking containers, etc. See Chapter 12: Management of Laboratory Wastes for advice on disposing outdated or unneeded chemicals. For advice on developing an inventory system, please contact EHS.

Figure 4.1 –

Examples of chemicals in poor condition, that you should NOT keep stored in your lab:

- ✓ Expired/outdated chemicals
- ✓ Illegible/removed labels
- ✓ Degraded containers
- ✓ Leaking lids

II. Proper Sealing of Chemical Containers

To prevent leakage, odors, or reaction with air, tightly seal all containers of highly toxic, highly volatile, malodorous, carcinogenic or reactive chemicals. Make sure that caps and other closures are tight on all hazardous chemicals. A limited exception is freshly-generated mixtures such as acids and organics that may generate gas pressure sufficient to burst a tightly sealed bottle. Keep the lids loose until sufficient time passes to complete the reactions, and then tightly close the lids. Until all reactions are completed, the contents of the bottle are not waste, but are instead the last step of the chemical procedure.

The best seal is the screw-cap with a conical polyethylene or Teflon insert (Figure 4.2). Seal the caps with tape or Parafilm® "M" as a further precaution. Additional protection can include wrapping in an absorbent paper and sealing inside a plastic bag, and storing the bag inside a metal can with a friction-fitting lid.

Figure 4.2 –

(Left) Screw caps with conical polyethylene inserts.

(Right) Screw caps with Teflon inserts.

III. Smaller Container Sizes - Less is Better

The real, or "life-cycle", cost of a chemical includes its initial purchase price plus the ultimate disposal costs. Keep the quantity of accumulated chemicals in the laboratory at a minimum to reduce the risk of exposures, fires, and waste disposal problems. Smaller package sizes provide the following advantages:

- Reduced storage hazards
- Reduced storage space
- Safety in handling smaller quantities
- Reduced losses due to out-of-date chemicals
- Minimized cost of disposal of "leftovers"

Frequently, it costs many times more than the original purchase price to dispose of leftover chemicals. The costs for waste disposal can run from approximately $1.00 per gallon for non-halogenated solvents to more than $50.00 per pound, including the weight of the container, for reactives, e.g., sulfides, cyanides, flammable solids. Chemical storerooms on campus keep supplies of the most frequently used solvents and chemicals to lessen the need for laboratory stockpiles.

IV. Storage Symbols

Most chemical manufacturers include chemical storage symbols on their labels. Many manufacturers use symbols that include a hazard ranking system, such as the National Fire Protection Association (NFPA 704) diamond symbol or the Hazardous Materials Identification System (HMIS) colored rectangle. Picture glyphs are another common label element. Below are examples of the NFPA and HMIS hazard ranking systems (Figure 4.3), and glyph systems from the European Union (Figure 4.4) and Canada (Figure 4.5) which are commonly seen on U.S. chemical labels and material safety data sheets.

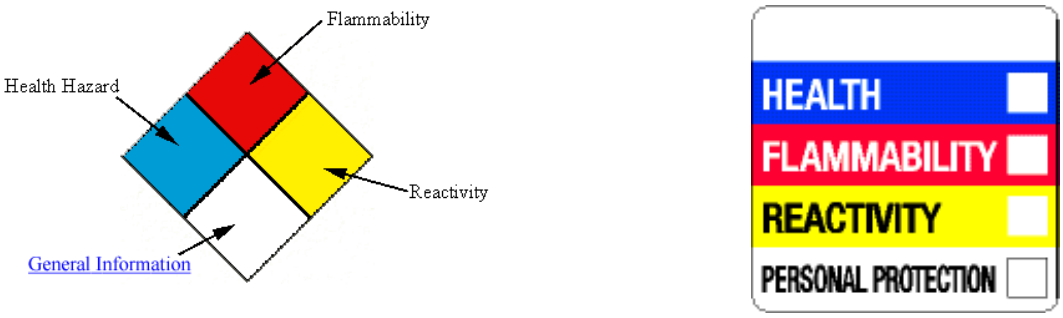


Figure 4.3 –
NFPA diamond symbol (left), HMIS label (right)

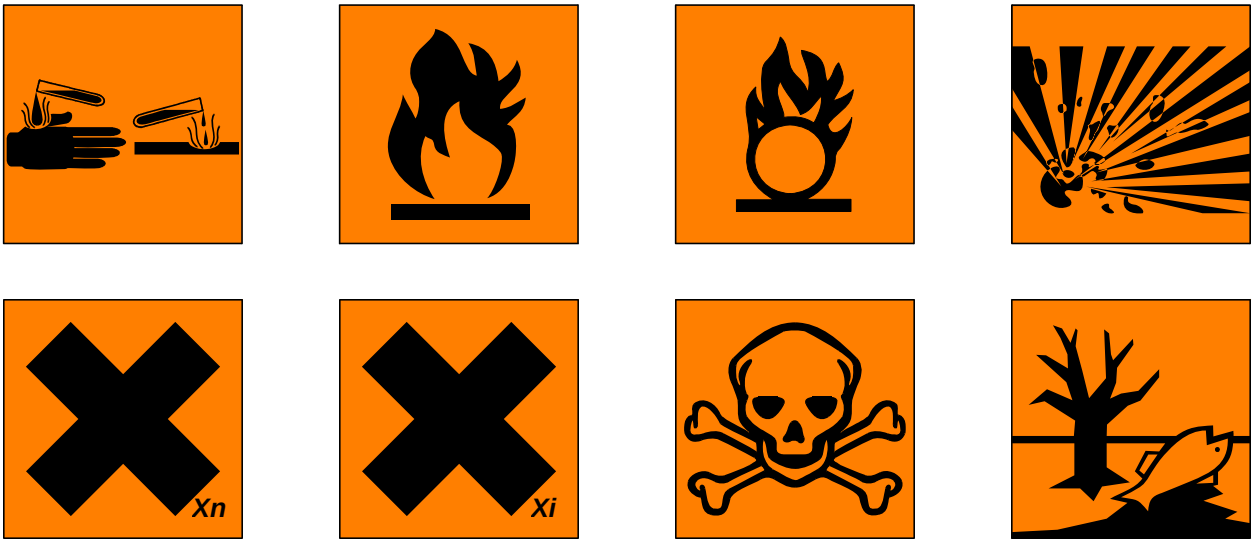


Figure 4.4 –
European Union hazard glyphs, which are now common on domestic chemicals.
(Top, left to right): Corrosive, Flammable, Oxidizing, Explosive
(Bottom, left to right): Harmful, Irritant, Poisonous, Toxic to the Environment

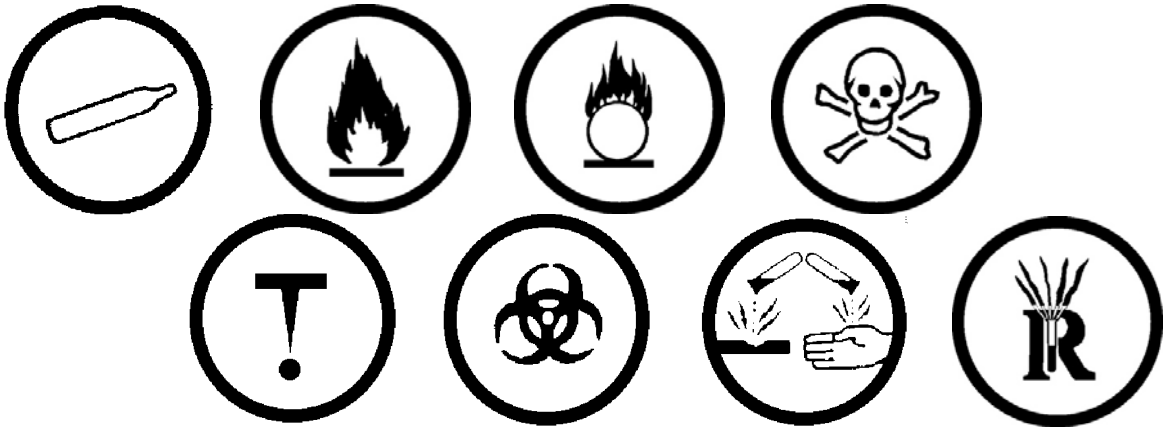


Figure 4.5 –
Canada's national hazard communication standard, the Workplace Hazardous Materials Information System (WHMIS) uses these symbols to represent and classify various materials.

From left to right: Compressed Gases and Aerosols, Toxic, Flammable/Combustible, Biohazardous, Oxidizing, Corrosive, Highly Toxic, and Reactive.

Recognizing the need for a universal method to identify potentially hazardous substances, the United Nations is working toward a worldwide Globally Harmonized System (GHS) for label elements and material safety data sheets, with targeted implementation from all member nations by 2008. Because of the numerous languages used by the worldwide research community, the GHS will rely heavily on picture glyphs to convey the basic information. Below are proposed GHS glyphs that soon might appear on chemical labels or MSDSs.

Figure 4.6 –
Proposed United Nations GHS label elements (left to right):
Flammable, Harmful, Oxidizing, Toxic to the Environment, Corrosive,
Compressed Gas, Explosive, Human Health Hazard, Highly Toxic

V. Color Codes

Some chemical manufacturers also use color codes on labels and/or caps to indicate health, physical, and chemical hazards. These colors can be used as a guide for storage groups - store same colors together, segregate from other colors. Unfortunately, the color schemes are not always consistent among manufacturers. Under most schemes, colors convey the following message:

Red:	Fire Hazard and/or Flammables
White:	Contact Hazard and/or Corrosive (acids or bases)
Blue:	Health Hazard and/or Toxic or Poisonous
Yellow:	Reactivity Hazard and/or Oxidizers
Green, **Gray** or **Orange**:	Moderate or slight hazard (general chemical storage)
Striped or "Stop":	Exceptions within the same color code labels (example - yellow label chemicals are stored apart from striped yellow label chemicals)

VI. Chemical Storage Locations

Optimally, incompatible chemicals such as acids and alkalis should be stored completely separate from one another to prevent mixing in the event of an accidental spill or release of the materials. Limited storage space within the laboratories, however, sometimes prevents such prudent practice of chemical segregation and storage. If space is limited, you can store incompatible chemicals in the same storage cabinet if you segregate the chemicals according to their hazard class and you store them tubs, trays, or buckets while in the cabinet. These secondary containers reduce the chance that incompatible chemicals will inadvertently contact each other.

Laboratory Hoods. Do not store chemicals in laboratory hoods because they may impede airflow and reduce the effectiveness of the hood.

Refrigerated Storage. Store flammable solvents that require storage at reduced temperature (such as isopentane) in refrigerators or freezers designed for storage of flammable liquids. "Safety" refrigerators for flammable liquid storage and "explosion-proof" refrigerators are both acceptable. Ordinary household refrigerators are not appropriate for storage of flammable liquids because of interior arcing contacts. Because refrigerators and freezers have no interior space venting, all chemicals should have tightly sealed caps. Apply signage to the doors of chemical refrigerators stating: NO FOOD, BEVERAGE, OR ICE FOR HUMAN CONSUMPTION."

Figure 4.7 – Example sign for a household refrigerator used for storage of lab materials.
Flammable storage requires a "safety" or "explosion-proof" refrigerator.
This sign is available at the EHS Safety Labels Page: (http://ehs.unc.edu/ih/lab/labels/)

Cold rooms have closed air-circulation systems that re-circulate escaped vapors within the chamber. The refrigeration coils in cold rooms are aluminum and subject to damage from corrosive atmospheres. The electrical systems normally have vapor-proof lights and duplex outlets, but added-on extension cords and plug strips compromise these safety features. Cold rooms are not acceptable for storage of flammables, dry ice, highly toxic liquid chemicals, or compressed gases. If you must refrigerate these chemicals, store them in an approved refrigerator or freezer, rather than a cold room. Post a warning sign on the cold room door as illustrated. This sign is also available from the EHS Safety Labels page.

Figure 4.8 – Sign for entry door to cold room.

Flammable and Combustible Liquid Storage. Fire protection regulations limit the storage of flammable and combustible liquids to 10 gallons (37.9 liters) in open storage, 25 gallons (94.7 liters) in "safety cans", and 60 gallons* (227.3 liters) in "flammable liquid storage cabinets" per laboratory room.

*Note that only 30 gallons (113.6 liters) of Class I liquids are permitted per room. Class I liquids have a flash points less than 100^{O}F (37.8^{O}C), and are traditionally known as “flammable” liquids. Most liquids labeled as flammable are Class I liquids. Combustible liquids are Class II or III liquids, and have flashpoints above 100^{O}F (37.8^{O}C). Regulations permit up to 60 gallons (227.3 liters) of combustible plus flammable liquids per room with two approved storage cabinets, provided no more than 30 gallons are Class I.

These limits are for the total quantities on hand, including chemicals in storage, chemicals in use, and wastes. Each lab can have a maximum of two flammable storage cabinets per room, with each cabinet containing a maximum of 30 gallons (113.6 liters) of Class I-III liquids.

Also, the International Fire Code (adopted by the State of North Carolina) places limits on the amounts of flammable and combustible liquids stored in new or renovated buildings as the number of floors above grade increases. For some laboratories located on higher floors in new or renovated buildings, the flammable liquid storage limit per room might be less than 30 gallons. Contact EHS if you have questions about the flammable storage limits for your lab spaces.

Cabinets. You can use cabinets under hoods and laboratory benches for storage of chemicals. In some cases, laboratory furniture manufacturers design cabinets specifically for storage of flammable and/or corrosive materials. However, do not store laboratory chemicals near or under sinks where there may be exposure to water. Storage of cleaning supplies under sinks is acceptable. Cabinets for chemical carcinogens or highly toxic chemicals should have a lock. Regulations of the Drug Enforcement Administration and Bureau of Alcohol, Tobacco, and Firearms require locked storage for controlled substances and some specific explosive compounds.

Desiccator Jars or Cabinets. Desiccator jars and cabinets are useful for storage of air and water reactive, toxic, and malodorous chemicals. In case of especially malodorous compounds such as mercaptans, replace the desiccator material with a vapor adsorber (e.g. charcoal) to control odors.

Bench Tops and Shelves. Chemical storage on bench tops is undesirable, and is vulnerable to accidental breakage by laboratory, housekeeping, and emergency response personnel. Do not store liquids on shelves that are above eye-level. When storing chemicals on open shelves, consider several factors such as compatibility grouping (see below), the container material (plastic or metal versus breakable glass), physical state of the chemical (it's riskier to store liquids on open shelves compared to solids), the relative toxicity of the chemical, and the height and depth of the shelving.

VII. Storage by Compatibility Group

Store chemicals in the laboratory according to their compatibility groups. Do not store chemicals in alphabetical order, as this might place incompatible chemicals next to each other (examples include acetic acid and acetaldehyde, sodium cyanide and sulfuric acid, sodium borohydride and sodium chlorate), increasing the potential for accidental mixing of incompatible chemicals. The diagram entitled "Suggested Shelf Storage Pattern" (Appendix 4-A) indicates a recommended arrangement of chemicals according to compatibility. These compatibility groups should be stored separately, especially chemicals with an NFPA 704 or HMIS reactive rating of 3 or higher, (see Section IV) and in dedicated and labeled cabinets. Within any compatibility group, you can arrange chemicals alphabetically to facilitate ease of retrieval. The following are recommended compatibility groupings:

Group A - Acids, Inorganics

Store large bottles of acid in special acid cabinets, cabinets under lab benches, or on low shelves. Place acids in plastic trays for secondary containment in case of breakage. Segregate inorganic and oxidizing acids from organic compounds including organic acids and other combustible materials. Segregate nitric acid (>40%) from other inorganic acids. Store acids separate from bases and other reducing agents. Inorganic salts, except those of heavy metals, may be stored in this group. Glacial acetic acid should be stored with flammable and combustible materials since it is combustible.

Group B - Bases

Segregate bases from acids and oxidizers on shelves near the floor. The preferred storage container for inorganic hydroxides is polyethylene instead of glass. Place containers in trays for secondary containment in the event of leakage or breaks.

Group C - Organic chemicals

Segregate organic compounds from inorganics. Organics and inorganics with NFPA 704 or HMIS reactive hazard rating of two (2) or less may be stored together. Chemicals with a reactive hazard rating of three (3) or four (4) are to be stored separately.

Group D - Flammable and Combustible Organic Liquids

Flammable and combustible liquid storage per room is limited to 10 gallons (37.9 liters) in open storage and use, 25 gallons (94.7 liters) in safety cans, and 60 gallons (227.3 liters) in flammable

storage cabinets. Keep in mind that the 60-gallon limit per room is based on a maximum of two approved storage cabinets per room, with a maximum of 30 gallons per cabinet. Also remember that only 30 gallons (113.6 liters) of Class I liquids are permitted per room, and International Fire Code restrictions might limit this even further if your lab is located on an upper floor in a new or renovated building. Store flammable and combustible materials away from sources of ignition such as heat, sparks, or open flames, and segregated from oxidizers.

Group E - Inorganic Oxidizers and Salts

Store inorganic oxidizers in a cool, dry place away from combustible materials such as zinc, alkaline metals, formic acid, and other reducing agents. Inorganic salts may also be stored in this group. Store ammonium nitrate separately.

Group F - Organic Peroxides and Explosives

Peroxides contain a double-oxygen bond (R_1-O-O-R_2) in their molecular structure. They are shock and heat sensitive (e.g. benzoyl peroxide), and readily decompose in storage. Store shock and heat-sensitive chemicals in a dedicated cabinet.

Some non-peroxide chemicals can readily form shock-sensitive, explosive peroxides when stored in the presence of oxygen. Examples include ethyl ether, tetrahydrofuran, and cumene. See Chapter 12 for information on safe storage of peroxidizable compounds.

Common explosive compounds include 2,4,6-trinitrotoluene (TNT), nitroglycerin, and several metal fulminates and azides. 2,4,6-trinitrophenol, also known as picric acid, is normally sold as a saturated solution containing at least 40% water, and classified as a flammable solid. If allowed to dry to less than 10% water, picric acid becomes a DOT Class 1.1 explosive. Nitroglycerin in research is usually sold as a tincture mixed with alcohol, but if the alcohol evaporates, the result is explosive nitroglycerin. Please contact EHS if you use or handle compounds that are explosive or can become explosive with age or evaporation.

Group G - Reactives

Water Reactives. Store water reactives in a cool dry place protected from water sources. Alkali metals (lithium, sodium, potassium, rubidium, and cesium) should be stored under mineral oil, or in waterproof enclosures such as glove boxes. A Class D fire extinguisher should be available in case of fire. Contact EHS if one is not available in your laboratory. As an added precaution, store containers in trays or other secondary containers filled with sand.

Pyrophorics (Air Reactives). Store pyrophorics in a cool, dry place, and provide for an air-tight seal. Store white or yellow phosphorous under water in glass-stoppered bottles inside a metal can for added protection.

Group H - Cyanides and Sulfides

Cyanides and sulfides react with acids to release highly toxic gases. They must be isolated from acids and other oxidizers.

Group I - Carcinogenic and Highly Toxic Chemicals

Provide a dedicated lockable storage cabinet in a "designated area" for highly toxic and carcinogenic chemicals. Use unbreakable, chemically resistant secondary containers. Post the storage cabinet with a sign stating “HIGHLY TOXIC CHEMICALS” or “CANCER-SUSPECT AGENT”. These signs are available at the EHS Safety Labels Page, and are depicted and described in Chapter 7. Maintain a separate inventory of all highly acute toxics, carcinogens, and reproductive toxins. See the Appendices to Chapter 7 for a listing of common carcinogenic and highly toxic chemicals.

APPENDIX 4 - A

Suggested Shelf Storage Pattern

Compatibility Group	Group Name	Chemical Class
Group A	Inorganic Acids, Inorganic Salts	inorganic acids (except nitric), sulfur, arsenic, halides, sulfates, sulfites, thiosulfates, halogens, phosphorus, phosphates
Group B	Inorganic Bases	hydroxides, oxides, silicates, carbonates
Group C	Organics	alcohols, glycols, amines, amides, hydrocarbons, esters, aldehydes, phenol cresols, organic sulfides, organic acids
Group D	Flammables, Combustibles	ethers, aliphatic solvents, aromatic solvents
Group E	Inorganic Oxidizers	borates, chromates, manganates, permanganates, chlorates, perchlorates, chlorites, hypochlorites, hydrogen peroxides, amides, nitrates, nitrites, azides
Group F	Organic Peroxides and Explosives	peroxides, azides, hydroperoxides
Group G	Reactives	air and water reactives, metals and hydrides
Group H	Cyanides, Sulfides	cyanides, cyanates, sulfides, carbides, nitrides
Group I	Highly Toxics, Carcinogens	highly toxic compounds, carcinogens

CHAPTER 5

PROTECTIVE CLOTHING AND EQUIPMENT

Overview

This chapter describes the various types of protective equipment and clothing that can protect you while working in the lab. Details for safe use, care, and acquisition are given for eye/face protection, gloves, lab apparel, foot protection, and respiratory protection.

Table of Contents

This page intentionally left blank.

CHAPTER 5

PROTECTIVE CLOTHING AND EQUIPMENT

I. Eye and Face Protection

University policy on eye protection requires students, faculty, staff, and visitors in laboratories wear eye protective devices during any experiment or laboratory procedure (regardless of anticipated eye hazards). The type of safety device required depends on the nature of the hazard and the frequency with which the wearer encounters it. There are three basic types of eye and face protection that meet the majority of University laboratory requirements: safety glasses with side shields, goggles, and face shields. Each of these meets basic eye protection standards for frontal exposure to flying particles. Laboratory supervisors must determine the appropriate level of eye protection for particular tasks, and enforce eye protection rules.

A. **Safety Glasses**: Ordinary prescription glasses do not provide adequate protection from injury to the eyes. Adequate eye protection requires the use of hardened-glass or plastic safety spectacles with side shields (Figure 5.1). Safety glasses used in the laboratory must comply with the Standard for Occupational and Educational Eye and Face Protection (Z87.1) established by the American National Standards Institute. This standard specifies a minimum lens thickness of 3 mm, impact resistance requirements, passage of a flammability test, and lens-retaining frames.

Figure 5.1 – Three types of safety glasses, each with a different method for approved side-shield protection

Three important dimensions for fit and comfort include temple length, nose bridge width, and lens diameter. Safety spectacles with side shields, bendable temples, and universal nose bridges are available in several lens diameters. Prescription safety spectacles are recommended for employees wearing glasses. Contact EHS for information on obtaining prescription safety glasses. Do not wear photogrey (transition) lenses indoors in laboratory environments, because the percentage of light transmitted under normal light conditions is below ANSI standards.

Wear chemical splash goggles or full-face shields (Figure 5.2) when significant liquid splash hazards exist. The side shields on safety glasses offer some protection from objects approaching from the side, but do not provide adequate splash protection.

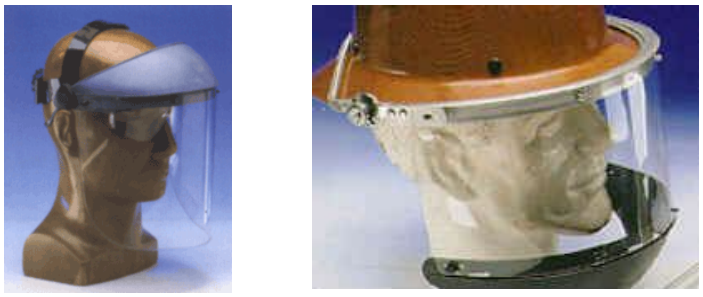


Figure 5.2 – Typical full-face shield (left); nitrometer mask (right).

B. **Goggles:** Goggles provide a tighter face seal than safety glasses, and are not for general laboratory use. Wear them when there is a hazard from splashing chemicals or flying particles. For example, wear goggles when using glassware under reduced or elevated pressure, or using glass apparatus in combustion or other high temperature operations. **Impact-protection goggles** have perforated sides to provide ventilation and reduce fogging of the lens, but do not offer full protection against chemical splashes. Use **chemical goggles** with splash-proof sides for protection from harmful chemical splash.

There are also specific goggles and masks for glassblowing and intense light sources such as welding or lasers. For questions about laser safety, including eye protection, consult the UNC Laser Safety Manual or the Radiation Safety Manual (http://ehs.unc.edu/manuals/index.shtml), or contact EHS at 962-5507.

C. **Face Shields:** Goggles or safety glasses alone do not meet ANSI standards for protection to the face and neck. When you need greater protection from flying particles and harmful liquids, wear full-face shields that protect the face and throat (Figure 5.2). For full protection, always wear a pair of safety glasses or goggles when wearing a face shield. A metal-framed "nitrometer" mask offers greater protection for the head and throat from hazards such as flying glass or other light fragments. Consider using a face shield or mask when operating a vacuum system (which may implode), or conducting a reaction with the potential for mild explosions. Always use a UV-blocking face shield when working with transilluminators or other devices that produce ultraviolet radiation.

D. **Cost, Care and Reclamation:** The University is committed to a policy of providing eye and face protection devices without cost to students, employees and visitors. Each department is responsible for funding its eye and face protection program. The employee and/or student are responsible for scheduling and payment for eye examinations to obtain safety glasses prescriptions. Eye protective devices issued to employees, students and visitors remain the property of the University. Persons issued eye protective devices return it when the use of the device is no longer necessary. For students, this is normally at the end of each semester, and for employees upon termination of employment or change in duties where eye protection is no longer required. The department shall determine the disposition of prescription glasses. You

may replace eye protective devices damaged during normal wear and use without charge at the discretion of the department head or designated administrative officer. Replacement of lost or stolen devices is the responsibility of the employee or student issued the equipment.

Eye protective devices are personal items, issued for the exclusive use of each individual. Clean with soap and water and store in a clean, protected area. Thoroughly clean and disinfect all eye protective devices before issuing to another person.

E. **Contact Lenses:** The National Society to Prevent Blindness points out that contact lenses do not provide adequate eye protection for hazardous operations and must be worn in conjunction with approved safety eyewear. The University permits the wearing of contact lenses in laboratories, only if the wearer has other forms of eye protection mentioned above. Earlier guidance recommended against wearing of contact lenses in laboratories, due to concerns about lenses trapping chemicals. However, several years of subsequent studies have shown that contact lenses do not create an additional hazard; in fact, the improved visual acuity from contact lenses might help prevent accidents, compared to no corrective lenses.

II. Use of Gloves

Wear proper protective gloves for potential contact with corrosive or toxic materials, materials of unknown toxicity, sharp edged objects, and very hot or cold materials. Select gloves based on the material handled, the particular hazard involved, and their suitability for the operation conducted.

Chemicals eventually permeate all glove materials. However, gloves are safe for limited periods if one knows the specific use and glove characteristics (such as thickness and permeation rate and time). Common glove materials include neoprene, polyvinyl chloride, nitrile, butyl, and natural rubbers (latex). These materials differ in their resistance to various substances (Appendix 5-B). Consider double gloving (the wearing of two gloves on each hand) when handling highly toxic or carcinogenic materials. Before each use, inspect gloves for discoloration, punctures, and tears. Before removal, wash gloves if the material is impermeable to water. Dispose single-use gloves after they are contaminated, or after you have removed them. Do not reuse single-use disposable gloves. Always store gloves properly (e.g. away from windows, transilluminators, etc.), since some glove materials are susceptible to ultraviolet damage.

Laboratory gloves have a shelf life stamped on the box. Dispose gloves if they are old. You can dispose gloves in the regular trash if they are not contaminated with bloodborne pathogens, radionuclides, highly toxic chemicals, or select carcinogens. For gloves contaminated with these substances, dispose in the proper waste stream. Do not dispose of contaminated gloves in a manner that could expose other personnel.

While it is important to wear gloves while performing laboratory manipulation of potentially hazardous materials, it is equally important to remove gloves before contacting "clean" areas such as food area surfaces, or common equipment such as telephones, computer keyboards, and photocopiers. Do not wear gloves outside the laboratory, as you could possibly contaminate surfaces you touch such as doorknobs, elevator buttons, or restroom fixtures (Figure 5.3). Remove your gloves even if you believe they are non-contaminated, as others do not know if you might have handled hazardous materials with your gloved hand(s). Consider posting a reminder at the exit door to your lab so that you do not wear lab gloves into common areas of your building. Use secondary containment for items that you must transport from your lab but do not want to touch with bare hands (e.g. samples susceptible to RNAse).

Figure 5.3 – Examples of improper use and disposal of gloves.
(Left): Gloves left on while using telephone.
(Center): Gloves left on while touching elevator buttons.
(Right): Glove with unknown contamination left in elevator.

Wear sturdier gloves such as leather for handling broken glassware, inserting glass tubes into rubber stoppers, and similar operations where you do not need protection from chemicals. Use insulated gloves when working at temperature extremes. Various synthetic materials such as Nomex® and Kevlar® can briefly withstand temperatures up to 1000 ^{o}F (538 ^{o}C). Gloves made with these materials or in combination with other materials, such as leather, are available. Do not use gloves containing asbestos, a regulated carcinogen under OSHA. Contact EHS for disposal of any asbestos containing gloves. The laboratory supervisor must determine the need for specialized hand protection in any operation, and ensure that needed protection is available.

Do not wear woven gloves while working with cryogens as the liquid may work its way through the glove to your hand. Use gloves specifically designed for work with cryogens. Gloves worn for working with elevated temperatures may not be appropriate for working with extremely low temperature liquids.

III. Laboratory Clothing and Protective Apparel

The clothing you wear in the laboratory can affect your safety. Do not wear loose (e.g., saris, dangling neckties, oversized or ragged laboratory coats), skimpy (e.g., shorts, halter-tops), or torn clothing in the laboratory. Loose or torn clothing and unrestrained long hair can easily catch fire, dip into chemicals, or become ensnared in apparatus and moving machinery. Skimpy clothing offers little protection to the skin in the event of chemical splash. If the possibility of chemical contamination exists, cover any personal clothing that you wear home with protective apparel. Finger rings can react with chemicals, and you should avoid wearing them around equipment with moving parts. Appropriate protective apparel is advisable for most laboratory work and may be required for some. Such apparel can include laboratory coats and aprons, jump suits, special boots, shoe covers, and gauntlets, which can be washable or disposable in nature. Commercial garments are available to protect from chemical splashes or spills, heat/cold, moisture, and radiation.

Laboratory coats help prevent contact with dirt and the minor chemical splashes or spills encountered in laboratory-scale work. The cloth laboratory coat is, however, primarily a protection for clothing and may itself present a hazard (e.g., combustibility) to the wearer. Cotton and synthetic materials such as Nomex® or Tyvek® are satisfactory, whereas rayon and polyesters are not. Laboratory coats do not significantly resist penetration by organic liquids. Remove your lab coat immediately upon significant contamination.

Do not take lab coats home and launder them because of the potential for contamination of the home environment. Currently, University Auxiliary Services offers a service through an outside vendor (e.g., Servitex) to clean, fold and press lab coats for $1.63 each, or to clean, dry, and fold other items (lab cloths or towels) for $0.84 each. You can contact University Auxiliary Services at 962-1261 to arrange for pick-up and delivery of lab coats. Check with your department's business manager to find out if your department already has an arrangement for laundering lab coats. Plastic or rubber aprons provide better protection from corrosive or irritating liquids but can complicate injuries in the event of fire. Furthermore, plastic aprons accumulate a considerable charge of static electricity, so avoid use in areas with flammable solvents or other materials ignitable by static discharge.

In some cases, disposable outer garments (e.g., Tyvek®) are preferable to reusable ones. One example is handling appreciable quantities of known carcinogenic materials, for which EHS also recommends long sleeves and gloves. Wear disposable full-length jump suits for high-risk exposure situations, which may also require the use of head and shoe covers. Many disposable garments, however, offer only limited protection from vapor penetration and you need to exercise considerable judgment when using them. Impervious suits fully enclosing the body may be necessary in emergencies.

Know the appropriate techniques for removing protective apparel if contaminated. Chemical spills on leather clothing accessories (watchbands, shoes, belts, etc.) are especially hazardous, since many chemicals absorb in the leather, which holds the chemical close to the skin for long periods. Remove such items promptly and decontaminate or discard them to prevent chemical burns.

IV. Foot Protection

Wear shoes at all times in laboratories or other chemical use and storage areas. Do not wear perforated shoes, sandals, or cloth sneakers in laboratories or mechanical work areas (Figure 5.4). Safety shoes protect the feet against injuries from heavy falling objects, crushing by rolling objects, or lacerations from sharp edges. Safety shoes are required for employees whose job duties require the lifting, carrying, moving, etc. of objects weighing more than fifteen pounds which, if dropped, would likely result in a foot or toe injury.

According to the state personal protective equipment policy, employees required to wear safety shoes can receive a subsidy for one pair of shoes per year. The current subsidy is $80 per year; contact your department if you have questions about whether your job duties require safety shoes, and your eligibility for this subsidy. Contact EHS for further questions about foot protection.

Figure 5.4 –

Open-toe shoes (left) are not appropriate for laboratory environments, as they offer no protection from dropped or spilled chemicals, containers, or apparatus. Wear sturdy closed-toe shoes (example on right) in the laboratory.

V. Respiratory Protection

Respiratory protection might be necessary when working with highly toxic chemicals, biological hazards, or dusts known to cause asthma or pulmonary fibrosis. However, respirators are a "last line" of defense, and should not be used until all engineering controls (e.g. ventilation) and work practice controls (e.g. product substitution) are exhausted. Respirators have specific regulatory requirements for equipment certification, fit testing, medical evaluation, and training. These requirements are from the OSHA Respiratory Protection Standard 29 CFR 1910.134. Requirements differ based on respirator type.

The respirator regulations do not cover "comfort masks" or surgical masks (Figure 5.5). These are technically not respirators, as they are not certified by NIOSH (the National Institute for Occupational Safety and Health), and have no protection factor rating. If you are using these masks in the lab, consider whether you might need a true respirator such as those depicted in Figure 5.6.

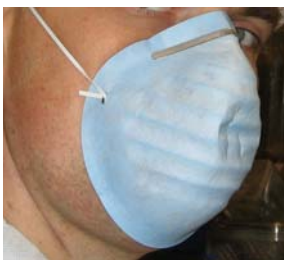


Figure 5.5 –
(Left) Comfort mask with single strap.
(Right) Surgical masks.
Do not wear these for respiratory protection, as they are not respirators per the OSHA Respiratory Protection Standard (29 CFR 1910.134) and are not certified by NIOSH.

Because of the training, fit testing, and medical evaluation requirements, you cannot "casually" wear

true respirators in the lab. If you wish to wear an N95 disposable respirator, you must receive training on its proper use and limitations. This training is available online at http://ehs.unc.edu/training/self_study/n95/index.shtml.

Other types of respirators such as APRs, PAPRs, SARs, and SCBAs have more rigorous training and fit testing requirements. Contact EHS if you are contemplating their use. If you will use any type of respirators voluntarily, including N95 disposable respirators, you must read and understand the information included in Appendix 5-A at the end of this chapter.

Figure 5.6 – Several types of NIOSH-certified respirators.
Left to right: N95 disposable respirator (with two straps), powered air-purifying respirator (PAPR), half-face air-purifying respirator (APR), full-face APR, supplied-air respirator, self-contained breathing apparatus (SCBA).

APPENDIX 5-A:

INFORMATION FOR EMPLOYEES USING RESPIRATORS WHEN NOT REQUIRED UNDER THE RESPIRATORY PROTECTION STANDARD

Respirators are an effective method of protection against designated hazards when properly selected and worn. Respirator use is encouraged, even when exposures are below the exposure limit, to provide an additional level of comfort and protection for workers. However, if a respirator is used improperly or not kept clean, the respirator itself can become a hazard to the worker.

Sometimes, workers may wear respirators to avoid exposures to hazards, even if the amount of hazardous substance does not exceed the limits set by OSHA standards. If your employer provides respirators for your voluntary use, of if you provide your own respirator, you need to take certain precautions to be sure that the respirator itself does not present a hazard.

You should do the following:

1. Read and heed all instructions provided by the manufacturer on use, maintenance, cleaning and care, and warnings regarding the respirators limitations.

2. Choose respirators certified for use to protect against the contaminant of concern. NIOSH, the National Institute for Occupational Safety and Health of the U.S. Department of Health and Human Services, certifies respirators. A label or statement of certification should appear on the respirator or respirator packaging. It will tell you what the respirator is designed for and how much it will protect you.

3. Do not wear your respirator into atmospheres containing contaminants for which your respirator is not designed to protect against. For example, a respirator designed to filter dust particles will not protect you against gases, vapors, or very small solid particles of fumes and smoke.

4. Keep track of your respirator so that you do not mistakenly use someone else's respirator.

Reference: 29 CFR 1910.134, Appendix D

APPENDIX 5-B: GLOVE SELECTION CHART

chemical tested	nitrile	neoprene	natural rubber	pvc	4mil silver shield	9mil vitron*	17mil butyl*
ACETALDEHYDE	NT	E	E	NT	G	NR	E
ACETIC ACID 50%	E	E	E	E	NT	NT	NT
ACETIC ACID GLACIAL	NT	NT	NT	NT	NT	NT	NT
ACETONE	P	E	E	P	G	P	E
ACETONITRILE	NT	E	NT	NT	E	ID	E
ACYLONITRILE	P	G	NT	NT			
AMMONIUM HYDROXIDE 29%	E	E	E	E	NT	NT	NT
ANILINE	P	E	E	G	E	P	E
AROCLOR	NT	NT	NT	NT			
BENZALDEHYDE	E	F	F	G			
BENZENE	P	NT	NT	NT	E	G	P
BENZENE CHLORIDE	NT	NT	NT	NT			
BIS(2-HYDROXYETHYL) AMINE	E	E	E	E			
BROMINE		G	G	G			
BUTANE		E	P	P			
2-BUTONE	NT	G	G	NT			
2-BUTOXYETHANOL	E	E	E	NT			
BUTYL ACETATE	F	E	NT	NT	G	NR	F
BUTYL CELLOSOLVE	E	E	E	NT			
BUTYLALDEHYDE		G	P	G			
CALCIUM HYPOCHLORITE	G	G	P	G			
CARBOLIC ACID	NT	E	E	NT			
CARBON DICHLORIDE	G	NT	NT	NT			
CARBON DISULFIDE	F	NT	NT	NT	G	G	P
CARBON TETRACHLORIDE	G	P	NT	NT	G	E	P
CELLOSOLVE	E	E	E	NT			
CELLOSOLVE ACETATE	F	E	G	NT			
CHLORINE		G	G	G			
CHLOROACETONE		E	F	P			
CHLOROBENZENE	NT	NT	NT	NT	E	E	P
CHLOROETHANE	P	P	NT	NT			
CHLOROFORM	NT	P	NT	NT	P	E	P
CHLORONAPHTHALENE					E	E	NR
CHROMIC ACID 50%	E	NT	NT	NT			
CUMENE	G	F	NT	NT			
CYCLOHEANONE					G	E	E
CYCLOHEXANE	E	E	NT	NT	E	E	P
CYCLOHEXANOL					G	E	E
DIAMINE	E	E	E	E			
DIBENZYL ETHER		G	F	P			
DIBUTYL PHTHALATE		G	F	P	G	E	E
1,2-DICHLOROBENZENE	NT	NT	NT	NT			
1,3-DICHLOROBENZENE	P	NT	TN	NT			
DICHLORODIFLUOROMETHANE	NT	NT	NT	NT			
1,2-DICHLOROETHANE	P	P	NT	NT	G	G	F
DICHLOROMETHANE	NT	F	NT	NT			
DIETHANOLAMINE	E	E	E	E			
DIETHANOLAMINE		E	F	E			
1,4-DIETHYLENE OXIDE	NT	NT	NT	NT			

APPENDIX 5-B: GLOVE SELECTION CHART

chemical tested	nitrile	neoprene	natural rubber	pvc	4mil silver shield	9mil vitron*	17mil butyl*
DIMETHYL ACETAMIDE	P	G	F	NT			
DIMETHYL FORMAMIDE	NT	E	E	NT	E	P	E
DIMETHYL SULFOXIDE (DMSO)	G	E	E	G	G	F	E
1,4-DIOXANE	NT	NT	NT	NT	E	P	E
DIVINYL BENZENE					E	G	F
ETHANOL	E	E	E	E			
2-ETHOXYETHANOL	E	E	E	NT			
2-ETHOXYETHYL ACETATE	F	G	G	NT			
ETHYL ACETATE	NT	G	NT	NT	G	P	G
ETHYL ALCOHOL	E	E	E	E			
ETHYL ETHER	E	E	NT	NT	G	P	P
ETHYLENE DICCHLORIDE	P	P	NT	NT			
ETHYLENE GYCOL	E	E	E	E			
ETHYLENE GYCOL MONOETHYL ETHER ACETATE	F	G	G	NT			
ETHYLENE GYCOL MONOETHYLACETATE	E	E	E	NT			
ETHYLENE OXIDE	NT	NT	NT	NT			
ETHYLENE TRICHLORIDE		P	P	P			
FLUORINE		G	G	G			
FORMALDEHYDE 37%	E	E	E	G	G	E	E
FORMALIN SOLUTION	E	E	E	G			
FREON 12	NT	NT	NT	NT			
FREON TF	E	E	NT	NT			
FURFURAL	P	F	NT	NT			
GASOLINE	E	E	NT	NT			
GLUTARALDEHYDE					E	E	E
GLYCEROL	E	G	G	E			
HEPTANE	E	E	NT	NT			
HEXANE	E	E	NT	NT	G	E	NR
HYDRAZINE	E	E	E	E	G	P	E
HYDROBROMIC		E	G	E			
HYDROCHLORIC ACID 37%	E	E	E	E	G	NR	E
HYDROFLUROIC ACID 48%	E	E	E	E	G	G	F
HYDROGEN PEROXIDE	G	G	G	E			
IODINE		G	G	G			
ISOAMYL ACETATE	NT	NT	NT	NT			
ISOBUTYL ALCOHOL	E	E	NT	NT			
ISOPROPANOL	E	E	E	E			
ISOPROPYL ALCOHOL	E	E	E	E			
ISOPROPYL BENZENE	E	F	NT	NT			
KEROSENE	E	E	NT	NT			
M-CRESOL (3-CRESOL)	F	E	E	E			
METHANE DICHLORIDE	NT	F	NT	NT			
METHANOL	E	E	E	NT			
METHYL ALCOHOL	E	E	E	NT			
METHYL CELLOSOLVE		E	F	P			
METHYL CHLOROFORM	P	P	NT	NT			
METHYL IODIDE	NT	NT	NT	NT			
METHYL ISOBUTYL KETONE (MIBK)	P	P	NT	NT			
METHYL MERCURY					E		
METHYLAMINE	E	G	G	E	F	E	E

APPENDIX 5-B: GLOVE SELECTION CHART

chemical tested	nitrile	neoprene	natural rubber	pvc	4mil silver shield	9mil vitron*	17mil butyl*
METHYLENE CHLORIDE	G	F	F	F			
MINERAL SPIRITS	E	E	NT	NT			
M-METHYLPHENOL	F	E	E	E			
MONOETHANOLAMINE		E	F	E			
MORPHOLINE		E	F	E	E	F	E
MURIATIC ACID	E	E	E	E			
NAPHTHA	E	E	NT	NT			
NITRIC ACID 50%	G	E	E	E	E	G	F
NITROBENZENE	P	G	NT	NT	E	E	E
NITROPROPANE					G	P	G
N-METHYL-2-PYRROLIDONE	P	G	NT	NT			
N-PENTANE					G	E	NR
O-CHLOROTOLULENE	NT	NT	NT	NT			
OLEIC ACID	E	E	NT	NT			
P-CHLOROTOLULENE	NT	NT	NT	NT			
PENTACHLOROPHENOL					E	E	NR
PENTANE	NT	NT	NT	NT	E	E	P
PERCHLORIC ACID	F	G	F	E			
PERCHLOROETHYLENE	G	NT	NT	NT	E	E	P
PETROLEUM ETHER	E	E	NT	NT			
PHENOL SAT.	NT	E	E	NT	G	E	E
PHOSPHORIC ACID 85%	E	E	E	E			
POLYCHLORINATED BIPHENYLS (PCBS/50%)	NT	NT	NT	NT	E	E	P
POTASSIUM HYDROXIDE 50%	E	E	E	E			
PROPYLENE DICHLORIDE		F	P	P			
P-TERT-BUTYLTOLUENE					E	E	F
PYRIDINE	NT	NT	NT	NT			
RULE 66 SOLVENT	E	E	NT	E			
SODIUM HYDROXIDE 50%	E	E	E	E	E	G	E
SODIUM HYPOCHLORITE	F	P	G	G			
SULFURIC ACID 50%	E	NT	E	E	E	E	G
1,1,2,2-TETRACHLOROETHANE	NT	NT	NT	NT			
TETRACHLOROETHYLENE					G	E	P
1,1,2,2-TETRACHLOROETHYLENE	G	P	NT	NT	G	NR	E
TETRAHYDROFURAN (THF)	P	P	NT	NT	E	P	F
TOLUENE (TOUOL)	P	P	NT	NT	G	E	P
TOLUENE DIISOCYANTE	F	NT	G	F	E	E	E
TOLUOL	P	P	NT	NT			
1,1,1-TRICHLOROETHANE	P	P	NT	NT	G	E	NR
TRICHLOROETHYLENE (TCE)	P	NT	NT	NT	G	G	P
TRICHLOROTRIFLUOROETHANE	E	E	NT	NT			
TRICRESYL PHOSPHATE		F	P	F			
TRIETHANOAMINE (TEA)	E	E	E	E			
VINYL ACETATE	F	G	NT	NT			
VINYL CHLORIDE					E	E	P
XYLOLS	F	F	NT	NT			
XYLENES	F	F	NT	NT	E	E	P
TRINITROTOLUENE		E	P	P			
TURPENTINE	E	E	NT	NT			

APPENDIX 5-B: GLOVE SELECTION CHART

Performance Rating		Weight Change	Penetration Time
E	Excellent	0-10%	>8 hours
G	Good	11-20%	>6 hours
F	Fair	21-30%	< 6 hours
P	Poor	>30%	minutes
NT	Not Tested		
NR	Not Recommended		

References:

Fisher Scientific
Lab Safety Supply
Direct Safety Catalog
"Prudent Practices"
MAPA Professional
Ansell Chemical Resistance Guide

CHAPTER 6

SAFE HANDLING OF CHEMICALS

Overview

This chapter discusses the major routes of exposure to chemical substances during laboratory work, and several safe handling practices that can minimize your risk while working with chemical substances. The last section lists practices for the safe use of hydrofluoric acid.

Table of Contents

This page intentionally left blank.

CHAPTER 6

SAFE HANDLING OF CHEMICALS

I. Introduction

All chemicals can have toxic effects at some dose level and particular route(s) of exposure. It is therefore wise to minimize exposure to chemicals. Chemicals can have local or systemic effects. Local toxicity refers to the direct action of chemicals at the point of contact. Systemic toxicity occurs when the chemical agent is absorbed into the bloodstream and distributed throughout the body, affecting one or more organs. Health effects can be acute or chronic. Acute effects last for a relatively short time and then disappear. Chronic effects are not reversible.

Do not confuse acute and chronic exposure with acute and chronic effects. Acute exposures to chemicals are for short periods. Chronic health effects can develop from acute exposures depending on the properties and amount of the chemical. Acute or chronic adverse health effects can also occur with chronic (repeated) exposure to chemicals, even at low concentrations.

II. Routes of Exposure

A. **Dermal Contact:** Skin contact is one of the most common chemical exposure routes in laboratory settings. Spills and splashes can result in overt skin contamination. In addition, laboratory personnel may unknowingly contaminate themselves when they touch work surfaces, glassware, or equipment contaminated during experiments. A common result of skin contact is localized irritation or dermatitis. However, a number of materials are absorbed through the skin to produce systemic poisoning. The main portals of entry for chemicals through the skin are the hair follicles, sebaceous glands, sweat glands, and cuts or abrasions of the outer layers of the skin. The follicles and the glands contain blood vessels, which facilitate the absorption of chemicals into the body. Chemicals can also enter the body when contaminated hands touch the mouth, nose, eyes, sores or cuts. For more information, refer to the glove use policy in Chapter 5: Protective Clothing and Equipment.

B. **Inhalation:** Inhalation of toxic vapors, mists, gases, or dusts can produce poisoning by absorption through the mucous membrane of the mouth, throat and lungs, and can seriously damage these tissues by local action. Inhaled gases or vapors may pass rapidly through the capillaries of the lungs and enter the circulatory system. The degree of injury from inhalation of toxic substances depends on the material's toxicity, solubility in tissue fluids, concentration, and the duration of exposure.

   Although inhalation hazards are more often associated with gases and volatile chemicals, both solids and non-volatile liquids can also present an inhalation hazard for laboratory personnel. Laboratory chemicals in the form of dusts and particulates can become airborne when transferred from one container to another. Grinding and crushing procedures can also produce aerosols. Splashes created from spills and vigorous shaking and mixing form aerosols. Many of these generated particulates do not settle out but remain suspended in the air and travel along air

currents in the room. Some of these particulates can be inhaled and deposit in the respiratory tract. For many operations, you might not recognize that aerosols are present and a hazardous situation exists. All laboratory operations involving an open vessel will result in aerosol release. Such operations include weighing, stirring, pouring, pipetting, injections with a needle and syringe, handling animals, and removing caps and stoppers. As an alert laboratory person, take care not to create aerosols.

C. **Ingestion:** Ingestion of toxic materials in the laboratory can occur when contaminated hands come in contact with the mouth, or with food items. The laboratory environment can contaminate food items and utensils. Do not mouth pipette, as this can result in aspiration of toxic materials. For more information, refer to the laboratory food policy in Chapter 3: General Safety Principles and Practices.

D. **Injection:** Accidents involving needles and syringes can result in injection of toxic and/or infectious materials through the skin. Needles and syringes are among the most hazardous items used in the laboratory, especially when combined with the task of inoculating an uncooperative animal. Containers of toxic chemicals may break, resulting in hazard from contact with contaminated broken glass.

E. **Ocular exposure:** The eyes are of particular concern, due to their sensitivity to irritants. Ocular exposure can occur via splash, or rubbing eyes with contaminated hands. Few substances are innocuous with eye contact, and several can cause burns and loss of vision. The eyes have many blood vessels, and rapidly absorb many chemicals. For more information, refer to the eye protection policy in Chapter 5.

III. Safe Handling Practices for Chemical Substances

A. **Access Control:** The Principal Investigator must control access to laboratories that contain chemicals. Keep the laboratory door closed while experiments are in progress. This practice not only protects persons who might otherwise enter the laboratory, it reduces interruptions to laboratory staff that could lead to accidents. Laboratory hoods work best, and offer the most worker protection, when the doors to the laboratory are closed.

B. **Personal Practices:** Wash your hands immediately after completion of any procedure involving chemicals, and when leaving the laboratory. Soap must be in liquid form, with a pump dispenser. Do not use bar soap in laboratories. Do not use liquid soap bottles that you must invert and squeeze. Liquid soap dispensers can be wall-mounted type or freestanding countertop bottles.

Figure 6.1 –
Wall-mounted and freestanding liquid soap pump dispensers are appropriate for laboratory use. Invert-squeeze soap bottles and bar soaps are not acceptable for laboratory use.

In laboratories where toxic materials are used, do not eat, drink, smoke, chew gum, apply cosmetics, or store utensils, food, and food containers, unless your laboratory has an authorized and clearly marked food item area. Refer to the food policy in Chapter 3. In some laboratories, it might not be possible to establish a food item area due to the lack of adequate containment of volatile or toxic substances. If your laboratory has a food item area, make sure no chemicals, procedures, or laboratory equipment end up in the area. Remove gloves or other personal protective equipment that could introduce contamination to the food item area.

Figure 6.2 – Improper use of food item areas.
(Left): Do not handle chemicals, or wear contaminated gloves, in a food item area.
(Right): Do not place laboratory equipment (such as this water bath) within three feet of a designated food item area.

Use mechanical pipetting aids for all pipetting procedures. **NEVER MOUTH PIPETTE.**

C. **Decontamination of Work Surfaces:** Protect work surfaces from contamination by using "bench paper" (disposable plastic-backed absorbent paper) or stainless steel trays. Place the plastic side down and the absorbent side facing up. Change worn or contaminated bench paper and dispose properly. Decontaminate other items and equipment with appropriate solvents when contaminated during experiments.

D. **Minimizing Aerosols:** Since a procedure with an open vessel of liquids or powders generates aerosols, you should develop techniques that will minimize the creation of aerosols. Such techniques might include discharging liquids from pipettes as close as possible to the fluid level of the receiving vessel, or allowing the contents to run down the wall of the receiving vessel. Dropping the contents from a height generates more aerosols.

Also, avoid rapid mixing of liquids with pipettes by alternate suction and expulsion, or forcibly expelling material from a pipette. Take extra care when discarding contaminated gloves or plastic-backed absorbent paper used to cover the work surface, to avoid aerosolizing contaminants. Clean floors with a wet mop or with a vacuum cleaner equipped with a HEPA filter, as dry sweeping or dry mopping contaminated laboratory floors could aerosolize contamination.

E. **Use of Laboratory Hoods and Biological Safety Cabinets:** When used properly, laboratory hoods and biological safety cabinets are among the most effective means for controlling exposures to toxic chemicals, since they move substances away from you before they can reach your breathing zone. Refer to Chapter 16: Biological Safety Cabinets and Chapter 17: Laboratory Hoods for a full discussion of the uses and limitations of these very important engineering controls.

IV. Specific Handling Procedures for Hydrofluoric Acid

A. Hazards – Overview

Hydrofluoric acid (HF) differs from other acids because it readily penetrates the skin and dissociates into fluoride ions, causing destruction of deep tissue layers, including bone. The fluoride ion affects tissue integrity and metabolism by liquefaction necrosis, decalcification and destruction of bone, and production of insoluble salts. Loss of calcium (hypocalcemia) results from precipitation of calcium from the blood as CaF_2. This results in calcium loss from the bones to equilibrate the decreased serum calcium. The development of hypocalcemia can be rapidly fatal because calcium is important for muscles, including the cardiac muscle (heart), to function properly. Fluoride ions might also bind to potassium and magnesium ions, leading to myocardial irritability and arrhythmia. Death from metabolic acidosis, hypocalcemia, or ventricular arrhythmias can occur several hours after exposure.

Pain associated with skin exposure to HF may not occur for 1-24 hours. Unless you can rapidly neutralize the HF and bind the fluoride ions, tissue destruction may continue for days and result in limb loss or death. HF is similar to other acids in that the initial extent of burn depends on the concentration, temperature, and duration of contact with the acid. Eye exposure to concentrations of HF greater than 0.5% can result in severe ocular damage, with delayed signs and symptoms.

Hydrofluoric acid vapors are also hazardous. Ocular irritation and injury can occur from working with HF outside a vented enclosure (laboratory hood). Inhalation can cause severe throat irritation, cough, dyspnea, cyanosis, lung injury and pulmonary edema. In severe exposure cases, these can result in death.

B. Dermal Exposure Case Studies

- An adult patient who developed 25% total body surface area second degree burns after exposure to a 70% hydrofluoric acid preparation died in cardiac arrest. Ionized serum calcium level was 1.7 milligrams per deciliter (mg/dL) immediately premortem. The normal range is 4 to 4.8 mg/dL.
- A dermal exposure to 70% hydrofluoric acid over a 2.5% total body surface area resulted in death. The serum calcium level was 2.2 mg/dL.
- Two workers died following a splash exposure of 70% hydrofluoric acid to the face, chest, arms and legs. Both workers were promptly removed from site of exposure. Clothing was removed and burns were initially treated at the workplace with a cold shower and alcohol applied to burn areas. No suitable protective clothing was worn at the workplace.
- A woman died from severe chemical burns of the skin and lungs, with intense pulmonary hemorrhagic edema after having acid thrown onto her face during an attack.
- A patient with HF burns over 8% of his body died from intractable cardiac arrhythmia secondary to the depletion of ionized calcium.

C. Handling and Personal Protective Equipment

- Familiarize yourself with the hazards specific to HF before handling. Consult this Chapter, the MSDS, and label information.
- Always handle HF in a properly functioning laboratory hood, and in an area equipped with an eyewash and safety shower.
- Required Personal Protective Equipment:
  - Goggles
  - Face shield (plastic)
  - Gloves: Thin disposable gloves (such as 4, 6, or 8 mil blue nitrile gloves) used in laboratory operations provide a contact barrier only and should be disposed immediately when contamination is suspected. Thicker (10-20 mil) PVC or neoprene gloves provide better resistance to HF but do not provide the necessary dexterity for many lab procedures. Thinner PVC or poly gloves can provide some resistance to HF, but require immediate changing at the first sign of contamination. Do not wear disposable gloves without double gloving because of the potential for exposure through pinholes
  - Acid resistant apron
  - Long pants and sleeves (note that these are required when working with all corrosive materials, including HF)
  - Closed toe shoes (required for ALL laboratory work)

D. Post-Exposure Treatment

This manual (Chapter 3, Section VIII) contains a recommendation that upon skin or eye exposure to hazardous materials, flush the affected area for at least 15 minutes with an eyewash or safety shower. This general guidance is appropriate for almost every lab chemical, including corrosive acids and bases. However, HF has more specific treatment requirements, outlined below.

In the event of a skin or eye exposure to HF:

- Have someone call 911 immediately, to facilitate arrival of medical assistance.

- Remove all exposed clothing and immediately wash all exposed areas with copious amounts of water from the safety shower or eyewash. Flush exposed eyes for at least 15 minutes, but flush exposed skin for only **five minutes**, followed by treatment with a calcium source.

- For skin exposures, after flushing for five minutes, apply a gel or slurry of calcium gluconate (preferred) or calcium carbonate directly to the exposed area. Use concentrations between 2.5% and 33%.

- For severe exposure cases, consider subcutaneous infiltration with calcium gluconate. Infiltrate each square centimeter of affected dermis and subcutaneous tissue with about 0.5 mL of 10% calcium gluconate, using a 30-gauge needle. Repeat as needed to control pain. Split or remove nails to treat nail bed burns. The earlier this is administered, the more rapidly symptoms resolve.

- CAUTION: Avoid administering large volumes of subcutaneous calcium gluconate, as this will result in decreased tissue perfusion and potential necrosis.

Note that calcium gluconate gel has an expiration date. Make sure that you always have access to a non-expired supply if you are working with HF.

DO NOT USE CALCIUM CHLORIDE – Calcium chloride is irritating to the tissues and may cause injury.

Figure 6.3 – Tube of calcium gluconate gel.

Make sure you have one or more non-expired tube of this present in your lab when working with HF.

E. Incompatibilities and Storage

Store HF in a cool, dry place away from incompatible materials. HF reacts with many materials; therefore, avoid contact with glass, concrete, metals, water, other acids, oxidizers, reducers, alkalis, combustibles, organics and ceramics. Store in containers made of polyethylene or fluorocarbon plastic, lead, or platinum. Place storage bottles in polyethylene secondary containment trays. **Never store HF, or HF waste, in glass containers.**

Figure 6.4 – Hydrofluoric acid. Note that the storage bottles are plastic. Make sure to store all forms of HF, including dilutions and waste, in compatible containers that are not glass.

F. Spills

Ensure all areas where HF is used are equipped with proper spill response equipment. You can neutralize small spills (100 ml or less) by covering with magnesium sulfate (dry) and absorbing with spill control pads or other absorbent materials. Add sodium bicarbonate or magnesium oxide to any absorbent and place in a plastic container for disposal. Wash the spill site with a sodium bicarbonate solution.

Use 3M's Universal Sorbent or similar, as it does not react with HF. Do not use spill sorbents that contain silicon, such as vermiculite or sand, as this can produce silicon tetrafluoride, an odorless toxic gas.

If the spill is large, in a confined space, or in an area where there is not adequate ventilation, evacuate the room and immediately report the spill to 911. Contact EHS at 962-5507 if you have questions about spill response, or if you do not feel comfortable trying to clean up the spill yourself.

This page intentionally left blank.

CHAPTER 7

HIGHLY TOXIC CHEMICALS AND SELECT CARCINOGENS

Overview

This chapter supplements previous chapters by giving specific extra precautions, postings, training, and protective equipment necessary when working with substances that are highly toxic and/or select carcinogens. The appendices at the end of the chapter are a thorough (but not exhaustive) list of substances that might be present in your lab that are highly toxic and/or carcinogenic.

Table of Contents

This page intentionally left blank.

CHAPTER 7

HIGHLY TOXIC CHEMICALS AND SELECT CARCINOGENS

I. Introduction

Work with highly toxic chemicals or select carcinogens require special containment practices in addition to those described in Chapter 6 for toxic chemicals. Highly toxic compounds have the ability to cause harmful effects, which can be local or systemic, after a single exposure. Among the most useful parameters for assessing the risk of acute toxicity of a chemical are its LD_{50} and LC_{50} values, the mean lethal dose or lethal concentration causing death in experimental animals. Per the Health Hazards Definitions of the OSHA Hazard Communication Standard, a substance is highly toxic if:

- the oral LD_{50} for albino rats is less than 50 mg/kg or
- the topical LD_{50} for albino rabbits is less than 200 mg/kg or
- the LC_{50} in albino rats is less than 200 ppm for one hour.

Examples of **highly toxic** substances include hydrogen cyanide, osmium tetroxide, phosgene, sodium azide, and tetrodotoxin. For a thorough (but not exhaustive) list of highly toxic substances, refer to Appendix 7-A.

A **select carcinogen** is a chemical agent that causes a malignant disease or statistically increases the risk of cancer, whether by initiation or promotion. Appendix 7-B lists select carcinogens that are:

1. listed as a known or reasonably anticipated human carcinogen in the biennial Report on Carcinogens published by the National Toxicology Program;

2. listed as carcinogenic to humans (Group 1), probably carcinogenic to humans (Group 2A), or possibly carcinogenic to humans (Group 2B) by the International Agency for Research on Cancer (IARC); or

3. regulated by OSHA as a carcinogen.

Some of these compounds are common materials used in many laboratories, such as acrylamide, chloroform, carbon tetrachloride, benzene, hydrazine, and thiourea. More than two-thousand substances exhibit some evidence for carcinogenicity. Many of these also warrant careful planning and control procedures.

II. Laboratory Safety Plans

Laboratories working with highly toxic chemicals and/or select carcinogens must include standard operating procedures in the Laboratory Safety Plan (LSP) describing the hazards of the compounds, safety precautions and emergency procedures in the event of a spill. The template is

located at the EHS Laboratory Safety Plan webpage: http://ehs.unc.edu/ih/lab/lsp.shtml. Refer to Chapter 2 for instructions on completing an LSP. In addition to the safety practices described for use of toxic materials, several other special safety precautions are necessary for highly toxic chemicals and select carcinogens.

III. Facility Requirements

Establish a "designated area", with access restricted to personnel who are aware of the hazards of the substances in use and the necessary precautions. A foot or elbow operated handwashing facility and an eyewash facility must be available within the work area. A shower facility, other than emergency drench showers, must be located in the building.

Exhaust ventilation systems are designed to maintain an inflow of air from the corridor into the work area. The exhaust air from the work area must discharge directly to the outdoors, and clear of occupied buildings and air intakes. Exhaust air from the work area must not recirculate. The exhaust air from glove boxes must filter through high-efficiency particulate air (HEPA) and charcoal filters. EHS shall determine the need for and type of treatment for other primary containment equipment. Exhaust air treatment systems that remove toxic chemicals from the exhaust air by collection mechanism such as filtration or absorption must operate in a manner that permits maintenance, to avoid direct contact with the collection medium. All exhaust air from primary containment equipment must discharge directly to the outdoors and disperse clear of occupied buildings and intakes. Exhaust systems for highly toxic substances must contain engineered fail-safe mechanisms to prevent loss of containment due to utility outages.

The EHS Director must approve the purchase and installation of any non-ducted hoods. EHS will not approve non-ducted hoods for use with volatile chemicals. Approval will be granted only in exceptional cases, and only when particulate handling (e.g., weighing solids) is its sole use.

IV. Protective Clothing (Refer to Chapter 5: Protective Clothing and Equipment)

Wear a full-fastened laboratory coat or a disposable jump suit in any area where chemical carcinogens are in use. The Principal Investigator is to provide clean clothing weekly and you cannot wear it outside of the work area. Following an obvious exposure, decontaminate or dispose immediately all clothing contaminated by highly toxic chemicals. Do not send contaminated clothing to the laundry until decontaminated. Wear appropriate gloves (Appendix 5-A) when handling. Double gloving is recommended. Discard disposable gloves after each use and immediately after known contact with a highly toxic chemical or select carcinogen.

V. Use of Primary Containment Equipment

Procedures involving volatile chemicals, and those involving solid or liquid chemicals that may result in the generation of aerosols, must occur in a laboratory hood, glove box, or other suitable containment equipment. Examples of aerosol-producing procedures include: opening of closed vessels; transfer operations; weighing; preparing feed mixtures; and the application, injection or intubation of a chemical into experimental animals. Class II, type B biological safety cabinets are

suitable for the conduct of tissue culture and other biological procedures involving highly toxic chemicals, reproductive toxins, and select carcinogens. The Principal Investigator is to obtain guidance from EHS on the selection and use of Class II biological safety cabinets. For more information on biological safety cabinets, refer to Chapter 16: Biological Safety Cabinets. Primary containment equipment used for chemical carcinogens must display a label bearing the legend: CAUTION - HIGHLY TOXIC CHEMICAL (OR SELECT CARCINOGEN), Authorized Personnel Only. The examples below in Figures 7.1 through 7.3 are available on the EHS Safety Labels Page for printing (http://ehs.unc.edu/ih/lab/labels/).

Figure 7.1 - Examples of postings for storage areas or primary containment equipment where highly toxic chemicals or select carcinogens are present.

A clean bench offers product protection, not personnel protection. Do not use highly toxic chemicals or select carcinogens in them. EHS will post clean benches with the following:

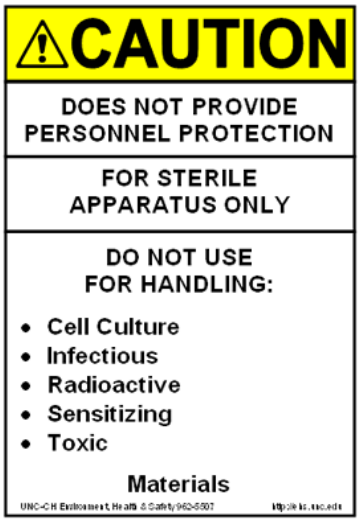


Figure 7.2 - Example posting for clean benches.

VI. Use and Decontamination of Analytical Instrumentation

Analytical instruments, when used with highly toxic chemicals, reproductive toxins, and select carcinogens, must be located entirely within a laboratory hood. When this is impossible, capture the vapors or aerosols produced by these instruments through local exhaust ventilation at the site of their production. When you remove a sample from the analytical instrument, place it in a tightly stoppered sample tube, or otherwise safeguarded from contaminating the laboratory. Do not use contaminated analytical equipment until it has been completely decontaminated. The following are some decontamination guidelines. Contact EHS if you have additional questions about equipment decontamination.

Safely remove, drain, or discharge chemicals from the equipment, collecting the chemicals for re-use or hazardous waste disposal. If applicable, use an inert gas or liquid to purge the chemical residues. In some cases, the rinsate might require disposal as hazardous waste. For equipment with non-permeable surfaces, decontaminate by scrubbing with warm, soapy water. For equipment that also might contain biological contamination, follow the soapy water wash with a 1:10 bleach solution soak. Rinse the equipment after at least 10 minutes contact time with the bleach.

VII. Storage, Inventory and Identification

Stock quantities of chemical carcinogens are to be stored in designated storage areas. Post these storage areas with signs bearing the legend: CAUTION - HIGHLY TOXIC CHEMICAL (OR SELECT CARCINOGEN), Authorized Personnel Only (Figure 7.1).

Label all storage vessels containing stock quantities with the following information: CAUTION - HIGHLY TOXIC CHEMICAL (OR SELECT CARCINOGEN). You may use these smaller labels available at the EHS Safety Labels website (for use with Avery™ Label 5160).

Figure 7.3 – Labels for storage vessels that contain highly toxic chemicals or select carcinogens.

VIII. Working Quantities

Keep quantities of highly toxic chemicals, reproductive toxins, and select carcinogens in the work area to a minimum. Quantities should not normally exceed the amounts required for use in one week. Use the label depicted in Figure 7.3 (or similar) for storage vessels containing working quantities of highly toxic chemicals or select carcinogens.

IX. Laboratory Transport

Place storage vessels containing highly toxic chemicals, reproductive toxins, and select carcinogens in an unbreakable outer container before transporting them from storage areas to laboratory work areas. Place contaminated materials to transfer from work areas to disposal areas in a closed plastic bag or other suitable impermeable and sealed primary container, and place the primary container in a durable outer container before transporting. Label the outer container with both the name of the substance and the warning from Figure 7.3.

X. Protection of Vacuum Lines

Each vacuum service, including water aspirators, must have protection via an absorbent or liquid trap and a HEPA filter to prevent entry of any highly toxic chemical, reproductive toxin, or select carcinogen into the system. When using a volatile chemical, use a separate vacuum pump or other device placed in an appropriate laboratory hood.

XI. Packaging and Shipping

Package highly toxic chemicals and select carcinogens to withstand shocks, pressure changes and any other condition that could cause the leakage of contents incident to ordinary handling during transportation. Shipments must be in accordance with DOT and IATA regulations. Contact EHS for advice on shipping and labeling.

XII. Decontamination

Highly toxic chemicals and select carcinogens that have spilled out of a primary container to create a hazard must be inactivated in situ or absorbed by appropriate means for subsequent disposal. Contaminated materials require decontamination by procedures that decompose the chemical, or removal for subsequent disposal. Write these decontamination protocols into your Laboratory Safety Plan, and update the protocols as necessary. Means for assuring the adequacy of clean up are required; for instance, wipe tests or fluorescence tests.

XIII. Disposal

EHS must approve all plans for handling and ultimate disposal of contaminated wastes. You must have written procedures in the Laboratory Safety Plan, Schedule B, Section III, and you must fully describe the highly toxic and/or carcinogenic substances in your waste stream when submitting an online hazardous materials transfer form. Refer to Chapter 12: Management of Laboratory Wastes for additional guidance.

XIV. Animal Experimentation

In all circumstances, research and animal care personnel must wear a disposable jumpsuit or lab coat, shoe coverings, gloves, and a face mask when entering DLAM animal housing facilities or procedure rooms. Some facilities also require hair and/or beard coverings. Personnel engaged in procedures with exposure to airborne particulates contaminated with highly toxic chemicals or

select carcinogens must wear an appropriate respirator of N100 or higher protection, rather than a comfort mask or surgical mask. Refer to the Respiratory Protection section of Chapter 5: Protective Clothing and Equipment, for a description of respirator types.

EHS must approve the selection and use of respirators, and wearers are to participate in the UNC Respiratory Protection Program. The UNC Respiratory Protection Program is located at http://ehs.unc.edu/workplace_safety/respiratory/index.shtml.

As discussed in Chapter 5, comfort masks and surgical masks are not respirators. The comfort masks and surgical masks provided in several DLAM facilities do not protect you from airborne exposures; instead, they protect the lab animals from your exhalations. Do not wear masks or respirators outside of the animal room or procedure room. For tight-fitting cartridge respirators, dispose of used filters and decontaminate the respirator housing daily. Personnel must shower after completion of procedures that may result in the creation of airborne contamination in the animal room.

House all experimental animals in cage systems that confine feed, feces, urine and bedding within the enclosure. When using a volatile chemical, use the cage in conjunction with appropriate ventilation systems. EHS must approve all alternative animal housing methods.

Employees working with animals must receive appropriate animal handling training from the Office of Animal Care and Use (OACU). Contact OACU for information regarding animal handler training at 6-5569 or http://research.unc.edu/iacuc/.

APPENDIX 7-A: HIGHLY TOXIC CHEMICALS LIST

The OSHA Hazard Communication Standard, 29 CFR 1910.1200, Appendix A, classifies chemicals as "Highly Toxic", if a chemical possess at least one of these three characteristics:

- LD_{50} equal or less than 50 mg/kg (oral, albino rat)
- LD_{50} equal or less than 200 mg/kg (topical for 24 hours, albino rabbit)
- LC_{50} equal or less than 200 ppm, or 2 mg/L (continuous inhalation for one hour, albino rat)

This attempt to identify and list the highly toxic chemicals that one could use in a University setting should NOT be considered exhaustive, and a chemical's absence from this list does not necessarily mean that it is not highly toxic. Check the chemical's Material Safety Data Sheet.

Chemical Name	Alternate Names	CAS#
Abrin	Toxalbumin; Rosary Pea	1393-62-0
Acrolein	2-Propen-1-one	107-02-8
Acrylonitrile	2-Propenenitrile; Cyanoethylene	107-13-1
Actinomycin	Actinomycin C; Oncostatin	1402-38-6
Actinomycin D	Oncostatin K	50-76-0
Activated Factor X	Factor X Activating Enzyme from Russell's Viper Venom	9002-05-5
Aflatoxin B1		1402-68-2
Aldicarb	Propanal, 2-methyl-2-(methylthio)-, O-((methylamino)carbonyl)oxime	116-06-3
Aldrin		309-00-2
Allyl iodide	Iodopropene, 3-	556-56-9
Amanitine, alpha-	Amatoxin, alpha-	23109-05-9
Aminopterin	Aminofolic Acid, 4-	54-62-6
Aminopyridine, 3-	Aminopyridine, m-	462-08-8
Aminopyridine, 4-	Aminopyridine, p-	504-24-5
Amiton		78-53-5
Amiton Oxalate	Tetram Monooxalate	3734-97-2
Amphetamine Sulfate, d-	Benzedrine Sulfate, d-	51-63-8
Amphetamine, d-	Amphetamine, (+)-	51-64-9
Antimony Hydride	Stibine	7803-52-3
Antimycin A	Virosin	1397-94-0
Arsenic Acid	Orthoarsenic Acid	7778-39-4
Arsenic(III) Chloride	Arsenic Trichloride	7784-34-1
Arsenic(III) Fluoride	Arsenic Trifluoride	7784-35-2
Arsenic(III) Oxide	Arsenic Trioxide; Arsenious Oxide	1327-53-3
Arsenic(III) Sulfide	Arsenic Trisulfide	1303-33-9
Arsenic(V) Oxide	Arsenic Pentoxide	1303-28-2
Arsenic(V) Sulfide	Arsenic Pentasulfide	1303-34-0
Arsine	Hydrogen Arsenide	7784-42-1
Azinphos-Methyl	Guthion	86-50-0

APPENDIX 7-A: HIGHLY TOXIC CHEMICALS LIST

Beryllium (powdered)		7440-41-7
Beryllium Sulfate Tetrahydrate	Sulfuric acid, beryllium salt (1:1), tetrahydrate	7787-56-6
Bidrin	Dipadrin; Dicrotphos	141-66-2
Bis(2-chloroethyl)-N-nitrosourea, N,N'-	BCNU; Carmustin	154-93-8
Bis(chloromethyl) Ether	BCME	542-88-1
Bis(dimethylamido)fluorophosphate	Dimefox	115-26-4
Boron Tribromide	Boron Bromide	10294-33-4
Boron Trichloride	Boron Chloride	10294-34-5
Boron Trifluoride	Boron Fluoride	7637-07-2
Botulinum Toxin B	Botulinum Toxin E	93384-44-2
Bromadiolone	Bromatrol	28772-56-7
Bungarotoxin, b-		
Butyronitrile	Cyanopropane, 1-	109-74-0
Calcium Arsenate	Arsenic Acid, Calcium Salt (2:3)	7778-44-1
Calcium Cyanide	Calcid; Cyanogas	592-01-8
Capsaicin	6-Nonenamide, 8-methyl-N-vanillyl-, (E)-	404-86-4
Carbachol Chloride	Doryl	51-83-2
Carbofuran	Yaltox	1563-66-2
Carbonyl Cyanide m-Chlorophenylhydrazone	Carbonyl Cyanide 3-Chlorophenyl Hydrazone	555-60-2
Carbophenothion	Acarithion	786-19-6
Chlorfenvinphos	Apachlor	470-90-6
Chlormephos	S-Chloromethyl-o,o-diethylphosphorodithioate	24934-91-6
Chlorophacinone		3691-35-8
Chlorthiophos		21923-23-9
Cholecalciferol	Quintox	67-97-0
Cholera Toxin		9012-63-9
Cisplatin		15663-27-1
Colchicine		64-86-8
Copper Acetoarsenite	C.I. Green 21	12002-03-8
Coumaphos		56-72-4
Crimidine	Crimitox	535-89-7
Cyanide		57-12-5
Cyanogen Chloride	Chlorine Cyanide	506-77-4
Cyanuric Fluoride	Trifluorotriazine	675-14-9
Cycloheximide	Actidione	66-81-9
Cytochalasin D	Zygosporin A	22144-77-0
Demecolcine	Colcemid	477-30-5
Dialifor		10311-84-9
Diborane	Boroethane	19287-45-7
Dibutyltin Diacetate		1067-33-0
Dichloroacetylene		7572-29-4
Dichloro-N-methyldiethylamine Hydrochloride, 2,2'-	Nitrogen Mustard Hydrochloride	55-86-7
Dichlorophenylarsine	Phenyl Dichloroarsine	696-28-6
Dichlorvos	DDVP	62-73-7
Dieldrin		60-57-1

APPENDIX 7-A: HIGHLY TOXIC CHEMICALS LIST

Diethyl 4-Nitrophenol Phosphate	Ethyl Paraoxon	311-45-5
Diethyl Chlorophosphate		814-49-3
Digitoxin		71-63-6
Digoxigenin		1672-46-4
Digoxin		20830-75-5
Diisopropyl Fluorophosphate	Isopropyl Phosphorofluoridate	55-91-4
Dimethyl Sulfate	Methyl Sulfate	77-78-1
Dimethylmercury	Methyl Mercury	593-74-8
Dimetilan		644-64-4
Dinitrobutylphenol	DNBP; 2-sec-butyl-4,6-Dinitrophenol	88-85-7
Dinitro-o-Cresol, 4,6-		534-52-1
Dinitrophenol, 2,4-	Aldifen; DNP, 2,4-	51-28-5
Dioxathion		78-34-2
Diphtheria Toxin		
Disulfoton		298-04-4
Di-tert-butyl Dicarbonate	BOC-Anhydride	24424-99-5
Dithiobiuret, 2,4-	DTB	541-53-7
Doxorubicin (Free Base)	Adriamycin (Free Base)	23214-92-8
Emetine Dihydrochloride		316-42-7
Endosulfan Sulfate		1031-07-8
Endothion		2778-04-3
Endrin	Hexadrin	72-20-8
Ergocalciferol	Vitamin D2	50-14-6
Ergosterol	Provitamin D2	57-87-4
ERL 4221	Chissonox 221 monomer	2386-87-0
Ethion		563-12-2
Ethoprophos	Ethoprop	13194-48-4
Ethylene Fluorohydrin	Fluoroethanol, 2-	371-62-0
Ethyleneimine	Aziridine	151-56-4
Ethylmercuric Phosphate		2235-25-8
Ethyl-p-nitrophenylbenzenethiophosphate	EPN	2104-64-5
Etorphine	Immobilon	14521-96-1
Fenamiphos		22224-92-6
Fensulfothion	Dasanit	115-90-2
Fluenetil		4301-50-2
Fluoride ion		16984-48-8
Fluorine		7782-41-4
Fluoroacetamide		640-19-7
Fluoroacetic Acid		144-49-0
Fonofos		944-22-9
Formaldehyde (gas)	Methyl Aldehyde	50-00-0
Formaldehyde Cyanohydrin	Glycolonitrile	107-16-4
Formetanate Hydrochloride		23422-53-9
Formparanate		17702-57-7
Gitoxin		4562-36-1

APPENDIX 7-A: HIGHLY TOXIC CHEMICALS LIST

Heptachlor		76-44-8
Heptachlor Epoxide		1024-57-3
Hexaethyl Tetraphosphate		757-58-4
Hydrazine		302-01-2
Hydrogen Cyanide	Hydrocyanic Acid	74-90-8
Hydrogen Selenide	Selenium Hydride	7783-07.5
Hygromycin B	Antihelmucin	31282-04-9
Iron Pentacarbonyl		13463-40-6
Isobenzan	Telodrin	297-78-9
Isobutyronitrile	Isopropyl Cyanide	78-82-0
Isocyanatoethyl Methacrylate, 2-		30674-80-7
Isodrin		465-73-6
Lactonitrile		78-97-7
Lannate	Methomyl	16752-77-5
Leptophos		21609-90-5
Lewisite		541-25-3
Malonitrile	Malononitrile	109-77-3
Mephosfolan		950-10-7
Mercaptofos	Demeton	8065-48-3
Mercury(II) Acetate	Mercuric Acetate	1600-27-7
Mercury(II) Bromide	Mercuric Bromide	7789-47-1
Mercury(II) Chloride	Mercuric Chloride	7487-94-7
Mercury(II) Cyanide	Mercuric Cyanide	592-04-1
Mercury(II) Iodide	Mercuric Iodide	7774-29-0
Mercury(II) Nitrate	Mercuric Nitrate	10045-94-0
Mercury(II) Oxide	Mercuric Oxide	21908-53-2
Mercury(II) Thiocyanate	Mercuric Sulfocyanate	592-85-8
Methacrolein Diacetate		10476-95-6
Methamidophos		10265-92-6
Methanesulfonyl Fluoride	Mesyl Fluoride; Fumette	558-25-8
Methidathion	Supracide	950-37-8
Methiocarb	Mecaptodimethur	2032-65-7
Methoxyethylmercuric Acetate		151-38-2
Methoxyethylmercuric Chloride		123-88-6
Methoxyflurane	Metofane; Penthrane	76-38-0
Methyl Chloroformate	Methyl Chlorocarbonate	79-22-1
Methyl Fluoroacetate	Fluoroacetic Acid, Methyl Ester	453-18-9
Methyl Isocyanate		624-83-9
Methyl Lactonitrile, 2-	Acetone Cyanohydrin	75-86-5
Methyl Phosphonic Dichloride		676-97-1
Methylaziridine, 2-	Propyleneimine	75-55-8
Methylhydrazine		60-34-4
Mevinphos	Phosdrin	7786-34-7
Mexacarbate		315-18-4
Mitomycin C	Ametycin	50-07-7

APPENDIX 7-A: HIGHLY TOXIC CHEMICALS LIST

Monensin Sodium	Coban	22373-78-0
Monochrotophos		6923-22-4
Muscimol	Pantherin; Aminomethyl-3-isoxyzole, 5-	2763-96-4
Mustard Gas	Bis(2-Chloroethyl)sulfide	505-60-2
Naphthylthiourea, alpha-	ANTU	86-88-4
Nickel Carbonyl	Nickel Tetracarbonyl	13463-39-3
Nickel Cyanide	Dicyanonickel	557-19-7
Nicotine		54-11-5
Nicotine Sulfate		65-30-5
Nitric Acid (Red Fuming)		7697-37-2
Nitric Oxide	Nitrogen Monoxide	10102-43-9
Nitrobenzonitrile, p-		619-72-7
Nitrogen Dioxide		10102-44-0
Nitrogen Mustard	Dichloro-N-methyldiethylamine, 2,2'-	51-75-2
Nitrogen Tetroxide		10544-72-6
Nitrosodimethylamine, N-	Dimethylnitrosamine	62-75-9
Nitrosomethylvinylamine, N-		4549-40-0
Norbormide		991-42-4
Ochratoxin A		303-47-9
Octamethyldiphosphoramide	Octamethylpyrophosphoramide	152-16-9
Osmium Tetroxide		20816-12-0
Ouabain	Acocantherin	630-60-4
Oxamyl		23135-22-0
Oxidiphenoxarsine, 10,10'-	Vinadine	58-36-6
Oxotremorine		70-22-4
Oxygen Difluoride	Fluorine Oxide; Oxygen Fluoride	7783-41-7
Parathion	Phosphostigmine	56-38-2
Parathion-Methyl	Methyl Parathione; Metaphor	298-00-0
Pentaborane(9)	Nonahydropentaborane	19624-22-7
Pentachlorophenol		87-86-5
Phalloidin	Phalloidon from Amanita Phalloides	17466-45-4
Phenyl Mercaptan	Thiophenol; Benzenethiol	108-98-5
Phenylmercuric Acetate	Phenylmercury Acetate	62-38-4
Phenylmercuric Triethanolamine Lactate		23319-66-6
Phenylphosphine		638-21-1
Phenylsilatrane		2097-19-0
Phenylthiocarbamide	Phenyl-2-Thiourea, 1-	103-85-5
Phorate		298-02-2
Phosacetim		4104-14-7
Phosfolan		947-02-4
Phosgene	Carbonyl Chloride	75-44-5
Phosphamidon		13171-21-6
Phosphine	Hydrogen Phosphide	7803-51-2
Phosphonothioic Acid, Methyl-, o-(4-nitrophenyl)o-phenyl Ester	Colep	2665-30-7
Phosphorus Oxychloride	Phosphoryl Chloride	10025-87-3

APPENDIX 7-A: HIGHLY TOXIC CHEMICALS LIST

Phosphorus Trichloride	Phosphorous Chloride	7719-12-2
Phosphorus, Yellow	Phosphorus, White	7723-14-0
Physostigmine	Eserine	57-47-6
Physostigmine Salicylate	Eserine Salicylate	57-64-7
Physostigmine Sulfate	Eserine Sulfate	64-47-1
Picrotoxin	Cocculin	124-87-8
Potassium Arsenite	Arsenenous Acid, Potassium Salt	10124-50-2
Potassium Azide		20762-60-1
Potassium Cyanide		151-50-8
Potassium Silver Cyanide	Silver Potassium Cyanide	506-61-6
Promecarb		2631-37-0
Propanenitrile	Propionitrile; Ethyl Cyanide	107-12-0
Propargyl Alcohol		107-19-7
Propiolactone, beta-	Propiolactone, 1,3-	57-57-8
Puromycin	Achromycin	53-79-2
Ricin		9009-86-3
Sarin	Isopropylmethanefluorophosphonate	107-44-8
Selenium Dioxide	Selenium(IV) Dioxide	7446-08-4
Sodium Arsenate	Arsenic Acid, Sodium Salt	7631-89-2
Sodium Azide		26628-22-8
Sodium Cyanide		143-33-9
Sodium Dichromate		10588-01-9
Sodium Fluoroacetate	Fluoroacetic Acid, Sodium Salt	62-74-8
Sodium Meta Arsenite		7784-46-5
Sodium Selenate	Selenic Acid, Disodium Salt	13410-01-0
Sodium Selenite	Selenious Acid, Disodium Salt	10102-18-8
Streptonigrin	Bruneomycin	3930-19-6
Strychnine		57-24-9
Strychnine Sulfate	Vampirol	60-41-3
Sulfur Pentafluoride	Sulfur Decafluoride	5714-22-7
Sulfur Tetrafluoride		7783-60-0
Tabun		77-81-6
Tellurium Hexafluoride		7783-80-4
Tetrachlorodibenzo-p-Dioxin, 2,3,7,8-	TCDD, 2,3,7,8-; Dioxine	1746-01-6
Tetraethyl Dithiopyrophosphate	Sulfotep; TEDP	3689-24-5
Tetraethyl Lead	Tetraethyl Plumbane	78-00-2
Tetraethyl Pyrophosphate	Vapatone	107-49-3
Tetraethyltin	Tetraethyl Stannate	597-64-8
Tetrodotoxin	Tetrodotoxin Citrate	4368-28-9
Thallium Malonate	Thallous Malonate	2757-18-8
Thallium Sulfate		10031-59-1
Thallium(I) Acetate	Thallous Acetate	563-68-8
Thallium(I) Carbonate	Thallous Carbonate	6533-73-9
Thallium(I) Chloride	Thallous Chloride	7791-12-0
Thallium(I) Nitrate	Thallous Nitrate	10102-45-1

APPENDIX 7-A: HIGHLY TOXIC CHEMICALS LIST

Thallium(I) Sulfate	Thallous Sulfate	7446-18-6
Thallium(III) Oxide	Thallic Oxide	1314-32-5
Thiocarbazide	Thiocarbohydrazide - TCH	2231-57-4
Thiodan	Endosulfan	115-29-7
Thiofanox	Dacamox	39196-18-4
Thionazin		297-97-2
Thiosemicarbazide	Thiocarbamylhydrazine	79-19-6
Tirpate	2,4-Dimethyl-1,3-dithiolane-2-carboxaldehyde O-(methylcarbamoyl)oxime	26419-73-8
Toluene Diisocyanate	Methyl-m-phenylene Diisocyanate	26471-62-5
Toluene-2,4-Diisocyanate		584-84-9
Toxaphene	Camphechlor	8001-35-2
Triamiphos		1031-47-6
Tricarbonylmethylcyclopentadienyl Manganese		12108-13-3
Trichloronate	Agrisil; Phytosol	327-98-0
Trimethylopropane Phosphite		824-11-3
Trimethyltin Chloride	Chlorotrimethylstannate	1066-45-1
Triphenyltin Hydroxide		76-87-9
Tris(1-aziridinyl)phosphine Sulfide	Thiotepa	52-24-4
Tris(2-chloroethyl)amine		555-77-1
Tubocurarine	Tubocurarine Hydrochloride	57-94-3
Tungsten Hexafluoride	Tungsten(VI) Fluoride	7783-82-6
Uracil Mustard	5-(Bis-(2-chloroethyl)-amino)-uracil	66-75-1
Valinomycin, (+)-	Valinomicin	2001-95-8
Vanadium(V) Oxide	Vanadium Pentoxide	1314-62-1
Warfarin		81-81-2
Warfarin Sodium	Sodium Coumadin	129-06-6
Yohimbine Hydrochloride		65-19-0
Zinc Phosphide		1314-84-7
Zinc Silicofluoride	Zinc Fluorosilicate	16871-71-9

This page intentionally left blank.

APPENDIX 7-B: SELECT CARCINOGENS LIST

The OSHA Laboratory Standard 29 CFR 1910.1450 defines select carcinogens as those chemicals that are:

- regulated by OSHA as carcinogens;
- listed by the National Toxicology Program (NTP) as "known to be carcinogens" (data taken from biennial Report on Carcinogens, Eleventh Edition, 2005);
- listed by the International Agency for Research on Cancer Monographs (IARC-2006) in Group 1 (carcinogenic to humans);
- listed by NTP as reasonably anticipated to be carcinogens (taken from RoC, 2005) or by IARC (2006) in Group 2A (probably carcinogenic to humans) or in Group 2B (possibly carcinogenic to humans) and causes statistically significant tumor incidence in experimental animals.

The following is a combined list of chemicals carcinogens from OSHA, NTP, and IARC.

Acetaldehyde
Acetamide
Acetylaminofluorene, 2-
Acrylamide
Acrylonitrile
Adriamycin (doxorubicin hydrochloride)
Aflatoxins
Aflatoxin M1
Alcoholic beverages (consumption)
Alpha-Chlorinated toluenes
Aluminium production
Amino-2,4-dibromoanthraquinone, 1-
Amino-2-methylanthraquinone, 1-
Amino-5-(5-nitro-2-furyl)-1,3,4-thiadiazole, 2-
Amino-9H-pyrido[2,3-beta]indole), A-alpha-C(2-
Aminoanthraquinone, 2-
Aminoazobenzene, para-
Aminoazotoluene, ortho-
Aminobiphenyl, 4-
Amitrole
Amsacrine
Analgesic mixtures containing phenacetin
Androgenic (anabolic) steroids
Anisidine, ortho-
Antimony trioxide
Aramite
Areca nut
Aristolochia genus herbal remedies
Arsenic and arsenic compounds
Asbestos
Attapulgite (palygorskite), long fibers >5mm
Auramine, technical-grade
Azacitidine
Azaserine
Azathioprine

APPENDIX 7-B: SELECT CARCINOGENS LIST

Aziridine
Benz(a)anthracene
Benzene
Benzidine
Benzidine-based dyes (technical grade)
Direct Black 38
Direct Blue 6
Direct Brown 95
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(j)fluoranthene
Benzo(k)fluoranthene
Benzofuran
Benzotrichloride
Benzyl violet 4B
Beryllium and beryllium compounds
Betel quid with tobacco
Betel quid without tobacco
Bis(2-chloroethyl)-2-naphthylamine(Chlornaphazine), N,N- Bis(chloromethyl)ether
Bis(bromomethyl)propane-1,3-diol, 2,2-
Bischloroethyl nitrosourea (BCNU)
Bis(chloromethyl) ether
Bitumens, extracts of steam-refined and air-refined
Bleomycins
Bracken fern
Bromodichloromethane
Butadiene, 1,3-
Butanediol dimethanesulphonate (myleran), 1,4-
Butanediol dimethylsulfonate (myleran), 1,4-
Butylated hydroxyanisole (BHA)
Butyrolactone, beta-
C.I. Basic Red 9 monohydrochloride
Cadmium and certain cadmium compounds
Caffeic acid
Captafol
Carbon black extract
Carbon tetrachloride
Carrageenan, degraded
Catechol
Ceramic fibers (respirable size)
Chlorambucil
Chloramphenicol
Chlordane
Chlordecone (kepone)
Chlorendic acid
Chloro-4-(dichloromethyl)5-hydroxy-2(*5H*)-furanone, 3-
Chloroaniline, para-
Chloroethyl)-3-cyclohexyl-1-nitrosourea (CCNU), 1-(2-

APPENDIX 7-B: SELECT CARCINOGENS LIST

Chloroethyl)-3-4-methylcyclohexyl-1 nitrosourea, 1-(2-
Chlorinated paraffins (C12, 60% Chlorine)
Chlorinated toluenes, alpha- (not necessarily all in group)
Chlornaphazine
Chloro-2-methylpropene, 1-
Chloro-2-methylpropene, 3-
Chloro-o-phenylenediamine, 4-
Chloro-ortho-toluidine, para-
Chloroform
Chloromethyl ether
Chloromethyl methyl ether (technical grade)
Chlorophenols and their sodium salts
Chlorophenoxy herbicides
Chloroprene
Chlorothalonil
Chlorozotocin
Chromium compounds, hexavalent
CI Acid Red 114
CI Basic Red 9
CI Direct Blue 15
Cisplatin
Citrus Red No. 2
Clonorchis sinensis (Oriental liver fluke)
Coal tar pitches
Coal tars
Cobalt and cobalt compounds
Cobalt metal with tungsten carbide
Cobalt metal without tungsten carbide
Cobalt(II) sulfate and other soluble cobalt(II) salts
Coffee (bladder)
Conjugated estrogens
Creosotes
Cresidine, para-
Cupferron
Cycasin
Cyclophosphamide
Cyclosporin A
Dacarbazine
Danthron (1,8-dihydroxyanthraquinone)
Daunomycin
DDT
Diacetylbenzidine, N,N'-
Diaminoanisole, 2,4-
Diaminoanisole sulfate, 2,4-
Diaminodiphenyl ether, 4,4'
Diaminotoluene, 2,4-
Diazoaminobenzene
Dibenz(a,h)acridine

APPENDIX 7-B: SELECT CARCINOGENS LIST

Dibenz(a,h)anthracene
Dibenz(a,j)acridine
Dibenzo(a,e)pyrene
Dibenzo(a,h)pyrene
Dibenzo(a,i)pyrene
Dibenzo(a,l)pyrene
Dibenzo(c,g)carbazole, 7H-
Dibromo-3-chloropropane, 1,2-
Dibromoethane (EDB), 1,2-
Dibromopropan-1-ol, 2,3-
Dichloroacetic acid
Dichlorobenzene, para-
Dichlorobenzene, 1,4-
Dichlorobenzidine, 3,3'-
Dichloro-4,4'-diaminodiphenyl ether, 3,3'-
Dichloroethane, 1,2-
Dichloromethane (methylene chloride)
Dichloropropene (technical grade), 1,3-
Dichlorvos
Diepoxybutane
Diesel engine exhaust
Diesel fuel (marine)
Di (2-ethylhexyl) phthalate
Diethyl sulphate
Diethylhydrazine, 1,2-
Diethylstilbestrol
Diglycidyl resorcinol ether
Dihydrosafrole
Diisopropyl sulfate
Dimethoxybenzidine, 3,3'-
Dimethoxybenzidine (ortho-dianisidine), 3,3'
Dimethyl sulphate
Dimethylaminoazobenzene, para
[(Dimethylamino) methylamino]-5-[2-(5-nitro-2-, trans-2-
Dimethylaniline, 2,6- (2,6-xylidene)
Dimethylbenzidine, 3,3'-
Dimethylbenzidine (ortho-toluidine), 3,3'-
Dimethylcarbamoyl chloride
Dimethylhydrazine, 1,1-
Dimethylhydrazine, 1,2-
Dimethylvinyl chloride
Dinitrofluoroanthrene, 3,7-
Dinitrofluoroanthrene, 3,9-
Dinitropyrene, 1,6-
Dinitropyrene, 1,8-
Dinitrotoluene, 2,4-
Dinitrotoluene, 2,6-
Dioctyl phthalate [Di(2-ethylhexyl)phthalate]

APPENDIX 7-B: SELECT CARCINOGENS LIST

Dioxane, 1,4-
Direct Black 38
Direct Blue 6
Direct Brown 95
Disperse Blue 1
Epichlorohydrin
Epoxybutane, 1,2-
Epstein-Barr virus
Erionite
Estrogens (not conjugated): estradiol-17
Estrogens (not conjugated): estrone
Estrogens (not conjugated): mestranol
Estrogens (not conjugated): ethinylestradiol
Ethylbenzene
Ethyl acrylate
Ethyl methanesulphonate
Ethyl-N-nitrosourea, N-
Ethylene oxide
Ethylene thiourea
Ethylene dibromide
Ethyleneimine
Etoposide
Etoposide in combination with cisplatin and bleomycin
Formaldehyde
Formylhydrazino)-4-(5-nitro-2-furyl)thiazole, 2-(2-
Fuel oils (residual, heavy)
Furan
Furyl)-3-(5-nitro-2-furyl)acrylamide], AF-2[2-
Fusarium moniliform (toxins derived from)
- Fumonisin B1
- Fumonisin B2
- Fusarin C

Gallium arsenide
Gamma radiation (ionizing radiation)
Gasoline
Gasoline engine exhausts
Glasswool (respirable size)
Glu-P-1 (2-amino-6-methyldipyrido[1,2-a:3',2'-d]imidazole)
Glu-P-2(2-aminodipyrido[1,2-a:3',2'-d]imidazole)
Glycidaldehyde
Glycidol
Griseofulvin
HC Blue No 1
Helicobacter pylori (infection with)
Hepatitis B virus (chronic infection with)
Hepatitis C virus (chronic infection with)
Heptachlor
Hexachlorobenzene

APPENDIX 7-B: SELECT CARCINOGENS LIST

Hexachlorocyclohexanes
Hexachloroethane
Hexamethylphosphoramide
Human immunodeficiency virus type 1 (infection with)
Human immunodeficiency virus type 2 (infection with)
Human papilloma virus type 16
Human papilloma virus type 18
Human papilloma virus type 31
Human papilloma virus type 33
Human papilloma virus: some types other than 16, 18, 31, and 33
Human T-cell lymphotropic virus type I
Hydrazine and hydrazine sulfate
Hydrazobenzene
Hydroxyanthroquinone, 1-
Indeno(1,2,3-cd)pyrene
Indium phosphide
Involuntary smoking
IQ (2-amino-3-methylimidazo[4,5-f]quinoline)
Iron-dextran complex
Isoprene
Kaposi's sarcoma herpesvirus/human herpesvirus 8
Kepone (chlordecone)
Lasiocarpine
Lead
Lead acetate and lead phosphate
Lead compounds, inorganic
Lindane and other hexachlorocyclohexane isomers
Magenta (containing CI Basic Red 9)
Magnetic fields (extremely low frequency)
Man-made mineral fibers (glasswool, rockwool, slagwool, and ceramic fibers), respirable size
Mate drinking (hot)
MeA-alpha-C(2-amino-3-methyl-9H-pyrido[2,3-b]indole)
MeIQ (2-amino-3,4-dimethylimidazo[4,5-f]-quinolone)
MeIQx (2-amino-3,8-dimethylamidazo[4,5-f] quinoxaline)
Medroxyprogesterone acetate
Melphalan
Merphalan
Methoxsalen with ultraviolet A therapy (PUVA)
Methoxypsoralen, 8- plus ultraviolet radiation
Methoxypsoralen, 5-
Methyl mercury compounds (methylmercuric chloride)
Methyl methanesulphonate
Methyl chloromethyl ether
Methyl-1-nitroanthraquinone (uncertain purity), 2-
Methyl-N'-nitro-N-nitrosoguanidine, N- (MNNG)
Methyl-N-nitrosourethane, N-
Methyl-N-nitrosourea, N-
Methylaziridine (propyleneimine), 2-

APPENDIX 7-B: SELECT CARCINOGENS LIST

Methylazoxymethanol and its acetate
Methylchrysene, 5-
Methylene bis(2-methylaniline), 4,4'-
Methylenebis (N,N-dimethyl)benzenamine, 4,4'-
Methylenebis(2-chloroaniline) (MBOCA), 4,4'-
Methylene chloride (dichloromethane)
Methylenedianiline, 4,4'- and its dihydrochloride
Methyleugenol
Methylthiouracil
Metronidazole
Michler's Ketone
Mineral oils - untreated and mildly treated oils
Mirex
Mitoxantrone
Mitomycin C
Monocrotaline
MOPP and other combined chemotherapy for cancer
Morpholinomethyl)-3-[(5-nitrofurfurylidene)amino]-2- oxazolidinone, 5-(
Mustard gas (sulphur mustard)
Nafenopin
Naphthalene
Naphthalamine, alpha-
Naphthylamine, beta-
Neutrons (ionizing radiation)
Nickel and certain nickel compounds
Niridazole
Nitrilotriacetic acid and its salts
Nitro-2-furyl)-2-thiazolyl]acetamide, N-[4-(5-
Nitroacenaphthene, 5-
Nitroanisole, 2-
Nitrobenzene
Nitrobiphenyl, 4-
Nitrochrysene, 6-
Nitrofen
Nitrofluorene, 2-
Nitrofurfurylidene)amino]-2-imidazolidinone, 1-[(5-
Nitro-2-furyl)-2-thiazolyl] acetamide, N-[4-(5-
Nitrogen mustard N-oxide
Nitrogen mustard hydrochloride
Nitrogen mustard
Nitrolotriacetic acid and its salts
Nitromethane
Nitropropane, 2-
Nitropyrene, 1-
Nitropyrene, 4-
Nitroso-N-ethylurea, N-
Nitroso-N-methylurea, N-
Nitrosodi-n-butylamine, N-

APPENDIX 7-B: SELECT CARCINOGENS LIST

Nitrosodi-n-propylamine, N-
Nitrosodiethanolamine, N-
Nitrosodiethylamine, N-
Nitrosodimethylamine, N-
Nitrosomethylamino)propionitrile, 3-(N-
Nitrosomethylamino)-1-(3-pyridyl)-1-butanone (NNK), 4-(N-
Nitrosomethylethylamine, N-
Nitrosomethylvinylamine, N-
Nitrosomorpholine, N-
Nitrosonornicotine, N- (NNN)
Nitrosopiperidine, N-
Nitrosopyrrolidine, N-
Nitrososarcosine, N-
Norethisterone
Ocratoxin A
Oestrogen-progestogen therapy, postmenopausal
Oestrogens, nonsteroidal*
Oestrogens, steroidal*
Oil Orange SS
Opisthorchis viverrini (infection with)
Oral contraceptives, sequential or combined
Oxazepam
Oxydianiline, 4,4'-
Oxymetholone
Panfuran S (containing dihydroxymethylfuratrizine)
Phenacetin
Phenazopyridine hydrochloride
Phenobarbital
Phenolphthalein
Phenoxybenzamine hydrochloride
Phenyl glycidyl ether
Phenytoin
PhIP (2-amino-1-methyl-6-phenylimidazo [4,5-b] pyridine)
Phosphorus-32 (^{32}P), as phosphate
Pickled vegetables, traditional Asian
Plutonium-239 (^{239}Pu) and its decay products, as aerosols
Polybrominated biphenyls (PBBs)
Polychlorinated biphenyls (PCBs)
Polycyclic aromatic hydrocarbons (PAHs)
Ponceau MX
Ponceau 3R
Potassium bromate
Procarbazine hydrochloride
Progesterone
Progestins
Propane sultone -propiolactone, 1,3-
Propane sultone, 1,3-
Propiolactone, beta-
Propylene oxide

APPENDIX 7-B: SELECT CARCINOGENS LIST

Propylthiouracil
Radionuclides, α and β particle emitting, internally deposited
Radium-224 (^{224}Ra) and its decay products
Radium-226 (^{226}Ra) and its decay products
Radium-228 (^{228}Ra) and its decay products
Radon-222 (^{222}Rn) and its decay products
Refractory ceramic fibers
Reserpine
Riddelliine
Safrole
Salted fish, Chinese style
Schistosoma haematobium (infection with)
Schistosoma japonicum (infection with)
Selenium sulfide
Shale oils
Silica (crystalline)
Sodium ortho-phenylphenate
Solar radiation
Soots
Sterigmatocystin
Streptozotocin
Styrene
Styrene oxide (styrene-7,8-oxide)
Sulfallate
Sulphuric acid (occupational exposures to strong inorganic acid mists)
Sunlamps and sunbeds (use of)
Talc containing asbestiform fibers
Tamoxifen
Tenopiside
Tetrachlorodibenzo-p-dioxin (TCDD), 2,3,7,8-
Tetrachloroethylene (perchloroethylene)
Tetrafluoroethylene
Tetranitromethane
Thioacetamide
Thiodianiline, 4,4'-
Thiotepa [tris(1-aziridinyl)phosphine sulfide]
Thiouracil
Thiourea
Thorium dioxide
Thorium-232 (^{232}Th) and its decay products
Tobacco products (smokeless)
Tobacco smoke
Toluene diisocyanates
Toluidine, ortho- (3,3-Dimethylbenzidine)
Toluidine hydrochloride, ortho-
Toxaphene (polychlorinated camphenes)
trans-2[(Dimethylamino)methylimino]-5-[2-(5-nitro-2-furyl)vinyl]- Treosulphan
Treosulphan

APPENDIX 7-B: SELECT CARCINOGENS LIST

Trichloroethylene
Trichlormethine (trimustine hydrochloride)
Trichlorophenol, 2,4,6-
Trichloropropane, 1,2,3-
Tris(2,3-dibromopropyl)phosphate
Trp-P-1 (3-Amino-1,4-dimethyl-5H-pyrido[4,3-b]indole)
Trp-P-2(3-Amino-1-methyl-5H-pyrido[4,3-b]indole)
Trypan blue
Ultraviolet radiation: A, B, and C including sunlamps and sunbeds
Uracil mustard
Urethane
Vanadium pentoxide
Vinyl acetate
Vinyl bromide
Vinyl chloride
Vinyl fluoride
Vinylcyclohexene, 4-
Vinylcyclohexene diepoxide, 4-
Welding fumes
Wood dust
X-radiation (ionizing radiation)
Zalcitabine
Zidovudine (AZT, retrovir)

Occupational exposures associated with a technological process known to be carcinogenic:

Boot and shoe manufacture and repair
Carpentry and joinery
Coal gasification
Coke oven emissions
Coke production
Dry cleaning
Furniture and cabinet making
Glass manufacturing industry (occupational exposure)
    Art glass, glass containers and pressed ware
Hairdresser or barber (occupational exposure to dyes)
Insecticide use (occupational)
Iron and steel founding
Isopropyl alcohol manufacture (strong-acid process)
Magenta manufacture
Painter (occupational exposures)
Printing processes (occupational exposures)
Petroleum refining (occupational refining exposures)
Rubber industry
Soots, tars, and mineral oils
Textile manufacturing (occupational exposures)
Wood industries

CHAPTER 8

REPRODUCTIVE HEALTH

Overview

This chapter supplements previous chapters by giving specific extra precautions, postings, training, and protective equipment necessary when working with reproductive hazards. These include chemical, biological, or radiological substances that can affect the developing fetus, or the reproductive health of the male or female parents. This chapter also outlines the UNC conceptus protection policy for laboratory workers who are pregnant or contemplating pregnancy. The appendix at the end of the chapter is a thorough (but not exhaustive) list of known reproductive toxins that might be present in your laboratory.

Table of Contents

This page intentionally left blank.

CHAPTER 8

REPRODUCTIVE HEALTH

I. Introduction

Work with reproductive hazards requires special containment practices in addition to those described in Chapter 6 for toxic chemicals and in the Biological Safety Manual. Reproductive hazards are defined by the OSHA Laboratory Standard as substances that cause chromosomal damage (mutagens) and substances with lethal or teratogenic (malformation) effects on fetuses. These can include chemicals, biological materials, and radioactive materials. The University policy for protecting pregnant employees is provided later in the section entitled "Reproductive Hazards and the Pregnant Employee". For a list of known reproductive toxins, refer to Appendix 8-A.

II. Laboratory Safety Plans

Laboratories working with reproductive hazards must include standard operating procedures in the Laboratory Safety Plan describing the hazards of the compounds or agents, safety precautions and emergency procedures in the event of a spill. The template for completing and submitting a laboratory safety plan is included in Chapter 2: Laboratory Safety Plan, and at the EHS Laboratory Safety Plan webpage: http://ehs.unc.edu/ih/lab/lsp.shtml. In addition to the safety practices described for use of toxic materials, several other special safety precautions are necessary for reproductive toxins.

III. Facility Requirements

Establish a "designated area", with access restricted to personnel who are aware of the hazards of the substances in use and the necessary precautions. A foot or elbow operated handwash facility and an eyewash facility must be available within the work area. A shower facility, other than emergency drench showers, must be located in the building.

Exhaust ventilation systems are designed to maintain an inflow of air from the corridor into the work area. The exhaust air from the work area must discharge directly to the outdoors, and clear of occupied buildings and air intakes. Exhaust air from the work area must not recirculate. The exhaust air from glove boxes must filter through high-efficiency particulate air (HEPA) and charcoal filters. EHS shall determine the need for and type of treatment for other primary containment equipment. Exhaust air treatment systems that remove toxic chemicals from the exhaust air by collection mechanisms such as filtration or absorption must operate in a manner that permits maintenance, in order to avoid direct contact with the collection medium. All exhaust air from primary containment equipment must discharge directly to the outdoors and disperse clear of occupied buildings and intakes. The EHS Director must approve the purchase and installation of any non-ducted hoods. Non-ducted hoods will not be approved for use with volatile chemicals. Approval will be granted only in exceptional cases, and only when particulate handling (e.g., weighing solids) is its sole use.

IV. Protective Clothing (Refer to Chapter 5: Protective Clothing and Equipment)

Wear a full-fastened laboratory coat or a disposable jump suit in any area where known or suspected reproductive toxins are in use. Clean clothing must be provided weekly and cannot be worn outside of the work area. Following an obvious exposure, decontaminate or dispose immediately all contaminated clothing. Do not send contaminated clothing to the laundry until decontaminated. Wear appropriate gloves (LSM Appendix 5-A) when handling reproductive toxins. EHS recommends double gloving. Discard disposable gloves after each use and immediately after known contact with a reproductive toxin.

V. Use of Primary Containment Equipment

Procedures involving volatile chemicals, and those involving solid or liquid chemicals that may result in the generation of aerosols, must occur in a laboratory hood, biological safety cabinet, glove box, or other suitable containment equipment. Examples of aerosol-producing procedures include: opening closed vessels; transfer operations; weighing; preparing feed mixtures; and the application, injection or intubation of a chemical into experimental animals. Class II, type B biological safety cabinets are suitable for the conduct of tissue culture and other biological procedures involving reproductive toxins. The Principal Investigator is to obtain guidance from EHS on the selection and use of Class II biological safety cabinets. For more information on biological safety cabinets, refer to Chapter 16: Biological Safety Cabinets. Primary containment equipment used for reproductive toxins must display a label bearing the legend: CAUTION - REPRODUCTIVE TOXIN, Authorized Personnel Only. The examples below in Figures 8.1 through 8.3 are available on the EHS Safety Labels Page for printing (http://ehs.unc.edu/ih/lab/labels/).

Figure 8.1 - Label for storage areas or primary containment equipment where reproductive toxins are present.

A clean bench offers product protection, not personnel protection. Do not use reproductive toxins in them. Post clean benches with the following information:

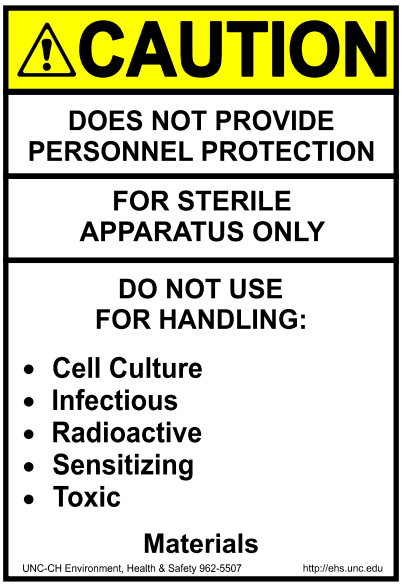


Figure 8.2 - Example posting for clean benches.

VI. Use and Decontamination of Analytical Instrumentation

Analytical instruments used with reproductive toxins must be entirely within a laboratory hood. When this is impossible, capture the vapors or aerosols produced by these instruments through local exhaust ventilation at the site of their production. When you remove a sample from the analytical instrument, place it in a tightly stoppered sample tube, or otherwise safeguarded from contaminating the laboratory. Do not use contaminated analytical equipment until it has been completely decontaminated. The following are some decontamination guidelines. Contact EHS if you have additional questions about equipment decontamination.

Safely remove, drain, or discharge chemicals from the equipment, collecting the chemicals for re-use or hazardous waste disposal. If applicable, use an inert gas or liquid to purge the chemical residues. In some cases, the rinsate might require disposal as hazardous waste. For equipment with non-permeable surfaces, decontaminate by scrubbing with warm, soapy water. For equipment that also might contain biological contamination, follow the soapy water wash with a 1:10 bleach solution soak. Rinse the equipment after at least 10 minutes contact time with the bleach.

VII. Storage, Inventory and Identification

Store stock quantities of reproductive toxins in designated storage areas. Post these storage areas with signs bearing the legend: CAUTION - REPRODUCTIVE TOXIN, Authorized Personnel Only (Figure 8.1).

Label all storage vessels containing stock quantities with the following information: CAUTION - REPRODUCTIVE TOXIN (Figure 8.3 or similar). This smaller label, which does not include the "Authorized Personnel Only" statement necessary for containment equipment or storage areas, is available at EHS Safety Labels Page, in a printable form suitable for use with Avery™ Label 5160.

Figure 8.3 – Label for storage vessels that contain reproductive toxins.

VIII. Working Quantities

Keep quantities of reproductive toxins in the work area to a minimum. Quantities should not normally exceed the amounts required for use in one week. Use the label depicted in Figure 8.3 (or similar) for storage vessels containing working quantities of reproductive toxins.

IX. Laboratory Transport

Place storage vessels containing reproductive toxins in an unbreakable outer container before transporting them from storage areas to laboratory work areas. Place contaminated materials to transfer from work areas to disposal areas in a closed plastic bag or other suitable impermeable and sealed primary container, and place the primary container in a durable outer container before transporting. Label the outer container with both the name of the substance and the hazard information from Figure 8.3.

X. Protection of Vacuum Lines

Each vacuum service, including water aspirators, must have protection via an absorbent or liquid trap and a HEPA filter to prevent entry of any reproductive toxin into the system. When using a volatile chemical, use a separate vacuum pump or other device placed in an appropriate laboratory hood.

XI. Packaging and Shipping

Package reproductive toxins to withstand shocks, pressure changes, or other condition that could cause the leakage of contents incident to ordinary handling during transportation. Shipments must be in accordance with DOT and IATA regulations. Contact EHS for advice on shipping and labeling.

XII. Decontamination

You must inactivate in situ reproductive toxins that spill out of a primary container and create a hazard or absorb by appropriate means for subsequent disposal. Contaminated materials require decontamination by procedures that decompose the chemical, or removal for subsequent disposal. Means for assuring the adequacy of clean up are required; for instance, wipe tests or fluorescence tests.

XIII. Disposal

EHS must approve all plans for handling and ultimate disposal of contaminated wastes. Write these into the Laboratory Safety Plan, Schedule B, Section III, and fully describe the reproductive toxins in your waste stream when submitting an online hazardous materials transfer form. Refer to Chapter 12: Management of Laboratory Wastes for additional guidance.

XIV. Animal Experimentation

In all circumstances, research and animal care personnel must wear a disposable jumpsuit or lab coat, shoe coverings, hair covering, gloves, and a respiratory comfort mask when entering DLAM animal housing facilities or procedure rooms (refer to Chapter 14: Safe Handling of Laboratory Animals). Personnel with exposure to airborne particulates contaminated with reproductive toxins must wear an appropriate respirator of N95 or higher protection, rather than a comfort mask. Refer to the Respiratory Protection section of Chapter 5: Protective Clothing and Equipment, for a description of respirator types.

EHS must approve the selection and use of respirators, and wearers are to participate in the UNC Respiratory Protection Program. The UNC Respiratory Protection Program is located at http://ehs.unc.edu/workplace_safety/respiratory/index.shtml.

As discussed in Chapter 5, comfort masks are not respirators. The comfort masks provided in several DLAM facilities do not protect you from airborne exposures; instead, they protect the laboratory animals from your exhalations. Do not wear the comfort mask or respirator outside of the animal room or procedure room. For tight-fitting cartridge respirators, dispose of used filters and decontaminate the respirator housing daily. Personnel must shower after completion of procedures that may result in the creation of airborne contamination in the animal room.

House all experimental animals in cage systems that confine feed, feces, urine and bedding within the enclosure. When using a volatile chemical, use the cage in conjunction with appropriate ventilation systems. EHS must approve all alternative animal housing methods.

Employees working with animals must receive appropriate animal handling training from the Office of Animal Care and Use (OACU). Contact OACU for information regarding animal handler training at 6-5569 or http://research.unc.edu/iacuc/.

XV. Reproductive Hazards and the Pregnant Employee

A. Introduction

Reproductive toxins are defined by the OSHA Laboratory Standard as substances that cause chromosomal damage (mutagens) and/or substances with lethal or teratogenic (malformation) effects on fetuses. Teratogens may affect the conceptus at any stage of its development, from fertilization to birth, although damage is most likely during the first 8 to 10 weeks of pregnancy. Mutagens can also affect conceptus development, or prevent fertilization entirely by damaging the egg or sperm. In addition, there are microbiological agents that can cause maternal morbidity, miscarriage, fetal death or birth defects.

Teratogens are chemical and physical agents that interfere with normal embryonic development. Teratogens differ from mutagens in that there must be a developing fetus. Reproductive toxins may produce congenital malformations or death of the fetus without inducing damage to the pregnant woman. In general, you should consider carcinogenic, mutagenic and teratogenic chemicals hazards to reproductive health. Even though OSHA has established hazardous material exposure limits, a developing fetus can suffer adverse effects at lower doses than those considered safe for adults. Thus, you must keep exposures as low as reasonably achievable to minimize reproductive health hazards.

UNC is committed to provide additional protection for the conceptus, and establish specific procedures to protect pregnant employees. Control of employee exposures will occur without economic penalty or loss of job opportunity, including, if necessary, consideration for work assignment changes, consistent with University personnel policy. Assuring protection from exposures to radiation and/or chemicals for the conceptus requires full cooperation of the employee with the Department of Environment, Health and Safety (EHS). If you wish to take advantage of this policy, contact EHS as soon as possible after determining or contemplating pregnancy, to ensure implementation of these policies.

B. Chemical and Radiological Reproductive Hazards

A thorough list of known reproductive toxins is found in Appendix 8-A to this Chapter. This list includes agents that cause fetal developmental toxicity, damage the male/female reproductive cells, or other difficulty with conception. Examples of reproductive toxins commonly found in laboratories include:

- Dibromochloropropane
- Lead
- Arsenic
- Benzene
- Cadmium
- Ethylene glycol monomethyl (and ethyl) ethers
- Carbon disulfide
- Ethylene thiourea

- Ethylene oxide
- Mercury compounds
- Toluene
- Polychlorinated biphenols (PCBs)
- Ethylene dibromide
- 1,3-Butadiene
- Fluorouracil
- Halothane
- Urethane
- Ionizing radiation

Please refer to Appendix 8-A for a thorough listing.

C. Microbiological Reproductive Hazards

Certain microbiological agents can cause miscarriages, fetal death and birth defects. Employees can be exposed to these agents via splashes or contact with mucous membranes, needlesticks or ingestion. The following agents are known to be reproductive hazards:

- **Rubella virus (German measles)**. Congenital rubella syndrome (CRS) may occur in infants born to women with rubella in 1st trimester. This can lead to fetal death, spontaneous abortions, congenital malformations of the eyes, ears and heart, mental retardation and/or poor childhood growth. The risk decreases with fetal development.

- **Human Parvovirus (Fifth Disease)**. Prenatal infection with human parvovirus can cause fetal edema and death. Intrauterine infection may cause fetal anaemia.

- **Cytomegalovirus (CMV)**. CMV is a known teratogen and congenital infection can cause mental retardation, cerebral palsy, epilepsy, vision and hearing problems especially during the first 20 weeks of fetal development.

- **Varicella virus (Chicken Pox)**. Congenital infection can cause limb atrophy, microcephaly, cortical atrophy, motor, sensory and eye problems. Infection in the during the first trimester can cause miscarriage, muscular atropy, clubbed foot, CNS disease and cataracts in the fetus.

- **Hepatitis A, B, C**. Prenatal infection can cause prematurity and psychomotor retardation.

- **Human Immunodeficiency Virus (HIV)**. HIV can affect fertility. HIV can also be transmitted to the fetus.

- **Listeria monocytogenes**. This bacterium is found in a variety of animals including mammals and birds so is of special concern to employees handling animals.

Perinatal infections occur transplacentally and can result in abortion, stillbirth; meningitis, endocarditis, and septicemia.

- **Toxoplasma gondii (toxoplasmosis)**. Congenital cases can result in abortion and stillbirth, live births may result in central nervous system disorders, hydrocephaly, mental retardation; transplacental infection is least likely during 1st trimester, but these cases are the most severe. Cats can carry this disease and employees conducting experiments with cats may need to take additional precautions.

This list is not all inclusive and EHS will evaluate work exposures to all infectious materials once an employee has declared their pregnancy.

D. Declared Pregnancy

If you wish the University to be involved in protecting your fetus, and exposures to the fetus kept below the 500 millirems limit if you are a radiation worker, you must declare your actual, suspected, or planned pregnancy to your supervisor and EHS in writing, or by e-mail. The University's responsibility for conceptus protection begins only after receipt of this notice of pregnancy, or intended pregnancy, to your supervisor and EHS. The involvement of supervisors is an essential part of the University's safety management. EHS urges every potentially pregnant employee to consider her supervisor's safety responsibilities and freely involve the supervisor in all work-related situations.

E. Conceptus Protection Program

Following written or e-mail notice of pregnancy or intended pregnancy to the EHS Director, Industrial Hygiene Manager, Chemical Hygiene Officer, or Radiation Safety Officer, EHS institutes a conceptus protection program (CPP). The CPP consists of three elements.

(1) Confidential Conferences

Conferences include the employee, her supervisor, and an EHS specialist. The employee is provided a copy of this policy and other pertinent literature on protecting pregnant employees from chemical exposures. Following the conference, EHS asks the employee and her supervisor to sign a statement confirming that this policy and other related information has been received, personnel monitoring has been established, and that supervision is involved. Adjustments should be made in work responsibilities, if practicable, to avoid higher risk operations. EHS reviews past records of work involving hazardous materials and the current occupational potential for chemical exposure.

An additional interview is available with an occupational health nurse or physician at the University Employee Occupational Health Clinic. This interview allows the employee to express concerns and to ask questions about reproductive and developmental health. A review of an occupational and reproductive health questionnaire facilitates collection of

employee-specific information, assists the employee in formulating concerns about chemical and physical hazards, and provides structure and focus for the interview. A preconception planning stage is also available. Obstetric specialists are available for consultation or referral for any specific concerns.

EHS understands that employees may choose to maintain their pregnancy status as personally confidential for a time. Any employee may still receive safety information about pregnancy and chemical exposures at any time from EHS without declaring her pregnancy status.

(2) **EHS Review of Laboratory Safety**

EHS will conduct a review of the laboratory or worksite safety plan to ensure that it provides appropriate guidance to protect workers and prevent occupational exposures. EHS inspects the work place to ensure that adequate engineering controls, such as laboratory hoods, are provided, and that safe handling procedures and the use of personal protective equipment are in place. Employees have the responsibility of adhering to University safety procedures described in the Laboratory (or worksite) Safety Plan, the Health and Safety Manual, Laboratory Safety Manual, and the Radiation Safety Manual.

(3) **Radiation and Chemical Exposure Monitoring**

EHS will monitor employee exposures levels for radiation and any chemicals of concern, especially those with evidence of reproductive toxicity. The employee and principal investigator, or supervisor, shall receive a copy of the monitoring report. The goal is to keep all exposures as low as reasonably achievable.

EHS performs the personnel radiation monitoring through the Radiation Safety Officer. EHS assigns the radiation employee a monthly radiation badge and/or places her on a monthly bioassay program.

F. Action Levels

(1) **Radiation Exposures**

Current investigational radiation dose limits for declared pregnant or planned pregnancy employees will direct the RSO in evaluating reported doses. The North Carolina Regulations for Protection Against Radiation has established a radiation dose limit of 500 millirems for the conceptus during the entire gestation period.

Action Level I: employees with exposures greater than 30 millirems in a month. The RSO or designee shall send a written description of the dose report statistics, including the dose history for the previous two monitoring periods, to the person involved with a copy to the Authorized User. EHS asks the individual to review his or her radiation safety procedures and work habits in an effort to maintain all doses as low as reasonably achievable. Health physics reviews and consultation are available.

Action Level II: greater than 40 millirems in a month. The RSO shall conduct a direct investigation of the situation, including an interview with the person involved. The RSO prepares a written investigation report, including trends over the past one year (as available) for that person. The RSO provides a copy of the report to the employee for review and signature. Conclusions drawn from the investigation provide a basis for confirming or modifying the dose and for establishing corrective actions to undertake.

When the occupational radiation dose of a declared radiation employee exceeds 50 millirems in a month since declaration, the employee may request:

- Maternity leave (for those employees actually pregnant),
- Other paid leave,
- Leave without pay,
- Reassignment within their work unit, or
- Transfer.

The supervisor should respond to requests in accordance with Human Resources personnel policies.

EHS and the Radiation Protection Section of the NC Department of Environment and Natural Resources accept doses reported from personnel monitoring badges generally as an uncorrected guide to any conceptus dose. If personnel monitoring results indicate the possibility of a conceptus dose in excess of the 500-millirem limit, a special investigation will result. The investigation will take into full consideration the type and energy of radiation involved, protective shielding that might have mitigated conceptus dose, and shielding afforded by the mother's body. The employee and EHS will discuss the investigation results, and a written report provided.

(2) **Chemical Exposures**

As stated earlier, the goal is to keep all exposures to both radiation and chemicals as low as reasonably achievable. The actions taken in response to a measured chemical exposure depend on the specific circumstances and chemicals involved. However, as a general rule, if any exposure measurements exceed 10% of the threshold limit value (TLV) or permissible exposure limit (PEL) action will be taken to prevent further exposure by instituting engineering controls, improved work practices, personal protective equipment (PPE), or job reassignment.

(3) **Microbiological Exposures**

There are no action levels for microbiological agents. Many of the agents listed above can be safely handled at Biosafety Level 2 practices and containment (culturing HIV requires Biosafety Level 3 practices). Biosafety Level 2 practices include wearing gloves, labcoats and eye protection, conducting any aerosol generating procedures inside of a biological safety cabinet, decontamination of surfaces, frequent handwashing, and no eating, drinking, smoking or handling contacts in areas where infectious materials are handled. Please refer to the UNC Biological Safety Manual for more detailed information. These practices are required to protect the employee; however, some procedures conducted in the laboratory may be higher risk for pregnant employees and should be evaluated by EHS. In addition, the risks to the fetus from exposure to these pathogens may warrant restriction from use during a pregnancy. EHS in consultation with the employee and their supervisor will determine when restriction or additional personal protective equipment is necessary.

APPENDIX 8-A: REPRODUCTIVE TOXINS LIST

The following list comes from the State of California, which by law requires the Governor to revise and republish at least annually the list of chemicals known by the State to cause reproductive toxicity and cancer, commonly known as the Proposition 65 list. Listed below are the substances from the Proposition 65 list that exhibit fetal development toxicity or female/male reproductive toxicity. The date of listing is in the right-hand column.

List date: December 8, 2006

Chemical Name	Type of Toxicity	CAS#	Date Listed
1-(2-Chloroethyl)-3-cyclohexyl-1-nitrosourea (CCNU) (Lomustine)	developmental	13010474	01-Jul-90
1,2-Dibromo-3-chloropropane (DBCP)	male	96128	27-Feb-87
1,3-Butadiene	developmental, female, male	106990	16-Apr-04
1,4-Butanediol dimethanesulfonate (Busulfan)	developmental	55981	01-Jan-89
1-Bromopropane	developmental, female, male	106945	07-Dec-04
2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (TCDD)	developmental	1746016	01-Apr-91
2,4-D butyric acid	male	94826	18-Jun-99
2,4-Dinitrotoluene	male	121142	20-Aug-99
2,6-Dinitrotoluene	male	606202	20-Aug-99
2-Bromopropane	female, male	75263	31-May-05
Acetazolamide	developmental	59665	20-Aug-99
Acetohydroxamic acid	developmental	546883	01-Apr-90
Actinomycin D	developmental	50760	01-Oct-92
All-trans retinoic acid	developmental	302794	01-Jan-89
Alprazolam	developmental	28981977	01-Jul-90
Altretamine	developmental, male	645056	20-Aug-99
Amantadine hydrochloride	developmental	665667	27-Feb-01
Amikacin sulfate	developmental	39831555	01-Jul-90
Aminoglutethimide	developmental	125848	01-Jul-90
Aminoglycosides	developmental	---	01-Oct-92
Aminopterin	developmental, female	54626	01-Jul-87
Amiodarone hydrochloride	developmental, female, male	19774824	26-Aug-97
Amitraz	developmental	33089611	30-Mar-99
Amoxapine	developmental	14028445	15-May-98
Anabolic steroids	female, male	---	01-Apr-90
Angiotensin converting enzyme (ACE) inhibitors	developmental	---	01-Oct-92
Anisindione	developmental	117373	01-Oct-92
Arsenic (inorganic oxides)	developmental	---	01-May-97
Aspirin (NOTE: It is especially important not to use aspirin during the last three months of pregnancy, unless specifically directed to do so by a physician because it may cause problems in the unborn child or complications during delivery.)	developmental, female	50782	01-Jul-90
Atenolol	developmental	29122687	26-Aug-97
Auranofin	developmental	34031328	29-Jan-99
Azathioprine	developmental	446866	01-Sep-96
Barbiturates	developmental	---	01-Oct-92
Beclomethasone dipropionate	developmental	5534098	15-May-98
Benomyl	developmental, male	17804352	01-Jul-91
Benzene	developmental, male	71432	26-Dec-97
Benzodiazepines	developmental	---	01-Oct-92
Benzphetamine hydrochloride	developmental	5411223	01-Apr-90
Bischloroethyl nitrosourea (BCNU) (Carmustine)	developmental	154938	01-Jul-90
Bromacil lithium salt	developmental	53404196	18-May-99
Bromacil lithium salt	male	53404196	17-Jan-03
Bromoxynil	developmental	1689845	01-Oct-90
Bromoxynil octanoate	developmental	1689992	18-May-99
Butabarbital sodium	developmental	143817	01-Oct-92

APPENDIX 8-A: REPRODUCTIVE TOXINS LIST

Butyl benzyl phthalate (BBP)	developmental	85687	02-Dec-05
Cadmium	developmental, male	---	01-May-97
Carbamazepine	developmental	298464	29-Jan-99
Carbon disulfide	developmental, female, male	75150	01-Jul-89
Carbon monoxide	developmental	630080	01-Jul-89
Carboplatin	developmental	41575944	01-Jul-90
Chenodiol	developmental	474259	01-Apr-90
Chinomethionat (Oxythioquinox)	developmental	2439012	06-Nov-98
Chlorambucil	developmental	305033	01-Jan-89
Chlorcyclizine hydrochloride	developmental	1620219	01-Jul-87
Chlordecone (Kepone)	developmental	143500	01-Jan-89
Chlordiazepoxide	developmental	58253	01-Jan-92
Chlordiazepoxide hydrochloride	developmental	438415	01-Jan-92
Chlorsulfuron	developmental, female, male	64902723	14-May-99
Cidofovir	developmental, female, male	113852372	29-Jan-99
Cladribine	developmental	4291638	01-Sep-96
Clarithromycin	developmental	81103119	01-May-97
Clobetasol propionate	developmental, female	25122467	15-May-98
Clomiphene citrate	developmental	50419	01-Apr-90
Clorazepate dipotassium	developmental	57109907	01-Oct-92
Cocaine	developmental, female	50362	01-Jul-89
Codeine phosphate	developmental	52288	15-May-98
Colchicine	developmental, male	64868	01-Oct-92
Conjugated estrogens	developmental	---	01-Apr-90
Cyanazine	developmental	21725462	01-Apr-90
Cycloate	developmental	1134232	19-Mar-99
Cycloheximide	developmental	66819	01-Jan-89
Cyclophosphamide (anhydrous)	developmental, female, male	50180	01-Jan-89
Cyclophosphamide (hydrated)	developmental, female, male	6055192	01-Jan-89
Cyhexatin	developmental	13121705	01-Jan-89
Cytarabine	developmental	147944	01-Jan-89
Dacarbazine	developmental	4342034	29-Jan-99
Danazol	developmental	17230885	01-Apr-90
Daunorubicin hydrochloride	developmental	23541506	01-Jul-90
Demeclocycline hydrochloride (internal use)	developmental	64733	01-Jan-92
Di(2-ethylhexyl)phthalate	developmental, male	117817	24-Oct-03
Diazepam	developmental	439145	01-Jan-92
Diazoxide	developmental	364987	27-Feb-01
Dichlorophene	developmental	97234	27-Apr-99
Dichlorphenamide	developmental	120978	27-Feb-01
Diclofop methyl	developmental	51338273	05-Mar-99
Dicumarol	developmental	66762	01-Oct-92
Diethylstilbestrol (DES)	developmental	56531	01-Jul-87
Diflunisal	developmental, female	22494424	29-Jan-99
Dihydroergotamine mesylate	developmental	6190392	01-May-97
Diltiazem hydrochloride	developmental	33286225	27-Feb-01
Di-*n*-butyl phthalate (DBP)	developmental, female, male	84742	02-Dec-05
Di-*n*-hexyl phthalate (DnHP)	female, male	84753	02-Dec-05
Dinitrotoluene (technical grade)	female, male	---	20-Aug-99
Dinocap	developmental	39300453	01-Apr-90
Dinoseb	developmental, male	88857	01-Jan-89
Diphenylhydantoin (Phenytoin)	developmental	57410	01-Jul-87
Disodium cyanodithioimidocarbonate	developmental	138932	30-Mar-99
Doxorubicin hydrochloride	developmental, male	23214928	29-Jan-99
Doxycycline (internal use)	developmental	564250	01-Jul-90
Doxycycline calcium (internal use)	developmental	94088854	01-Jan-92
Doxycycline hyclate (internal use)	developmental	24390145	01-Oct-91
Doxycycline monohydrate (internal use)	developmental	17086281	01-Oct-91
Endrin	developmental	72208	15-May-98
Environmental tobacco smoke (ETS)	developmental	---	09-Jun-06
Epichlorohydrin	male	106898	01-Sep-96

APPENDIX 8-A: REPRODUCTIVE TOXINS LIST

Ergotamine tartrate	developmental	379793	01-Apr-90
Estropipate	developmental	7280377	26-Aug-97
Ethionamide	developmental	536334	26-Aug-97
Ethyl alcohol in alcoholic beverages	developmental	---	01-Oct-87
Ethyl dipropylthiocarbamate	developmental	759944	27-Apr-99
Ethylene dibromide	developmental, male	106934	15-May-98
Ethylene glycol monoethyl ether	developmental, male	110805	01-Jan-89
Ethylene glycol monoethyl ether acetate	developmental, male	111159	01-Jan-93
Ethylene glycol monomethyl ether	developmental, male	109864	01-Jan-89
Ethylene glycol monomethyl ether acetate	developmental, male	110496	01-Jan-93
Ethylene oxide	female	75218	27-Feb-87
Ethylene thiourea	developmental	96457	01-Jan-93
Etodolac	developmental, female	41340254	20-Aug-99
Etoposide	developmental	33419420	01-Jul-90
Etretinate	developmental	54350480	01-Jul-87
Fenoxaprop ethyl	developmental	66441234	26-Mar-99
Filgrastim	developmental	121181531	27-Feb-01
Fluazifop butyl	developmental	69806504	06-Nov-98
Flunisolide	developmental, female	3385033	15-May-98
Fluorouracil	developmental	51218	01-Jan-89
Fluoxymesterone	developmental	76437	01-Apr-90
Flurazepam hydrochloride	developmental	1172185	01-Oct-92
Flurbiprofen	developmental, female	5104494	20-Aug-99
Flutamide	developmental	13311847	01-Jul-90
Fluticasone propionate	developmental	80474142	15-May-98
Fluvalinate	developmental	69409945	06-Nov-98
Ganciclovir sodium	developmental, male	82410320	26-Aug-97
Gemfibrozil	female, male	25812300	20-Aug-99
Goserelin acetate	developmental, female, male	65807025	26-Aug-97
Halazepam	developmental	23092173	01-Jul-90
Halobetasol propionate	developmental	66852548	20-Aug-99
Haloperidol	developmental, female	52868	29-Jan-99
Halothane	developmental	151677	01-Sep-96
Heptachlor	developmental	76448	20-Aug-99
Hexachlorobenzene	developmental	118741	01-Jan-89
Hexamethylphosphoramide	male	680319	01-Oct-94
Histrelin acetate	developmental	---	15-May-98
Hydramethylnon	developmental, male	67485294	05-Mar-99
Hydroxyurea	developmental	127071	01-May-97
Idarubicin hydrochloride	developmental, male	57852570	20-Aug-99
Ifosfamide	developmental	3778732	01-Jul-90
Iodine-131	developmental	10043660	01-Jan-89
Isotretinoin	developmental	4759482	01-Jul-87
Lead	developmental, female, male	---	27-Feb-87
Leuprolide acetate	developmental, female, male	74381536	26-Aug-97
Levodopa	developmental	59927	29-Jan-99
Levonorgestrel implants	female	797637	15-May-98
Linuron	developmental	330552	19-Mar-99
Lithium carbonate	developmental	554132	01-Jan-91
Lithium citrate	developmental	919164	01-Jan-91
Lorazepam	developmental	846491	01-Jul-90
Lovastatin	developmental	75330755	01-Oct-92
m-Dinitrobenzene	male	99650	01-Jul-90
Mebendazole	developmental	31431397	20-Aug-99
Medroxyprogesterone acetate	developmental	71589	01-Apr-90
Megestrol acetate	developmental	595335	01-Jan-91
Melphalan	developmental	148823	01-Jul-90
Menotropins	developmental	9002680	01-Apr-90
Meprobamate	developmental	57534	01-Jan-92
Mercaptopurine	developmental	6112761	01-Jul-90
Mercury and mercury compounds	developmental	---	01-Jul-90

APPENDIX 8-A: REPRODUCTIVE TOXINS LIST

Methacycline hydrochloride	developmental	3963959	01-Jan-91
Metham sodium	developmental	137428	15-May-98
Methazole	developmental	20354261	01-Dec-99
Methimazole	developmental	60560	01-Jul-90
Methotrexate	developmental	59052	01-Jan-89
Methotrexate sodium	developmental	15475566	01-Apr-90
Methyl bromide, as a structural fumigant	developmental	74839	01-Jan-93
Methyl chloride	developmental	74873	10-Mar-00
Methyl mercury	developmental	---	01-Jul-87
Methyltestosterone	developmental	58184	01-Apr-90
Metiram	developmental	9006422	30-Mar-99
Midazolam hydrochloride	developmental	59467968	01-Jul-90
Minocycline hydrochloride (internal use)	developmental	13614987	01-Jan-92
Misoprostol	developmental	59122462	01-Apr-90
Mitoxantrone hydrochloride	developmental	70476823	01-Jul-90
Myclobutanil	developmental, male	88671890	16-Apr-99
Nabam	developmental	142596	30-Mar-99
Nafarelin acetate	developmental	86220420	01-Apr-90
Neomycin sulfate (internal use)	developmental	1405103	01-Oct-92
Netilmicin sulfate	developmental	56391572	01-Jul-90
Nickel carbonyl	developmental	13463393	01-Sep-96
Nicotine	developmental	54115	01-Apr-90
Nifedipine	developmental, female, male	21829254	29-Jan-99
Nimodipine	developmental	66085594	24-Apr-01
Nitrapyrin	developmental	1929824	30-Mar-99
Nitrofurantoin	male	67209	01-Apr-91
Nitrogen mustard (Mechlorethamine)	developmental	51752	01-Jan-89
Nitrogen mustard hydrochloride (Mechlorethamine hydrochloride)	developmental	55867	01-Jul-90
N-Methylpyrrolidone	developmental	872504	15-Jun-01
Norethisterone (Norethindrone)	developmental	68224	01-Apr-90
Norethisterone (Norethindrone) /Ethinyl estradiol	developmental	68224/57636	01-Apr-90
Norethisterone (Norethindrone) /Mestranol	developmental	68224/72333	01-Apr-90
Norethisterone acetate (Norethindrone acetate)	developmental	51989	01-Oct-91
Norgestrel	developmental	6533002	01-Apr-90
o,p'-DDT	developmental, female, male	789026	15-May-98
o-Dinitrobenzene	male	528290	01-Jul-90
Oxadiazon	developmental	19666309	15-May-98
Oxazepam	developmental	604751	01-Oct-92
Oxydemeton methyl	female, male	301122	06-Nov-98
Oxymetholone	developmental	434071	01-May-97
Oxytetracycline (internal use)	developmental	79572	01-Jan-91
Oxytetracycline hydrochloride (internal use)	developmental	2058460	01-Oct-91
p,p'-DDT	developmental, female, male	50293	15-May-98
Paclitaxel	developmental, female, male	33069624	26-Aug-97
Paramethadione	developmental	115673	01-Jul-90
p-Dinitrobenzene	male	100254	01-Jul-90
Penicillamine	developmental	52675	01-Jan-91
Pentobarbital sodium	developmental	57330	01-Jul-90
Pentostatin	developmental	53910251	01-Sep-96
Phenacemide	developmental	63989	01-Jul-90
Phenprocoumon	developmental	435972	01-Oct-92
Pimozide	developmental, female	2062784	20-Aug-99
Pipobroman	developmental	54911	01-Jul-90
Plicamycin	developmental	18378897	01-Apr-90
Polybrominated biphenyls	developmental	---	01-Oct-94
Polychlorinated biphenyls	developmental	---	01-Jan-91
Potassium dimethyldithiocarbamate	developmental	128030	30-Mar-99
Pravastatin sodium	developmental	81131706	03-Mar-00
Prednisolone sodium phosphate	developmental	125020	20-Aug-99
Procarbazine hydrochloride	developmental	366701	01-Jul-90

APPENDIX 8-A: REPRODUCTIVE TOXINS LIST

Propargite	developmental	2312358	15-Jun-99
Propylthiouracil	developmental	51525	01-Jul-90
Pyrimethamine	developmental	58140	29-Jan-99
Quazepam	developmental	36735225	26-Aug-97
Quizalofop-ethyl	male	76578148	24-Dec-99
Resmethrin	developmental	10453868	06-Nov-98
Retinol/retinyl esters, when in daily dosages in excess of 10,000 IU, or 3,000 retinol equivalents. (NOTE: Retinol/retinyl esters are required and essential for maintenance of normal reproductive function. The recommended daily level during pregnancy is 8,000 IU.)	developmental	---	01-Jul-89
Ribavirin	developmental	36791045	01-Apr-90
Ribavirin	male	36791045	27-Feb-01
Rifampin	developmental, female	13292461	27-Feb-01
Secobarbital sodium	developmental	309433	01-Oct-92
Sermorelin acetate	developmental	---	20-Aug-99
Sodium dimethyldithiocarbamate	developmental	128041	30-Mar-99
Sodium fluoroacetate	male	62748	06-Nov-98
Streptomycin sulfate	developmental	3810740	01-Jan-91
Streptozocin (streptozotocin)	developmental, female, male	18883664	20-Aug-99
Sulfasalazine	male	599791	29-Jan-99
Sulindac	developmental, female	38194502	29-Jan-99
Tamoxifen citrate	developmental	54965241	01-Jul-90
Temazepam	developmental	846504	01-Apr-90
Teniposide	developmental	29767202	01-Sep-96
Terbacil	developmental	5902512	18-May-99
Testosterone cypionate	developmental	58208	01-Oct-91
Testosterone enanthate	developmental	315377	01-Apr-90
Tetracycline (internal use)	developmental	60548	01-Oct-91
Tetracycline hydrochloride (internal use)	developmental	64755	01-Jan-91
Tetracyclines (internal use)	developmental	---	01-Oct-92
Thalidomide	developmental	50351	01-Jul-87
Thioguanine	developmental	154427	01-Jul-90
Thiophanate methyl	female, male	23564058	18-May-99
Tobacco smoke (primary)	developmental, female, male	---	01-Apr-88
Tobramycin sulfate	developmental	49842071	01-Jul-90
Toluene	developmental	108883	01-Jan-91
Triadimefon	developmental, female, male	43121433	30-Mar-99
Triazolam	developmental	28911015	01-Apr-90
Tributyltin methacrylate	developmental	2155706	01-Dec-99
Trientine hydrochloride	developmental	38260014	27-Feb-01
Triforine	developmental	26644462	18-Jun-99
Trilostane	developmental	13647353	01-Apr-90
Trimethadione	developmental	127480	01-Jan-91
Trimetrexate glucuronate	developmental	82952645	26-Aug-97
Triphenyltin hydroxide	developmental	76879	18-Mar-02
Uracil mustard	developmental, female, male	66751	01-Jan-92
Urethane (Ethyl carbamate)	developmental	51796	01-Oct-94
Urofollitropin	developmental	97048130	01-Apr-90
Valproate (Valproic acid)	developmental	99661	01-Jul-87
Vinblastine sulfate	developmental	143679	01-Jul-90
Vinclozolin	developmental	50471448	15-May-98
Vincristine sulfate	developmental	2068782	01-Jul-90
Warfarin	developmental	81812	01-Jul-87
Zileuton	developmental, female	111406872	22-Dec-00

CHAPTER 9

CONTROLLED SUBSTANCES

Overview

This chapter gives definitions and protocols for chemicals that are classified as controlled substances by the U.S. Drug Enforcement Administration. Controlled substances have special rules for acquisition, storage, security, inventory/recordkeeping, disposal, and importing or exporting, detailed in this chapter. The appendices include a current list of controlled substances and forms for inventory support and personnel screening.

Table of Contents

This page intentionally left blank.

CHAPTER 9

CONTROLLED SUBSTANCES

I. Introduction

Because of their potential for abuse, controlled substances have specific regulatory requirements for their acquisition, storage, security, use, and disposal.

Controlled substances are any drugs or chemical substances whose possession and use are regulated under the United States Controlled Substances Act, or the North Carolina Controlled Substances Act. The U.S. Department of Justice, Drug Enforcement Administration (DEA) administers the federal law, and the North Carolina Department of Health and Human Services, Drug Control Branch (NC-DCB) administers the state law. Controlled substances have stimulant, depressant, or hallucinogenic effects on the higher functions of the central nervous system, and tend to promote abuse or physiological/psychological dependence.

II. Controlled Substance Requirements

A. Schedules

Substances regulated under the U.S. Controlled Substances Act (CSA) are in one of five schedules. Schedule I substances have the most restrictions, and Schedule V substances the least. The CSA defines the schedules as follows:

Schedule I: Drug or other substance with a high potential for abuse, no currently accepted medical use in treatment in the United States, and a lack of accepted safety protocols for use under medical supervision.

Schedule II: High potential for abuse; a currently accepted use in treatment in the United States, or currently accepted medical use with severe restrictions; abuse may lead to severe psychological or physical dependence.

Schedule III: Potential for abuse less than Schedule I or II substances; currently accepted medical use in treatment in the United States; abuse may lead to moderate or low physical dependence or high psychological dependence.

Schedule IV: Low potential for abuse relative to Schedule III; currently accepted medical use in treatment in the United States; abuse may lead to limited physical or psychological dependence relative to Schedule III.

Schedule V: Low potential for abuse relative to Schedule IV; currently accepted medical use in treatment in the United States; abuse may lead to limited physical or psychological dependence relative to Schedule IV.

Appendix 9-A is an alphabetical list of the drugs and substances currently regulated by the CSA, and their corresponding schedule.

B. Registration and Acquisition

Only registered personnel with the appropriate state and federal licenses can order controlled substances. Some departments at UNC have one or more persons who maintain controlled substance licenses, and order these substances for authorized researchers within their department; other departments require each investigator seeking to use controlled substances to obtain their own licenses. Contact your department administrator to determine licensing and ordering requirements within the department.

For departments that allow license holders to authorize (and order substances for) additional personnel, see section II-C(2) below for further details. License holders who wish to transfer these substances to a designated authorized user can do so, but the license holder retains all liabilities for loss, theft, or misuse of the substance. Individual registration and licensing is required for use of Schedule I controlled substances without exception.

To order controlled substances, you must register at the state level with the NC-DCB and the Federal level with the DEA. At this time, the NC-DCB does not have a Webpage or online information available. Contact the NC-DCB by phone at 919-733-1765 in order to begin the registration process.

The state requires that registrants fill out the DHHS 225 form (for researchers and analytical laboratories) or DHHS 224 form (for clinicians and instructional activities). In order to properly complete this form, you must know which schedule(s) your controlled substance(s) are in, and whether they are narcotic or non-narcotic (required for Schedule II and III substances only). You can find this information in Appendix 9-A. The registration fee is currently $125 for researchers and $100 for analytical laboratories.

For Federal registration, researchers and analytical laboratory personnel must complete the DEA Form 225 for new applications, or the Form 225-A for renewal applications. For Practitioners/Physicians who plan to use the controlled substances in their professional practice, or teaching institutions using the substances for instructional activities, use DEA Form 224 for new applications, or Form 224-A for renewal applications. Because UNC is a state institution, UNC personnel are exempt from the Federal registration fee. Online versions of the Federal registration forms are on the DEA Office of Diversion Control website:

http://www.deadiversion.usdoj.gov/drugreg/index.html

Once registration at the State and Federal level is complete, and you have passed a background check and received your licenses for controlled substances, you can proceed to ordering. Note that the NC-DCB and the DEA can (and often do) send out inspectors to verify that adequate security is in place before they issue the licenses. For ordering

Schedule I and II substances, you must use the Official Order Form – DEA 222. You can obtain these forms free of charge from the DEA Greensboro Field Office:

DEA – Office of Diversion Control
1801 Stanley Road, Suite 201
Greensboro, NC 27407
(336) 547-4219 – phone
(336) 547-4209 – fax

You can also contact the Field Registration Technician at the DEA Atlanta Regional Office at 1-888-219-8689 to obtain Official Order Form – DEA 222, or for any questions about registration.

C. Security

The registrant is responsible for managing the controlled substances in accordance with all regulatory requirements including security, inventory, and recordkeeping.

(1) Facility Security

Regardless of schedule, all controlled substances must be kept under lock and key, in a substantially constructed cabinet or safe, and accessible only to authorized personnel. Storage cabinets must be heavy enough to be essentially immovable, or built into the structure of the building. Doors must not be prone to forced opening by prying tools, or easily removable at the hinges. Wood or laminate casework is not likely to provide adequate security (Figure 9.1).

Keep the controlled substances locked in their storage locations except for the time required for authorized staff to remove, work with, and replace them.

Schedule I and II substances have the highest security requirements, and must be stored in an approved safe, steel cabinet, or vault. The facility security requirements for researchers and analytical laboratory personnel who are not practitioners are at http://www.deadiversion.usdoj.gov/21cfr/cfr/1301/1301_72.htm. The practitioner requirements are at http://www.deadiversion.usdoj.gov/21cfr/cfr/1301/1301_75.htm. Please contact EHS if you have questions about whether your facility security is adequate.

Figure 9.1 –
(Left): Sturdy lockable steel cabinet for storage of controlled substances.
(Middle): Safe that is anchored to the wall and approved for Schedule I-II controlled substances.
(Right): Wood laminate casework island with drawers that could be pried open, and laminate wall cabinets with glass doors; no appropriate areas for secure storage of controlled substances.

(2) Personnel Security

For substances in Schedules II-V, the registrant may authorize additional personnel to use the substances for approved activities. The registrant is required to screen these employees prior to authorization, using the following questions for non-practitioners who seek access to DEA controlled substances (ref. 21 CFR 1301.90):

- Within the past five years, have you been convicted of a felony, or, within the past two years, any misdemeanor, or, are you presently charged with committing a criminal offense?
- In the past three years, have you knowingly used narcotics, amphetamines, or barbiturates other than those prescribed to you by a physician?
- Have you had an application for registration with the DEA denied, revoked, or surrendered for cause?

Use the questionnaire in Appendix 9-B to record these answers. Registrants must maintain the answers to these screening questions for authorized personnel in a secure place, away from the purview of unauthorized personnel.

Schedule I substances may not be issued to anyone other than the registrant, or used by anyone other than the registrant. If additional personnel need to use Schedule I substances, they must individually register with NC-DCB and DEA.

(3) Inventory and Recordkeeping

Registrants must maintain complete and accurate inventory records for all controlled substances. These records must be in or near the primary work area, separate from all other records and documents, and available for inspection during regular work hours.

Records must include at least the following information:

a. Receipt of Controlled Substance: A separate and current record indicating the date received, name and address of supplier, the type, strength, and concentration of substance, and the amount received. The person receiving the substance must sign each record.

b. Use of Controlled Substance: A separate and current record for the storage and use of each controlled substance, indicating the starting quantity, use date, building and room, specific research experiment or analysis, type and strength used, and the quantity used. Each use is a subtraction from the starting quantity, and the running amount must equal the total amount remaining. The person working with the substance must sign each record of use. Because these records require subtracting balances as the substances are used, they are often called "substance balance log sheets". See Appendix 9-C for an example of a substance balance log sheet.

c. Inventory of Controlled Substance: In addition to the balance log records, initial and biennial inventory records are required for Schedule I and II substances. These shall include the name of each substance, each finished form of the substance (solid, tincture, inhalant, etc.), the number of units or volume of each finished form, and the number of containers of each finished form. Damaged, defective, expired, or impure substances awaiting disposal must be included in the inventory until they are disposed. See Appendix 9-D for an example biennial inventory sheet for Schedule I and II substances.

Maintain all of the above-referenced records for a period of at least three years from the date of the last entry. In the event of an audit by DEA or NC-DCB, you will need to produce these records.

(4) Loss, Theft, or Misuse

In the event that controlled substances are lost, stolen, or used in an unauthorized manner, the registrant must immediately contact the UNC Police at 962-8100 (or 911), and the DEA Office of Diversion Control in Greensboro, phone number 336-547-4219. The DEA staff will let you know whether you need to fill out a copy of DEA Form 106: Report of Theft or Loss of Controlled Substances. The Form 106 is at http://www.deadiversion.usdoj.gov/21cfr_reports/theft/106_blank.pdf.

If you are told to fill out a Form 106, send the original and a copy to the DEA office:

DEA – Office of Diversion Control
1801 Stanley Road, Suite 201
Greensboro, NC 27407

Diversions are likely to trigger audits. Please follow the facility and personnel security measures outlined above to reduce the chances of loss, theft, or misuse of controlled substances.

D. Disposal

You must account for all controlled substances upon their disposal. Substances that are expired, unused, or neat waste must be stored under lock and key until ready for disposal. For substances that do not pose an ecological hazard (e.g. pure substances not commingled with other waste types), the registrant can dispose the substances down the sanitary sewer with a witness present. **Note that only the registrant can do this.** Wear a dust mask and nitrile gloves during disposal, and flush down the substances with copious amounts of water. The registrant and witness must sign DEA Form 41 (http://www.ehs.unc.edu/pdf/dea_form41.pdf) stating the date of disposal and the type/quantity of substances disposed. Fax a copy to the DEA Office of Diversion Control in Greensboro (fax 336-547-4209). As with other records, keep a copy for at least three years.

The registrant must perform the disposal. If the registrant is not available to perform the disposal (for example, the registrant has left the institution, or is deceased), contact the NC-DCB at 919-733-1765 or DEA Diversion Control at 336-547-4219 for guidance.

For controlled substances that are converted into a non-recoverable hazardous waste mixture, contact the Hazardous Materials Manager at 962-5509 for advice on disposal.

E. Importing and Exporting Controlled Substances

If you plan to import controlled substances into the United States, or export them out of the United States, you must complete additional forms. See the Import/Export pages of the DEA Office of Diversion Control website for additional information.

http://www.deadiversion.usdoj.gov/imp_exp/index.html

APPENDIX 9-A

CONTROLLED SUBSTANCES – ALPHABETICAL ORDER LISTING

April 2006 Revision

SUBSTANCE	DEA NUMBER	CSA SCH	NARC	OTHER NAMES
1-(1-Phenylcyclohexyl)pyrrolidine	7458	I	N	PCPy, PHP, rolicyclidine
1-(2-Phenylethyl)-4-phenyl-4-acetoxypiperidine	9663	I	Y	PEPAP, synthetic heroin
1-[1-(2-Thienyl)cyclohexyl]piperidine	7470	I	N	TCP, tenocyclidine
1-[1-(2-Thienyl)cyclohexyl]pyrrolidine	7473	I	N	TCPy
13Beta-ethyl-17beta-hydroxygon-4-en-3-one	4000	III	N	
17Alpha-methyl-3alpha,17beta-dihydroxy-5alpha-androstane	4000	III	N	
17Alpha-methyl-3beta,17beta-dihydroxy-5alpha-androstane	4000	III	N	
17Alpha-methyl-3beta,17beta-dihydroxyandrost-4-ene	4000	III	N	
17Alpha-methyl-4-hydroxynandrolone (17alpha-methyl-4-hydroxy-17beta-hydroxyestr-4-en-3-one)	4000	III	N	
17Alpha-methyl-delta1-dihydrotestosterone (17beta-hydroxy-17alpha-methyl-5alpha-androst-1-en-3-one)	4000	III	N	17-Alpha-methyl-1-testosterone
19-Nor-4-androstenediol (3beta,17beta-dihydroxyestr-4-ene; 3alpha,17beta-dihydroxyestr-4-ene)	4000	III	N	
19-Nor-4-androstenedione (estr-4-en-3,17-dione)	4000	III	N	
19-Nor-5-androstenediol (3beta,17beta-dihydroxyestr-5-ene; 3alpha,17beta-dihydroxyestr-5-ene)	4000	III	N	
19-Nor-5-androstenedione (estr-5-en-3,17-dione)	4000	III	N	
1-Androstenediol (3beta,17beta-dihydroxy-5alpha-androst-1-ene; 3alpha,17beta-dihydroxy-5alpha-androst-1-ene)	4000	III	N	
1-Androstenedione (5alpha-androst-1-en-3,17-dione)	4000	III	N	
1-Methyl-4-phenyl-4-propionoxypiperidine	9661	I	Y	MPPP, synthetic heroin
1-Phenylcyclohexylamine	7460	II	N	PCP precursor
1-Piperidinocyclohexanecarbonitrile	8603	II	N	PCC, PCP precursor
2,5-Dimethoxy-4-(n)-propylthiophenethylamine	7348	I	N	2C-T-7
2,5-Dimethoxy-4-ethylamphetamine	7399	I	N	DOET
2,5-Dimethoxyamphetamine	7396	I	N	DMA, 2,5-DMA
3,4,5-Trimethoxyamphetamine	7390	I	N	TMA
3,4-Methylenedioxyamphetamine	7400	I	N	MDA, Love Drug
3,4-Methylenedioxymethamphetamine	7405	I	N	MDMA, Ecstasy, XTC
3,4-Methylenedioxy-N-ethylamphetamine	7404	I	N	N-ethyl MDA, MDE, MDEA
3Alpha,17beta-dihydroxy-5alpha-androstane	4000	III	N	
3Beta,17beta-dihydroxy-5alpha-androstane	4000	III	N	
3-Methylfentanyl	9813	I	Y	China White, fentanyl
3-Methylthiofentanyl	9833	I	Y	Chine White, fentanyl

APPENDIX 9-A, Continued

SUBSTANCE	DEA NUMBER	CSA SCH	NARC	OTHER NAMES
4-Androstenediol (3beta,17beta-dihydroxy-androst-4-ene)	4000	III	N	4-AD
4-Androstenedione (androst-4-en-3,17-dione)	4000	III	N	
4-Bromo-2,5-dimethoxyamphetamine	7391	I	N	DOB, 4-bromo-DMA
4-Bromo-2,5-dimethoxyphenethylamine	7392	I	N	2C-B, Nexus, has been sold as Ecstasy, i.e.
4-Dihydrotestosterone (17beta-hydroxyandrostan-3-one)	4000	III	N	Anabolex, Andractim, Pesomax, Stanolone
4-Hydroxy-19-nortestosterone (4,17beta-dihydroxyestr-4-en-3-one)	4000	III	N	
4-Hydroxytestosterone (4,17beta-dihydroxyandrost-4-en-3-one)	4000	III	N	
4-Methoxyamphetamine	7411	I	N	PMA
4-Methyl-2,5-dimethoxyamphetamine	7395	I	N	DOM, STP
4-Methylaminorex (cis isomer)	1590	I	N	U4Euh, McN-422
5-Androstenediol (3beta,17beta-dihydroxy-androst-5-ene)	4000	III	N	
5-Androstenedione (androst-5-en-3,17-dione)	4000	III	N	
5-Methoxy-3,4-methylenedioxyamphetamine	7401	I	N	MMDA
5-Methoxy-N,N-diisopropyltryptamine	7439	I	N	5-MeO-DIPT
Acetorphine	9319	I	Y	
Acetyl-alpha-methylfentanyl	9815	I	Y	
Acetyldihydrocodeine	9051	I	Y	Acetylcodone
Acetylmethadol	9601	I	Y	Methadyl acetate
Alfentanil	9737	II	Y	Alfenta
Allylprodine	9602	I	Y	
Alphacetylmethadol except levo-alphacetylmethadol	9603	I	Y	
Alpha-ethyltryptamine	7249	I	N	ET, Trip
Alphameprodine	9604	I	Y	
Alphamethadol	9605	I	Y	
Alpha-methylfentanyl	9814	I	Y	China White, fentanyl
Alpha-methylthiofentanyl	9832	I	Y	China White, fentanyl
Alpha-methyltryptamine	7432	I	N	AMT
Alphaprodine	9010	II	Y	Nisentil
Alprazolam	2882	IV	N	Xanax
Aminorex	1585	I	N	has been sold as methamphetamine
Amobarbital	2125	II	N	Amytal, Tuinal
Amobarbital & noncontrolled active ingred.	2126	III	N	
Amobarbital suppository dosage form	2126	III	N	
Amphetamine	1100	II	N	Dexedrine, Adderall, Obetrol
Anabolic steroids	4000	III	N	"Body Building" drugs
Androstanedione (5alpha-androstan-3,17-dione)	4000	III	N	

APPENDIX 9-A, Continued

SUBSTANCE	DEA NUMBER	CSA SCH	NARC	OTHER NAMES
Anileridine	9020	II	Y	Leritine
Aprobarbital	2100	III	N	Alurate
Barbital	2145	IV	N	Veronal, Plexonal, barbitone
Barbituric acid derivative	2100	III	N	Barbiturates not specifically listed
Benzethidine	9606	I	Y	
Benzoylecgonine	9180	II	Y	Cocaine metabolite
Benzphetamine	1228	III	N	Didrex, Inapetyl
Benzylmorphine	9052	I	Y	
Betacetylmethadol	9607	I	Y	
Beta-hydroxy-3-methylfentanyl	9831	I	Y	China White, fentanyl
Beta-hydroxyfentanyl	9830	I	Y	China White, fentanyl
Betameprodine	9608	I	Y	
Betamethadol	9609	I	Y	
Betaprodine	9611	I	Y	
Bezitramide	9800	II	Y	Burgodin
Bolasterone (7alpha,17alpha-dimethyl-17beta-hydroxyandrost-4-en-3-one)	4000	III	N	
Boldenone (17beta-hydroxyandrost-1,4-diene-3-one)	4000	III	N	Equipoise, Parenabol, Vebonol,
Bromazepam	2748	IV	N	Lexotan, Lexatin, Lexotanil
Bufotenine	7433	I	N	Mappine, N,N-dimethylserotonin
Buprenorphine	9064	III	Y	Buprenex, Temgesic, Subutex, Suboxone
Butabarbital (secbutabarbital)	2100	III	N	Butisol, Butibel
Butalbital	2100	III	N	Fiorinal, Butalbital with aspirin
Butobarbital (butethal)	2100	III	N	Soneryl (UK)
Butorphanol	9720	IV	N	Stadol, Stadol NS, Torbugesic, Torbutrol
Calusterone (7beta,17alpha-dimethyl-17beta-hydroxyandrost-4-en-3-one)	4000	III	N	Methosarb
Camazepam	2749	IV	N	Albego, Limpidon, Paxor
Carfentanil	9743	II	Y	Wildnil
Cathine	1230	IV	N	Constituent of "Khat" plant, (+)-norpseudoephedrine
Cathinone	1235	I	N	Constituent of "Khat" plant
Chloral betaine	2460	IV	N	Beta Chlor
Chloral hydrate	2465	IV	N	Noctec
Chlordiazepoxide	2744	IV	N	Librium, Libritabs, Limbitrol, SK-Lygen
Chlorhexadol	2510	III	N	Mechloral, Mecoral, Mededorm, Chloralodol
Chlorphentermine	1645	III	N	Pre-Sate, Lucofen, Apsedon, Desopimon
Clobazam	2751	IV	N	Urbadan, Urbanyl
Clonazepam	2737	IV	N	Klonopin, Clonopin
Clonitazene	9612	I	Y	
Clorazepate	2768	IV	N	Tranxene

APPENDIX 9-A, Continued

SUBSTANCE	DEA NUMBER	CSA SCH	NARC	OTHER NAMES
Clortermine	1647	III	N	Voranil
Clostebol (4-chloro-17beta-hydroxyandrost-4-en-3-	4000	III	N	Alfa-Trofodermin, Clostene, 4-chlorotestosterone
Clotiazepam	2752	IV	N	Trecalmo, Rize, Clozan, Veratran
Cloxazolam	2753	IV	N	Akton, Lubalix, Olcadil, Sepazon
Coca Leaves	9040	II	Y	
Cocaine	9041	II	Y	Methyl benzoylecgonine, Crack
Codeine	9050	II	Y	Morphine methyl ester, methyl morphine
Codeine & isoquinoline alkaloid 90 mg/du	9803	III	Y	Codeine with papaverine or noscapine
Codeine combination product 90 mg/du	9804	III	Y	Empirin,Fiorinal,Tylenol,ASA or APAP w/codeine
Codeine methylbromide	9070	I	Y	
Codeine preparations - 200 mg/100 ml or 100 gm		V	Y	Cosanyl,Robitussin A-C,Cheracol,Cerose,Pediacof
Codeine-N-oxide	9053	I	Y	
Cyprenorphine	9054	I	Y	
Dehydrochloromethyltestosterone (4-chloro-17beta-hydroxy-17alpha-methylandrost-1,4-dien-3-one)	4000	III	N	Oral-Turinabol
Delorazepam	2754	IV	N	
Delta1-dihydrotestosterone (17beta-hydroxy-5alpha-androst-1-en-3-one)	4000	III	N	1-Testosterone
Desomorphine	9055	I	Y	
Dexfenfluramine	1670	IV	N	Redux
Dextromoramide	9613	I	Y	Palfium, Jetrium, Narcolo
Dextropropoxyphene dosage forms	9278	IV	Y	Darvon, propoxyphene, Darvocet, Propacet
Dextropropoxyphene, bulk (non-dosage forms)	9273	II	Y	Propoxyphene
Diampromide	9615	I	Y	
Diazepam	2765	IV	N	Valium, Diastat
Dichloralphenazone	2467	IV	N	Midrin, dichloralantipyrine
Diethylpropion	1610	IV	N	Tenuate, Tepanil
Diethylthiambutene	9616	I	Y	
Diethyltryptamine	7434	I	N	DET
Difenoxin	9168	I	Y	Lyspafen
Difenoxin 1 mg/25 ug AtSO4/du	9167	IV	Y	Motofen
Difenoxin preparations - 0.5 mg/25 ug AtSO4/du		V	Y	Motofen
Dihydrocodeine	9120	II	Y	Didrate, Parzone
Dihydrocodeine combination product 90 mg/du	9807	III	Y	Synalgos-DC, Compal
Dihydrocodeine preparations 10 mg/100 ml or 100 gm		V	Y	Cophene-S, various others
Dihydroetorphine	9334	II	Y	DHE
Dihydromorphine	9145	I	Y	
Dimenoxadol	9617	I	Y	
Dimepheptanol	9618	I	Y	
Dimethylthiambutene	9619	I	Y	

APPENDIX 9-A, Continued

SUBSTANCE	DEA NUMBER	CSA SCH	NARC	OTHER NAMES
Dimethyltryptamine	7435	I	N	DMT
Dioxaphetyl butyrate	9621	I	Y	
Diphenoxylate	9170	II	Y	
Diphenoxylate preparations 2.5 mg/25 ug AtSO4		V	Y	Lomotil, Logen
Dipipanone	9622	I	Y	Dipipan, phenylpiperone HCl, Diconal, Wellconal
Diprenorphine	9058	II	Y	M50-50
Dronabinol in sesame oil in soft gelatin capsule	7369	III	N	Marinol, synthetic THC in sesame oil/soft gelatin
Drostanolone (17beta-hydroxy-2alpha-methyl-5alpha-androstan-3-one)	4000	III	N	Drolban, Masterid, Permastril
Drotebanol	9335	I	Y	Metebanyl, oxymethebanol
Ecgonine	9180	II	Y	Cocaine precursor, in Coca leaves
Estazolam	2756	IV	N	ProSom, Domnamid, Eurodin, Nuctalon
Ethchlorvynol	2540	IV	N	Placidyl
Ethinamate	2545	IV	N	Valmid, Valamin
Ethyl loflazepate	2758	IV	N	
Ethylestrenol (17alpha-ethyl-17beta-hydroxyestr-4-	4000	III	N	Maxibolin, Orabolin, Durabolin-O, Duraboral
Ethylmethylthiambutene	9623	I	Y	
Ethylmorphine	9190	II	Y	Dionin
Ethylmorphine combination product 15 mg/du	9808	III	Y	
Ethylmorphine preparations 100 mg/100 ml or 100 gm		V	Y	
Etonitazene	9624	I	Y	
Etorphine (except HCl)	9056	I	Y	
Etorphine HCl	9059	II	Y	M 99
Etoxeridine	9625	I	Y	
Fencamfamin	1760	IV	N	Reactivan
Fenethylline	1503	I	N	Captagon,amfetyline,ethyltheophylline amphetamine
Fenfluramine	1670	IV	N	Pondimin, Ponderal
Fenproporex	1575	IV	N	Gacilin, Solvolip
Fentanyl	9801	II	Y	Duragesic, Oralet, Actiq, Sublimaze, Innovar
Fludiazepam	2759	IV	N	
Flunitrazepam	2763	IV	N	Rohypnol, Narcozep, Darkene, Roipnol
Fluoxymesterone (9-fluoro-17alpha-methyl-11beta,17beta-dihydroxyandrost-4-en-3-one)	4000	III	N	Anadroid-F, Halotestin, Ora-Testryl
Flurazepam	2767	IV	N	Dalmane
Formebolone (2-formyl-17alpha-methyl-11alpha,17beta-dihydroxyandrost-1,4-dien-3-one)	4000	III	N	Esiclene, Hubernol
Furazabol (17alpha-methyl-17beta-hydroxyandrostano[2,3-c]-furazan)	4000	III	N	Frazalon, Miotolon, Qu Zhi Shu
Furethidine	9626	I	Y	
Gamma Hydroxybutyric Acid	2010	I	N	GHB, gamma hydroxybutyrate, sodium oxybate
Gamma Hydroxybutyric Acid preparations	2012	III	N	Zyrem

APPENDIX 9-A, Continued

SUBSTANCE	DEA NUMBER	CSA SCH	NARC	OTHER NAMES
Glutethimide	2550	II	N	Doriden, Dorimide
Halazepam	2762	IV	N	Paxipam
Haloxazolam	2771	IV	N	
Heroin	9200	I	Y	Diacetylmorphine, diamorphine
Hydrocodone	9193	II	Y	dihydrocodeinone
Hydrocodone & isoquinoline alkaloid <15 mg/du	9805	III	Y	Dihydrocodeinone+papaverine or noscapine
Hydrocodone combination product <15 mg/du	9806	III	Y	Lorcet, Lortab,Vicodin, Vicoprofen,Tussionex,
Hydromorphinol	9301	I	Y	
Hydromorphone	9150	II	Y	Dilaudid, dihydromorphinone
Hydroxypethidine	9627	I	Y	
Ibogaine	7260	I	N	Constituent of "Tabernanthe iboga" plant
Isomethadone	9226	II	Y	Isoamidone
Ketamine	7285	III	N	Ketaset, Ketalar, Special K, K
Ketazolam	2772	IV	N	Anxon, Loftran, Solatran, Contamex
Ketobemidone	9628	I	Y	Cliradon
Levo-alphacetylmethadol	9648	II	Y	LAAM, long acting methadone, levomethadyl acetate
Levomethorphan	9210	II	Y	
Levomoramide	9629	I	Y	
Levophenacylmorphan	9631	I	Y	
Levorphanol	9220	II	Y	Levo-Dromoran
Loprazolam	2773	IV	N	
Lorazepam	2885	IV	N	Ativan
Lormetazepam	2774	IV	N	Noctamid
Lysergic acid	7300	III	N	LSD precursor
Lysergic acid amide	7310	III	N	LSD precursor
Lysergic acid diethylamide	7315	I	N	LSD, lysergide
Marihuana	7360	I	N	Cannabis, marijuana
Mazindol	1605	IV	N	Sanorex, Mazanor
Mebutamate	2800	IV	N	Capla
Mecloqualone	2572	I	N	Nubarene
Medazepam	2836	IV	N	Nobrium
Mefenorex	1580	IV	N	Anorexic, Amexate, Doracil, Pondinil
Meperidine	9230	II	Y	Demerol, Mepergan, pethidine
Meperidine intermediate-A	9232	II	Y	Meperidine precursor
Meperidine intermediate-B	9233	II	Y	Meperidine precursor
Meperidine intermediate-C	9234	II	Y	Meperidine precursor
Meprobamate	2820	IV	N	Miltown, Equanil, Micrainin, Equagesic, Meprospan
Mescaline	7381	I	N	Constituent of "Peyote" cacti
Mestanolone (17alpha-methyl-17beta-hydroxy-5alpha-androstan-3-one)	4000	III	N	Assimil, Ermalone, Methybol, Tantarone

APPENDIX 9-A, Continued

SUBSTANCE	DEA NUMBER	CSA SCH	NARC	OTHER NAMES
Mesterolone (1alpha-methyl-17beta-hydroxy-5alpha-androstan-3-one)	4000	III	N	Androviron, Proviron, Testiwop
Metazocine	9240	II	Y	
Methadone	9250	II	Y	Dolophine, Methadose, Amidone
Methadone intermediate	9254	II	Y	Methadone precursor
Methamphetamine	1105	II	N	Desoxyn, D-desoxyephedrine, ICE, Crank, Speed
Methandienone (17alpha-methyl-17beta-hydroxyandrost-1,4-diene-3-one)	4000	III	N	Dianabol, Metabolina, Nerobol, Perbolin
Methandriol (17alpha-methyl-3beta,17beta-dihydroxyandrost-5-ene)	4000	III	N	Sinesex, Stenediol, Troformone
Methaqualone	2565	I	N	Quaalude, Parest, Somnafac, Opitimil, Mandrax
Methcathinone	1237	I	N	N-Methylcathinone, "cat"
Methenolone (1-methyl-17beta-hydroxy-5alpha-androst-1-en-3-one)	4000	III	N	Primobolan, Primobolan Depot, Primobolan S
Methohexital	2264	IV	N	Brevital
Methyldesorphine	9302	I	Y	
Methyldienolone (17alpha-methyl-17beta-hydroxyestr-4,9(10)-dien-3-one)	4000	III	N	
Methyldihydromorphine	9304	I	Y	
Methylphenidate	1724	II	N	Concerta, Ritalin, Methylin
Methylphenobarbital (mephobarbital)	2250	IV	N	Mebaral, mephobarbital
Methyltestosterone (17alpha-methyl-17beta-hydroxyandrost-4-en-3-one)	4000	III	N	Android, Oreton, Testred, Virilon
Methyltrienolone (17alpha-methyl-17beta-hydroxyestr-4,9,11-trien-3-one)	4000	III	N	Metribolone
Methyprylon	2575	III	N	Noludar
Metopon	9260	II	Y	
Mibolerone (7alpha,17alpha-dimethyl-17beta-hydroxyestr-4-en-3-one)	4000	III	N	Cheque, Matenon
Midazolam	2884	IV	N	Versed
Modafinil	1680	IV	N	Provigil
Moramide-intermediate	9802	II	Y	
Morpheridine	9632	I	Y	
Morphine	9300	II	Y	MS Contin, Roxanol, Oramorph, RMS, MSIR
Morphine combination product/50 mg/100 ml or gm	9810	III	Y	
Morphine methylbromide	9305	I	Y	
Morphine methylsulfonate	9306	I	Y	
Morphine-N-oxide	9307	I	Y	
Myrophine	9308	I	Y	
N,N-Dimethylamphetamine	1480	I	N	
Nabilone	7379	II	N	Cesamet
Nalorphine	9400	III	Y	Nalline
Nandrolone (17beta-hydroxyestr-4-en-3-one)	4000	III	N	Deca-Durabolin, Durabolin, Durabolin-50

APPENDIX 9-A, Continued

SUBSTANCE	DEA NUMBER	CSA SCH	NARC	OTHER NAMES
N-Benzylpiperazine	7493	I	N	BZP, 1-benzylpiperazine
N-Ethyl-1-phenylcyclohexylamine	7455	I	N	PCE
N-Ethyl-3-piperidyl benzilate	7482	I	N	JB 323
N-Ethylamphetamine	1475	I	N	NEA
N-Hydroxy-3,4-methylenedioxyamphetamine	7402	I	N	N-hydroxy MDA
Nicocodeine	9309	I	Y	
Nicomorphine	9312	I	Y	Vilan
Nimetazepam	2837	IV	N	Erimin
Nitrazepam	2834	IV	N	Mogadon
N-Methyl-3-piperidyl benzilate	7484	I	N	JB 336
Noracymethadol	9633	I	Y	
Norbolethone (13beta,17alpha-diethyl-17beta-hydroxygon-4-en-3-one)	4000	III	N	Genabol
Norclostebol (4-chloro-17beta-hydroxyestr-4-en-3-one	4000	III	N	Anabol-4-19, Lentabol
Nordiazepam	2838	IV	N	Nordazepam, Demadar, Madar
Norethandrolone (17alpha-ethyl-17beta-hydroxyestr-4-en-3-one)	4000	III	N	Nilevar, Pronabol, Solevar
Norlevorphanol	9634	I	Y	
Normethadone	9635	I	Y	Phenyldimazone
Normethandrolone (17alpha-methyl-17beta-hydroxyestr-4-en-3-one)	4000	III	N	Lutenin, Matronal, Orgasteron
Normorphine	9313	I	Y	
Norpipanone	9636	I	Y	
Opium combination product 25 mg/du	9809	III	Y	Paregoric, other combination products
Opium extracts	9610	II	Y	
Opium fluid extract	9620	II	Y	
Opium poppy	9650	II	Y	Papaver somniferum
Opium preparations - 100 mg/100 ml or /100 gm		V	Y	Parepectolin, Kapectolin PG, Kaolin Pectin P.G.
Opium tincture	9630	II	Y	Laudanum
Opium, granulated	9640	II	Y	Granulated opium
Opium, powdered	9639	II	Y	Powdered opium
Opium, raw	9600	II	Y	Raw opium, gum opium
Oxandrolone (17alpha-methyl-17beta-hydroxy-2-oxa-5alpha-androstan-3-one)	4000	III	N	Anavar, Lonavar, Oxandrin, Provitar, Vasorome
Oxazepam	2835	IV	N	Serax, Serenid-D
Oxazolam	2839	IV	N	Serenal, Convertal
Oxycodone	9143	II	Y	OxyContin, Percocet, Endocet, Roxicodone,
Oxymesterone (17alpha-methyl-4,17beta-dihydroxyandrost-4-en-3-one)	4000	III	N	Anamidol, Balnimax, Oranabol, Oranabol 10
Oxymetholone (17alpha-methyl-2-hydroxymethylene-17beta-hydroxy-5alpha-androstan-3-one)	4000	III	N	Anadrol-50, Adroyd, Anapolon, Anasteron, Pardroyd
Oxymorphone	9652	II	Y	Numorphan

APPENDIX 9-A, Continued

SUBSTANCE	DEA NUMBER	CSA SCH	NARC	OTHER NAMES
Para-Fluorofentanyl	9812	I	Y	China White, fentanyl
Parahexyl	7374	I	N	Synhexyl,
Paraldehyde	2585	IV	N	Paral
Pemoline	1530	IV	N	Cylert
Pentazocine	9709	IV	N	Talwin, Talwin NX, Talacen, Talwin Compound
Pentobarbital	2270	II	N	Nembutal
Pentobarbital & noncontrolled active ingred.	2271	III	N	FP-3
Pentobarbital suppository dosage form	2271	III	N	WANS
Petrichloral	2591	IV	N	Pentaerythritol chloral, Periclor
Peyote	7415	I	N	Cactus which contains mescaline
Phenadoxone	9637	I	Y	
Phenampromide	9638	I	Y	
Phenazocine	9715	II	Y	Narphen, Prinadol
Phencyclidine	7471	II	N	PCP, Sernylan
Phendimetrazine	1615	III	N	Plegine, Prelu-2, Bontril, Melfiat, Statobex
Phenmetrazine	1631	II	N	Preludin
Phenobarbital	2285	IV	N	Luminal, Donnatal, Bellergal-S
Phenomorphan	9647	I	Y	
Phenoperidine	9641	I	Y	Operidine, Lealgin
Phentermine	1640	IV	N	Ionamin, Fastin, Adipex-P, Obe-Nix, Zantryl
Phenylacetone	8501	II	N	P2P, phenyl-2-propanone, benzyl methyl ketone
Pholcodine	9314	I	Y	Copholco, Adaphol, Codisol, Lantuss, Pholcolin
Piminodine	9730	II	Y	
Pinazepam	2883	IV	N	Domar
Pipradrol	1750	IV	N	Detaril, Stimolag Fortis
Piritramide	9642	I	Y	Piridolan
Poppy Straw	9650	II	Y	Opium poppy capsules, poppy heads
Poppy Straw Concentrate	9670	II	Y	Concentrate of Poppy Straw, CPS
Prazepam	2764	IV	N	Centrax
Pregabalin	2782	V	N	Lyrica
Proheptazine	9643	I	Y	
Properidine	9644	I	Y	
Propiram	9649	I	Y	Algeril
Psilocybin	7437	I	N	Constituent of "Magic mushrooms"
Psilocyn	7438	I	N	Psilocin, constituent of "Magic mushrooms"
Pyrovalerone	1485	V	N	Centroton, Thymergix
Quazepam	2881	IV	N	Doral
Racemethorphan	9732	II	Y	
Racemoramide	9645	I	Y	

APPENDIX 9-A, Continued

SUBSTANCE	DEA NUMBER	CSA SCH	NARC	OTHER NAMES
Racemorphan	9733	II	Y	Dromoran
Remifentanil	9739	II	Y	Ultiva
Secobarbital	2315	II	N	Seconal, Tuinal
Secobarbital & noncontrolled active ingred	2316	III	N	
Secobarbital suppository dosage form	2316	III	N	
Sibutramine	1675	IV	N	Meridia
SPA	1635	IV	N	1-dimethylamino-1,2-diphenylethane, Lefetamine
Stanozolol (17alpha-methyl-17beta-hydroxy-5alpha-androst-1-eno[3,2-c]-pyrazole)	4000	III	N	Winstrol, Winstrol-V
Stenbolone (17beta-hydroxy-2-methyl--5alpha-androst-1-en-3-one)	4000	III	N	
Stimulant compounds previously excepted	1405	III	N	Mediatric
Sufentanil	9740	II	Y	Sufenta
Sulfondiethylmethane	2600	III	N	
Sulfonethylmethane	2605	III	N	
Sulfonmethane	2610	III	N	
Talbutal	2100	III	N	Lotusate
Temazepam	2925	IV	N	Restoril
Testolactone (13-hydroxy-3-oxo-13,17-secoandrosta-1,4-dien-17-oic acid lactone)	4000	III	N	Teolit, Teslac
Testosterone (17beta-hydroxyandrost-4-en-3-one)	4000	III	N	Android-T, Androlan, Depotest, Delatestryl
Tetrahydrocannabinols	7370	I	N	THC, Delta-8 THC, Delta-9 THC and others
Tetrahydrogestrinone (13beta,17alpha-diethyl-17beta-hydroxygon-4,9,11-trien-3-one)	4000	III	N	THG
Tetrazepam	2886	IV	N	Myolastan, Musaril
Thebacon	9315	I	Y	Acetylhydrocodone, Acedicon, Thebacetyl
Thebaine	9333	II	Y	Precursor of many narcotics
Thiamylal	2100	III	N	Surital
Thiofentanyl	9835	I	Y	Chine white, fentanyl
Thiopental	2100	III	N	Pentothal
Tiletamine & Zolazepam Combination Product	7295	III	N	Telazol
Tilidine	9750	I	Y	Tilidate, Valoron, Kitadol, Lak, Tilsa
Trenbolone (17beta-hydroxyestr-4,9,11-trien-3-one)	4000	III	N	Finaplix-S, Finajet, Parabolan
Triazolam	2887	IV	N	Halcion
Trimeperidine	9646	I	Y	Promedolum
Vinbarbital	2100	III	N	Delvinal, vinbarbitone
Zaleplon	2781	IV	N	Sonata
Zolpidem	2783	IV	N	Ambien, Ivadal, Stilnoct, Stilnox
Zopiclone	2784	IV	N	Lunesta

APPENDIX 9-B

QUESTIONNAIRE FOR PERSONNEL WHO WILL HAVE ACCESS TO SUBSTANCES REGULATED BY THE U.S. DRUG ENFORCEMENT ADMINISTRATION

The University of North Carolina at Chapel Hill

Department/Supervisor _____

The Drug Enforcement Administration requires that any person who will have access to controlled substances due to employment at the University of North Carolina at Chapel Hill to answer the following questions. Any false information or omission of information may jeopardize you position with respect to employment. Information revealed in this questionnaire will not necessarily preclude your employment, but will be considered as an overall evaluation of your qualifications. The responses to this questionnaire are held in the strictest confidence.

1. Within the past five years, have you been convicted of a felony, or, within the past two years, any misdemeanor, or, are you presently charged with committing a criminal offense? If yes, furnish the details of conviction, offense, location, date and sentence. Do not include traffic violations, juvenile offenses or military convictions, except by general court martial.

Yes_____ No _____

Details: _____

2. In the past 3 years, have you knowingly used narcotics, amphetamines, or barbiturates other than those prescribed to you by a physician?

Yes_____ No _____

Details: _____

3. Have you had an application for registration with the DEA denied, revoked, or surrendered for cause?

Yes_____ No_____

Details: _____

Signature:_____ Registrant Signature: _____

Name (Print): _____ Registrant Name (print): _____

Date _____

APPENDIX 9-C

CONTINUING RECORD FOR ACQUISTION AND DISPOSITION OF CONTROLLED SUBSTANCES
The University of North Carolina at Chapel Hill

Name of Registrant: _____ DEA #: _____
Name of Controlled Substance:_____
Manufacturer:_____ Date Received:_____
Lot or ID:_____ Finished form: _____
Units per Container:_____ Number of Containers:_____
Total Units:_____

If substance was acquired from or distributed to another registrant, provide name, address, DEA # of registrant, date and number of units:

_____
_____
_____

Date Dispensed:	**Units Dispensed:**	**Units Remaining:**	**Dispensed By:**	**Notes:**

APPENDIX 9-D

INVENTORY OF SCHEDULE I AND II CONTROLLED SUBSTANCES
The University of North Carolina at Chapel Hill

Registrant:	Current Date:
DEA#:	Last Inventory Date*:

*Note: This list must be updated at least every 24 months, and retained for at least three years after last entry date.

Name of Substance:	**Finished Form:**	**Number of Units in each Container:**	**Number of Containers:**	**Total Units:**

This page intentionally left blank.

CHAPTER 10

FIRE SAFETY

Overview

This chapter outlines the properties of flammable liquids, solids, and gases, the proper storage and use of flammable substances, and the properties of fire extinguishers.

Table of Contents

This page intentionally left blank.

CHAPTER 10

FIRE SAFETY

I. Introduction

Flammable substances are among the most common hazardous materials found in laboratories. The main objective in working safely with flammable liquids is to avoid accumulation of vapors and to control sources of ignition. However, the ability of a material to vaporize, ignite or explode varies with the type or class of substance. Prevention of fires and explosions requires knowledge of the flammability characteristics (e.g. upper and lower flammability limits, ignition requirements, and burning rates) of materials encountered in the laboratory.

II. Properties of Flammable and Combustible Substances

A. Liquids

Flammable liquids have a **flash point** below 100 ºF (37.7 ºC) and a vapor pressure not exceeding 40 psi (276 kPa). By contrast, **combustible liquids** have a flash point at, or above, 100 ºF (37.7 ºC). Classes of flammable and combustible liquids are further defined in Appendix 10-A.

> The ***flash point*** is the lowest temperature, as determined by standard tests, at which a liquid gives off vapor in sufficient concentration to form an ignitable mixture with air near the surface of the liquid within the test vessel. Many common laboratory solvents and chemicals have flash points that are lower than room temperature.

Actually, the vapor, not the liquid, burns. The rate at which different liquids produce flammable vapors depends on their vapor pressure. The degree of fire hazard depends also on the ability to form combustible or explosive mixtures with air.

B. Solids

The United States Department of Transportation (DOT) defines and classifies flammable solids in one of three categories (source: 49 CFR 173.124):

(1) Class 4, Division 4.1: **Flammable Solid**-
Self-reactive materials that are thermally unstable and can undergo a strongly exothermic decomposition even without participation of oxygen; desensitized explosives also fall within this category.

(2) Class 4, Division 4.2: **Spontaneously Combustible Material**-
Pyrophoric (air-reactive) materials or self-heating materials, likely to self-heat when in contact with air and without energy supply.

(3) Class 4, Division 4.3: **Dangerous when wet material**-
Liable to spontaneously combust or give off flammable/toxic gas when in contact with water.

Flammable, pyrophoric, self-heating, or dangerous when wet solids will have the following DOT placards on the shipping container when transporting more than 1,001 pounds of Division 4.1 or 4.2 materials, or any quantity of Division 4.3 material. Smaller versions of these placard labels are frequently on the substance container as well.

Figure 10.1 – DOT placards for Class 4 materials (Flammable Solids)

C. Gases

The DOT defines flammable gases in 49 CFR 173.115 as materials that are:

(1) Gases at 20 ^{o}C (68 ^{o}F) or less and 101.3 kPa (14.7 psi) of pressure, and:

(2) Are ignitable at 101.3 kPa (14.7 psi) when in a mixture of 13 percent or less by volume with air; or

(3) Have a flammable range at 101.3 kPa (14.7 psi) with air of at least 12 percent regardless of the lower limit.

The DOT classifies flammable gases as Class 2, Division 2.1 materials.

D. Ignitability

The auto-ignition temperature of a substance, whether solid, liquid or gaseous, is the minimum temperature required to initiate self-sustained combustion independent of the heat source. A steam line or a glowing light bulb may ignite carbon disulfide (ignition temperature 80^{o} C).

Diethyl ether (ignition temperature 160^{o} C) can be ignited by the surface of a hot plate. Silane gas (ignition temperature 21^{o} C) can spontaneously ignite at or near room temperature.

Spontaneous ignition or combustion takes place when a substance reaches its ignition temperature without the application of external heat. Consider the possibility of spontaneous combustion, especially when materials are stored or disposed. Materials susceptible to spontaneous combustion include oily rags, dust accumulation, organic materials mixed with strong oxidizing agents (such as nitric acid, chlorates, permanganates, peroxides and persulfates), the alkali metals (lithium, sodium, potassium, rubidium, and cesium), finely divided metal powders, and phosphorus.

III. Sources of Ignition

Many potential sources of spark, flame, or heat in laboratories can ignite flammable substances, such as open flames, static electricity, lighted matches and hot surfaces. When flammable materials are in use, pay close attention to all potential ignition sources in the vicinity. The vapors of flammable liquids are heavier than air, and can travel considerable distances. Recognize this possibility and take special note of ignition sources at a lower level than the level of flammable liquid use.

Flammable vapors from massive sources such as spills can descend into stairwells and elevator shafts and ignite on a lower story. If the path of vapor is continuous, the flame can propagate itself from the point of ignition back to its source.

Make sure to properly bond and ground all metal lines and vessels dispensing flammable substances to discharge static electricity. When nonmetallic containers (especially plastic) are used, the bonding can be made to the liquid rather than to the container.

IV. Use of Flammable Substances

The basic precautions for safe handling of flammable materials include the following:

- Handle flammable substances only in areas free of ignition sources.

- Do not heat flammable substances with an open flame. Preferred heat sources include steam baths, water baths, oil baths, heating mantles and hot air baths.

- When you transfer flammable liquids in metal equipment, avoid static-generated sparks by bonding, and the use of ground straps.

- Ventilation is one of the most effective ways to prevent the formation of flammable mixtures. Use an exhaust hood when you handle appreciable quantities of flammable substances (e.g. transferring between containers or in an open container, especially if you are heating it).

- When withdrawing a flammable liquid from a drum, or filling a drum, both the drum and other equipment must be individually, electrically grounded and bonded to each other.

- Containers of flammable liquids shall not be drawn from or filled within buildings without provisions to prevent the accumulation of flammable vapors in hazardous concentrations.

V. Storage Rules

Basic rules for safe storage of flammable materials include the following:

- Store flammable and combustible liquids only in approved containers. Approval for containers is based on specifications developed by organizations such as DOT, the Occupational Safety and Health Administration (OSHA), the National Fire Protection Agency (NFPA), or American National Standards Institute (ANSI). Containers used by the manufacturers of flammable and combustible liquids generally meet these specifications.

- Flammables stored in the open in the laboratory work area shall be kept to the minimum necessary for the work being done.

- Do not store flammable liquids in domestic type refrigerators. Domestic type refrigerators are not recommended for laboratory use, even if flammable storage is not contemplated, since future research needs may require the use of flammables. Existing domestic refrigerators in labs must have a posting stating that no flammable storage is permitted. "Safety" refrigerators are recommended for laboratories. These have the electrical contacts (doorswitch, light, thermostat, etc.) removed or exteriorized. "Explosion-proof" refrigerators are not necessary except in unusual circumstances, such as within an inside storage room (for flammables) or other potentially hazardous atmospheres.

- Flammable liquids must not block laboratory aisles or exits. Do not locate flammable storage cabinets near an exit or in the hallway.

- Keep flammable liquids away from heat and direct sunlight.

- Store flammable liquids in a way that prevents accidental contact with strong oxidizing agents (such as permanganates or chlorates).

- University policy prohibits smoking in all University buildings; remove other sources of ignition from areas where flammable liquids are stored.

- Maximum allowable size of containers for flammable and combustible liquids shall be in accordance with Appendix 10-A.

- The potential fire hazard also depends on the total quantity of flammable and combustible liquids present within a laboratory unit (room) and the type of containers in which the liquids are stored. The maximum quantity allowed per laboratory unit is as follows:

(1) Shelf or open storage/use

a)	glass, approved plastic or metal	10 gallons (37.9 liters)
b)	safety cans	25 gallons (94.7 liters)

(2) Approved storage cabinets (maximum - 2 per laboratory unit)

a)	Class I	30 gallons (113.6 liters)
b)	Class I, II, & III	60 gallons (227.2 liters)

(3) Inside storage room (meeting NFPA Code recommendations)

a)	with sprinkler	4-10 gal/ft^2
b)	without sprinkler	2-4 gal/ft^2

(4) For laboratories located on upper floors within new or remodeled buildings, the limits for flammable and combustible liquids might be more restrictive due to the North Carolina Fire Prevention Code. Refer to Chapter 4 for more details, or contact EHS at 962-5507 if you have questions.

VI. Fire Extinguisher Labeling

For ease of identification, labels A, B, C, D, and K (and, more recently, pictograms) indicate the type of fire on which one can use an extinguisher.

Type	Materials	Description	Label	Pictogram
A	Ordinary Combustibles	Fires in paper, cloth, wood, rubber, and many plastics require a water or dry chemical type extinguisher labeled **A**.		
B	Flammable Liquids	Fires in solvents and other flammable liquids require dry chemical, Halon™, or CO_2 extinguisher labeled **B**.		
C	Electrical Equipment	Fires in wiring, fuse boxes, energized equipment and other electrical sources require a dry chemical, Halon™, or CO_2 extinguisher labeled **C**.		
D	Metals	Combustible metals such as magnesium and sodium require special extinguishers labeled **D**.		

K	Cooking Oils and Fats	Wet chemical extinguishers specially designed to put out fires of cooking oils or fats are labeled **K**; unlikely to be needed in a laboratory setting.	**K** COMBUSTIBLE COOKING	

Most chemical laboratory fire hazards require multipurpose dry chemical extinguishers (ABC) located in hallways. "Gas" extinguishers, containing Halon™ 1211 or CO_2, offer a first defense against flammable liquids or electrical fires without leaving a powder residue that could harm electronic equipment.

VII. Fire Extinguisher Maintenance

EHS personnel perform annual inspection and maintenance of campus fire extinguishers. Laboratory personnel are encouraged to check their extinguishers regularly for these items:

- Accessibility
- Charge Gauge (CO_2 units lack gauges)*
- Tamper Seal
- Physical Damage

Report any problems or missing extinguishers to EHS at 962-5507.

***EHS recharges extinguishers at no cost to the department or building to which the extinguisher was assigned if one the following applies:**

- **If there is evidence of pressure leakage, or**
- **If the extinguisher has been used.**

VIII. Training

EHS offers training in the correct use of fire extinguishers and building evacuation. For information and training dates, contact EHS at 962-5507. You are NOT required to use a fire extinguisher on campus. However, if you wish to use one on campus you must receive training in their correct use.

Additional information on University Fire Safety policies is found in Chapter 3 of the UNC Environment, Health and Safety Manual, at http://ehs.unc.edu/manuals/ehsmanual/index.shtml.

APPENDIX 10 -A

ALLOWED CONTAINER SIZES FOR FLAMMABLE AND COMBUSTIBLE LIQUIDS

Container Type	Class IA	Class IB	Class IC	Class II	Class III
Glass	1 pt. (0.47 L)	1 qt. (0.95 L)	1 qt. (0.95 L)	1 gal. (3.79 L)	1 gal. (3.79 L)
Metal or Approved Plastic	1 gal. (3.79 L)	5 gal. (18.94 L)	5 gal. (18.94 L)	5 gal. (18.94 L)	5 gal. (18.94 L)
Safety Cans	2 gal. (75.8 L)	5 gal. (18.94 L)	5 gal. (18.94 L)	5 gal. (18.94 L)	5 gal. (18.94 L)

Class IA: Liquids having flash points below 73^{o}F (22.8^{o}C) and having a boiling point below 100^{o}F (37.8^{o}C).

Class IB: Liquids having flash points below 73^{o}F and having a boiling point at or above 100^{o}F.

Class IC: Liquids having a flash point at or above 73^{o}F (22.8^{o}C) and below 100^{o}F (37.8^{o}C).

Class II: Liquids with flash points at or above 100^{o}F and below 140^{o}F (60^{o}C).

Class III: Liquids with flash points at or above 140^{o}F.

Safety Can: Many types of containers are required depending on the quantities and classes of flammable or combustible liquids in use. An approved container, of not more than 5 gallons capacity, having a spring-closing lid and spout cover and so designed that it will safely relieve internal pressure when subjected to fire exposure.

Figure 10.2 – Safety Cans

This page intentionally left blank.

CHAPTER 11

EXPLOSIVE AND REACTIVE CHEMICAL HAZARDS

Overview

This chapter provides resources that can help you prevent a laboratory accident due to mishandling explosive substances, or mixing incompatible reactive substances. This chapter details several specific examples of explosive and reactive hazards that are common in laboratories.

Table of Contents

This page intentionally left blank.

CHAPTER 11

EXPLOSIVE AND REACTIVE CHEMICAL HAZARDS

I. Introduction

The variety of chemicals commonly present in the laboratory poses the potential for accidental hazardous chemical reactions or explosions. A hazardous reaction occurs when two or more incompatible chemicals combine, resulting in an undesirable or uncontrolled reaction with adverse consequences. Such reactions may result when incompatible chemicals spill by accident, inadvertently mix as chemical waste, or combine unwittingly during experimental procedures.

Hazardous reactions may cause any one or more of the following:

- heat generation,
- fire,
- explosion,
- formation of toxic vapors,
- formation of flammable gases,
- volatilization of toxic or flammable substances,
- formation of substances of greater toxicity,
- formation of shock or friction sensitive compounds,
- pressurization in closed vessels,
- solubilization of toxic substances,
- dispersal of toxic dusts, mists, particles, and
- violent polymerization.

It is easy to become complacent with chemicals used everyday in routine procedures. It is prudent to check for incompatibility whenever making a change in chemical procedures. Chemical incompatibility is the primary reason you do not store chemicals on the shelf alphabetically. If there is an accident, adverse reactions may make the situation worse.

Material Safety Data Sheets will list "Reactivity Data" in one of the sections on the form. Some MSDSs title this section “Stability and Reactivity Data”. References of incompatible chemical combinations include:

- Handbook of Reactive Chemical Hazards; L. Bretherick, 6th edition 1999,
- Manual of Hazardous Chemical Reactions, National Fire Protection Association Manual 491M,
- National Oceanic and Atmospheric Administration’s Chemical Reactivity Worksheet (information and free download available at http://www.epa.gov/emergencies/content/cameo/index.htm).

II. Explosive Materials in Laboratories

Explosives are solid, liquid, or gaseous chemicals that can cause a sudden, almost instantaneous release of pressure, gas, and heat when subjected to shock, pressure, or high temperature. Their acquisition, storage, use, and disposal are highly regulated, and these materials demand the highest safety precautions.

The U.S. Department of Justice, Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) has an extensive set of regulations entitled Commerce in Explosives (27 CFR 555). These rules govern the acquisition, use, storage, and security requirements for a specific list of explosive materials, updated annually. The most recent list is in the September 27, 2006 Federal Register: http://a257.g.akamaitech.net/7/257/2422/01jan20061800/edocket.access.gpo.gov/2006/pdf/E6-15850.pdf. This list includes obvious explosive materials such as 2,4,6-trinitrotoluene (TNT), lead azide, and mercury fulminate. The list also includes more common laboratory chemicals in dried out or non-reagent form such as dinitrophenol, picric acid, and sodium azide.

Public educational institutions such as UNC are exempt from several of the provisions of 27 CFR 555, except for storage requirements. If you use any substance on the ATF List of Explosive Materials in your research, you might be required to comply with the requirements for magazine storage, depending on the concentration of substance and whether it is packaged in reagent form.

The U.S. Department of Transportation (DOT) classifies explosive (Class 1) materials into one of six divisions. Division 1.1 materials are the most hazardous due to their sensitivity and mass explosion hazard, whereas Division 1.6 materials are insensitive and not a mass explosion hazard. Other divisions fall between these extremes. The DOT also maintains a forbidden explosives list (http://hazmat.dot.gov/regs/intl/usvar/cfr_forbidden.pdf). This list is similar but not identical to the ATF list. Under most circumstances, you cannot receive forbidden explosives from vendors, drive them over the road, ship them to other collaborators, or receive them from other off-site collaborators.

Please contact EHS first if you contemplate receiving, synthesizing (directly or as by-product), using, or shipping any substance on the ATF List of Explosive Materials or the DOT Forbidden Explosives List.

Figure 11.1 – Common placards and pictograms for explosive materials (left to right): DOT placard for Division 1.1 – 1.3 materials; DOT placard for Division 1.4 materials; European Union glyph for explosive materials; iconic glyph for explosive materials.

III. Common Reactive Hazards in Laboratories

Listed below are some specific, representative chemical reactive hazards in laboratories that can lead to fires or explosions. Any solid, liquid, or gaseous chemical substances that have the potential to react rapidly to release relatively large amounts of energy and/or dangerous by-products (e.g., toxic gas) are considered reactive.

Keep in mind, this list is not exhaustive; space does not permit us to list all the potential reactive hazards that could exist in a laboratory. Consult the resources mentioned in Section I of this Chapter for more information.

- **Acetylenic Compounds** are explosive in mixtures of 2.5-80% with air at pressures of two or more atmospheres. Acetylene (C_2H_2) subjected to an electrical discharge or high temperature decomposes with explosive violence. Dry acetylides detonate on receiving the slightest shock.

- **Aluminum Chloride** ($AlCl_3$) is a potentially dangerous material because if moisture is present, decomposition can produce hydrogen chloride (HCl) and build up considerable container pressure. When opening a bottle that has been stored for a long time, completely enclose it in a heavy towel.

- **Ammonia** (NH_3) reacts with iodine to produce nitrogen tri-iodide (which is explosive), and with hypochlorites to produce chlorine. Do not mix ammonia-based cleaners with bleach. Mixtures of ammonia and organic halides sometimes react violently when heated under pressure.

- ***Aqua Regia*** is a mixture of nitric acid and hydrochloric acid, and is sometimes used for dissolving noble metals or as glassware cleaner. Try to avoid using *aqua regia*. If you require it, make and use only what you need in a laboratory hood, and destroy it within the hood after use. Do not store it in closed containers; attempts to store *aqua regia* will most likely rupture the storage container. Upon generation, the nitric acid begins to reduce, with evolution of toxic nitrogen dioxide gas.

- **Benzoyl Peroxide** $(C_6H_5CO_2)_2$ is easily ignited and sensitive to shock. It decomposes spontaneously at temperatures above 50^oC, but can be desensitized by addition of 20% by volume of water.

- **Carbon Disulfide** (CS_2) is highly toxic and highly flammable; when mixed with air, its vapors can ignite by a steam bath or pipe, a hot plate, or a glowing light bulb. Carbon disulfide catches fire spontaneously upon contact with a hot surface at temperatures approximating or exceeding 80°C.

- **Chlorine** (Cl_2) may react violently with hydrogen (H_2) or with hydrocarbons when exposed to sunlight.

- **Diazomethane** (CH_2N_2) and related diazo compounds require extreme caution. They are very toxic, and the pure forms (gases and liquids) explode readily. Diazald (a precursor to diazomethane) is a high explosive. Solutions in ether are safer, and are rendered harmless by dropwise addition of acetic acid.

- **Diethyl, Isopropyl, and other Ethers** (particularly the branched-chain type) may explode during heating or refluxing due to the presence of peroxides. Ferrous salts or sodium bisulfite can decompose these peroxides, and passage over basic active alumina will remove most of the peroxidic material. Mark containers with the date received, date opened, and date to be discarded, and discard them before they are out of date. For more detail, see Chapter 13: Safe Handling of Peroxidizable Compounds.

- **Diethylzinc** [$(C_2H_5)_2Zn$] is a violently pyrophoric (air-reactive), water-reactive, and light-sensitive liquid, and is generally sold in mixture with toluene, hexane, or other organic solvents. At concentrations above 1.1 molar, store diethylzinc in an inert atmosphere at or below room temperature. Do not use water for extinguishing fires; use dry powder, soda ash, or lime.

- **Dimethyl Sulfoxide** [$(CH_3)_2SO$] decomposes violently on contact with a wide variety of active halogen compounds. Explosions from contact with active metal hydrides have been reported. Its toxicity is still unknown, but it penetrates and carries dissolved substances through the skin membrane.

- **Dinitrophenols** [$(NO_2)_2C_6H_3OH$] such as 2,4-DNP and 2,6-DNP are sensitive to light, heat, friction, and shock, and should never be allowed to dry out. 2,4-DNP forms explosive salts with alkalis and ammonia. Oxidative decomposition can produce nitrogen oxides. At water concentrations less than 15%, DNPs are explosive and subject to the storage requirements of the ATF regulations.

- **Dry Ice**, solid carbon dioxide (CO_2), is not to be kept in a container that is not designed to withstand pressure. Containers of other substances stored over dry ice for extended periods generally absorb carbon dioxide (CO_2) unless sealed with care. When removing such containers from storage and allowing them to come rapidly to room temperature, the CO_2 may develop sufficient pressure to burst the container with explosive violence. On removal of such containers from storage, loosen the stopper, or wrap the container in towels and keep it behind a shield. Dry ice can produce serious burns; this is also true for all types of cooling baths. Do not store dry ice in walk-in cold rooms, as this may result in oxygen-deficient atmosphere.

- **Drying Agents-Ascarite** must not mix with phosphorus pentoxide (P_2O_5) because the mixture may explode if warmed with a trace of water. Because organic solvents may extract the cobalt salts used as moisture indicators in some drying agents, the use of these drying agents shall be restricted to gases.

- **Ethylene Oxide** (C_2H_4O) can explode when heated in a closed vessel. Carry out experiments using ethylene oxide under pressure behind suitable barricades.

- **Fulminic Acid (**HCNO), its metal salts, and other compounds that contain the fulminate ion ($^-C{\equiv}N^+{-}O^-$) are highly unstable due to the weak single N-O bond. Fulminates are friction-sensitive primary explosives. The DOT Forbidden Explosives List includes fulminic acid, and both the DOT List and the ATF List of Explosive Materials include mercury fulminate and silver fulminate (not to be confused with fulminating silver, Ag_3N, an explosive decomposition product of Tollens Reagents that is also on the DOT List – refer to section on Tollens Reagents below). Contact EHS if your research must involve fulminates.

- **Grignard Reagents** (R-Mg-X) are alkyl- or aryl- magnesium halides that are highly reactive with oxygen and carbonyls. They can spontaneously ignite in moist air; handle Grignard reagents under inert gases such as argon or nitrogen, or in solvents such as tetrahydrofuran or ethyl ether.

- **Halogenated Compounds** such as chloroform ($CHCl_3$), methylene chloride (CH_2Cl_2), carbon tetrachloride (CCl_4), and other halogenated solvents shall not be dried with sodium, potassium, or other active metal; violent explosions can result.

- **Hydrogen Peroxide** (H_2O_2) stronger than three percent (3%) can be dangerous; in contact with the skin, it may cause severe burns. Thirty percent H_2O_2 may decompose violently if contaminated with iron, copper, chromium, other metals or their salts. Stirring bars may inadvertently bring metal into a reaction, so use with caution.

- **Liquid-Nitrogen Cooled Traps**, when open to the atmosphere, rapidly condense liquid air. With coolant removal, a pressure buildup may occur sufficient to shatter glass equipment. Only cool sealed or evacuated equipment with liquid nitrogen.

- **Liquid Nitrogen Storage Dewars** are common for cryopreservation of samples. Cryopreservation vials stored in the liquid phase of liquid nitrogen can rupture upon warming if liquid nitrogen has infiltrated them, as the liquid nitrogen expands more than 600 times during evaporation. Store vials in the gaseous phase above the liquid nitrogen to avoid infiltration.

- **Lithium Aluminum Hydride** ($LiAlH_4$) shall not be used to dry methyl ethers or tetrahydrofuran; fires from this are common. The products of its reaction with CO_2 can be explosive. Do not use carbon dioxide or bicarbonate extinguishers against $LiAlH_4$ fires; use sand or a Class D extinguisher.

- **Nitric Acid** (HNO_3) is a powerful oxidizing agent that ignites on contact or reacts explosively with a variety of organic substances including acetic anhydride, acetone, acetonitrile, many alcohols, benzene, DMSO, and methylene chloride (Figure 11.2). Do not store nitric acid with combustible organic acids such as acetic acid or formic acid.

Nitric acid can also react violently with many inorganic substances including bases, reducing agents, alkali metals, copper, phosphorus, and ammonia.

Figure 11.2 –

This explosion within a storage cabinet resulted from nitric acid mixed with an organic solvent in a closed container. The pressure build-up ruptured the container and blew the cabinet doors open.

- **Nitrocellulose** [$(C_6H_7O_{11}N_3)_n$] in dry, unstabilized form is explosive when heated or subjected to sudden shock. Synonyms include Pyroxylin, Parlodion®, and Guncotton. Store moist, away from heat sources and sunlight, and segregated from other materials. Nitrocellulose in membrane filters with polyester backing and mixed cellulose ester (MCE) filters is more stable, but can still spontaneously combust when exposed to oxidizing agents or sources of heat. Do not store filters where exposure to direct sunlight could occur.

- **Nitroglycerin** [$C_5H_3(NO_3)_3$] for research purposes is usually in tincture form, mixed with alcohol. Do not allow the carrier to evaporate, as this will result in high explosive nitroglycerin.

- **Oxygen Tanks** can explode due to contact between oil and high-pressure oxygen. Do not use oil on connections to an oxygen cylinder or regulator. Do not use soap-based leak detector compounds on the connection threads of an oxygen cylinder.

- **Ozone** (O_3) is a highly reactive and toxic gas. It forms by the action of ultraviolet light on oxygen (air) and, therefore, certain ultraviolet sources may require venting to the exhaust hood.

- **Palladium or Platinum on Carbon, Platinum Oxide, Raney Nickel, and other Catalysts** must be carefully filtered from catalytic hydrogenation reaction mixtures. The recovered catalyst is usually saturated with hydrogen and highly reactive; thus, it will ignite spontaneously on exposure to air. Particularly for large-scale reactions, do not allow the filter cake to dry. Place the funnel containing the still-moist catalyst filter cake into a water bath immediately after completion of the filtration. Another hazard in working with such catalysts is the potential of explosion when adding additional catalyst to a flask in which hydrogen is present.

- **Parr Bombs** used for digestions or hydrogenations have failed and exploded. Handle all high-stress equipment such as bomb calorimeters with care behind bench top shields, and wear proper eye protection.

- **Perchlorate** use should be avoided whenever possible. Do not use perchlorates as drying agents if there is a possibility of contact with organic compounds, or in proximity to a dehydrating acid strong enough to concentrate the perchloric acid ($HClO_4$) to more than 70% strength (e.g., in a drying train that has a bubble counter containing sulfuric acid). Use safer drying agents.

  Seventy percent (70%) $HClO_4$ can be boiled safely at approximately 200°C, but contact of the boiling undiluted acid or the hot vapor with organic matter, or even easily oxidized inorganic matter (such as compounds of trivalent antimony), will lead to serious explosions. Do not allow oxidizable substances to contact $HC1O_4$. Use beaker tongs, rather than rubber gloves, when handling fuming $HClO_4$. Carry out perchloric acid evaporations and digestions in a dedicated hood that has a good draft, and that is washable. Frequent (weekly) washing out of the hood and ventilator ducts with water is necessary to avoid the danger of metal perchlorate buildup, which could lead to spontaneous combustion or explosion. Contact Environment, Health & Safety to determine if you have a washable hood.

- **Permanganates** are explosive when treated with sulfuric acid. When both compounds are in an absorption train, place an empty trap between them.

- **Peroxides (inorganic)**, when mixed with combustible materials, barium, sodium, and potassium, form explosives that ignite easily.

- **Phosphorus** (P), both red and white, forms explosive mixtures with oxidizing agents. White (also called yellow) P should be stored under water, in glass, because it is pyrophoric. The reaction of P with aqueous hydroxides gives phosphine (PH_3), a highly toxic gas that can also ignite spontaneously in air or explode.

- **Phosphorus Trichloride** (PCl_3) reacts with water to form phosphorous acid, which decomposes on heating to form phosphine, which may ignite spontaneously in air or explode. Take care when opening containers of PCl_3, and do not heat samples that were exposed to moisture without adequate shielding to protect you.

- **Picric Acid** $[(NO_2)_3C_6H_2OH]$, also known as 2,4,6-trinitrophenol, can form explosive compounds with many combustible materials. Do not store in metal containers, as this can cause the formation of highly explosive metal picrate salts. Picric acid in saturated aqueous solution is relatively stable, but becomes less stable with age; in solutions of 10% to 40% water, it is considered a flammable solid. If picric acid dries to less than 10% water (Figure 11.3), it is a high explosive (DOT Class 1, Division 1.1), and must not be touched or disturbed except by trained high-hazard removal specialists.

Figure 11.3 – A bottle of dried-out picric acid, which has become a highly shock sensitive Division 1.1 explosive (Photo courtesy of Robert Burke, www.firehouse.com)

- **Piranha Solutions** (mixtures of sulfuric acid and hydrogen peroxide) used for removal of organic materials must never be stored, as they are likely to pressurize and explode their container. Make only what you need, and discard immediately after use. Solutions are very energetic and heat to over 100 ^{o}C during mixing; handle with care.

- **Potassium** (K) is in general more reactive than sodium, and ignites quickly on exposure to humid air; therefore, handle it under the surface of a hydrocarbon solvent such as mineral oil or kerosene (see Sodium). Potassium may also form peroxides even while stored under oil.

- **Propargyl Bromide** (C_3H_3Br), also known as 3-bromopropyne, is an unstable water-insoluble compound that is usually stored in a solvent such as toluene. Do not allow propargyl bromide to dry out, do not store it in an area near heat sources, and do not expose it to mild mechanical shocks.

- **Residues from Vacuum Distillations** (for example, ethyl palmitate) have exploded when the still was vented to the air before the residue was cool. Avoid such explosions by venting the still pot with nitrogen, cooling it before venting, or restoring the pressure slowly.

- **Sodium** (Na) shall be stored in a closed container under kerosene, toluene or mineral oil. Destroy scraps of Na or K by reaction with n-butyl alcohol. Avoid contact with water, as sodium reacts violently with water to form hydrogen with evolution of sufficient heat to cause ignition. Use sand or Class D extinguishers on alkali metal fires. Do not use CO_2 fire extinguishers.

- **Sodium Amide** ($NaNH_2$) can rapidly absorb water and carbon dioxide from humid air. Oxidation can produce sodium nitrite in a mixture that is unstable and may explode. Store sodium amide in a cool, dry place in a tightly-sealed container under inert gas blanket.

- **Sodium Azide** (NaN_3) can react with copper and lead (including copper and lead in plumbing) to produce explosive copper or lead azide. Use caution when drain disposing substances that contain ANY amount of sodium azide. Even the trace amounts (<1%) used

as an antimicrobial in many chemical mixtures and reagent test kits can react with copper or lead in areas such as P-traps; there is the potential for prolonged contact between the azide and lead/copper that might be in these traps. If you drain dispose any substances with trace amounts of sodium azide, flush with copious amounts of water. Sodium azide is also highly toxic, and can explosively decompose due to heat, shock, concussion, or friction. Do not mix with sulfuric or nitric acid.

- **Sulfuric Acid** (H_2SO_4) should be avoided, if possible, as a drying agent in desiccators. If used, place glass beads in it to prevent splashing when the desiccator is moved. Avoid using H_2SO_4 in melting point baths, use silicone oil instead. To dilute H_2SO_4, add the acid slowly to cold water.

- **Tollens Reagents**, which contain an aqueous diamine silver complex [$Ag(NH_3)_2^+$] and are used to test for aldehydes, must be freshly prepared and NEVER stored for longer than 1-2 hours. Stored Tollens Reagent can form explosive fulminating silver (Ag_3N). Acidify with dilute acid before disposal.

- **Trichloroethylene** (Cl_2CCHCl) reacts under a variety of conditions with potassium or sodium hydroxide to form dichloroacetylene ($ClC{\equiv}CCl$), which ignites spontaneously in air and detonates readily even at dry-ice temperatures. The compound itself is toxic, so take suitable precautions when using as a degreasing solvent. Methyl chloroform (1,1,1-trichloroethane) is a less toxic substitute.

This page intentionally left blank.

CHAPTER 12

MANAGEMENT OF LABORATORY WASTES

Overview

This chapter discusses the basic rules and restrictions for the accumulation, storage, and disposal of laboratory wastes. This chapter also includes a brief overview of the regulatory requirements and agencies having jurisdiction, and several waste management definitions.

Table of Contents

This page intentionally left blank.

CHAPTER 12

MANAGEMENT OF LABORATORY WASTES

I. Introduction

The disposal of laboratory wastes (chemical – hazardous and non-hazardous, radioactive, or unwanted materials including Universal wastes) has become more complex and expensive as regulations have become more stringent. The Principal Investigator is responsible for identifying and labeling waste generated in his/her laboratory, and storing it safely until it is picked up for disposal by EHS or Housekeeping. EHS is responsible for transfer of chemical and radioactive wastes from laboratories to the UNC Hazardous Materials Facility for treatment or packaging prior to shipment to off-site disposal facilities.

II. Hazardous Waste Inspections – Lids, Leaks, Labels, and Location

The NC Department of Environment and Natural Resources (NCDENR) and the U.S. Environmental Protection Agency (EPA) inspect the University frequently. These agencies refer to University laboratories as "satellite accumulation areas", because hazardous waste is not stored long-term or disposed in the lab. EHS is responsible for identifying and removing waste from laboratories upon notification, and transporting or shipping wastes to approved treatment, storage, and disposal facilities.

For the most part, satellite accumulation areas (labs) have fewer regulatory requirements than long-term or central accumulation areas. However, there are still some very strict requirements for satellite accumulation areas. The University uses "Four L's": Lids, Leaks, Labels, and Location to sum up these rules. Violation of any of the following rules during an Agency inspection could result in a citation or fine to the University:

A. LIDS

- Keep lids or caps securely in place and tight except when you add materials. A funnel resting on the mouth of a bottle is not a lid; neither is Parafilm®.
- Note: Be sure that gas-producing reactions (e.g. organics in acids) have worked to completion before transferring the material to a hazardous waste container.
- Remember: A closed container, when tipped over, will not leak.

B. LEAKS

- Secondary containment is required for all glass containers of liquid hazardous materials (including waste) stored on the floor.
- Secondary containment is also required for all containers of liquid hazardous waste, with capacity of 4 liters or less, regardless of storage location.

C. LABELS

- Hazardous waste regulations require the words "Hazardous Waste" on waste containers, OR words which identify the contents (e.g. "Acetone Waste").
- Hazard communication regulations require clear identification of the chemical(s). Abbreviations such as H_2SO_4, HCl, EtBr, EtOH, etc. are not acceptable.

D. LOCATION

- You must keep the waste container(s) at or near the point of generation and under control or supervision of the individual directly responsible for the waste-generating process. Do not store wastes in a separate room or down the hall.
- Do not accumulate more than fifty-five gallons (208 liters) of hazardous waste or one quart (0.95 liters) of acutely hazardous waste in the laboratory.

III. Hazardous Waste Containers

Hazardous waste containers must be in good condition and chemically compatible with their contents. Waste containers must have securely fitting lids; do not use corks or stoppers. Laboratory beakers, flasks, or plastic milk cartons are not acceptable as waste containers. Metal containers are not acceptable unless they are the original containers. Glass and plastic reagent bottles are generally the most convenient. **Before discarding materials, allow them to react completely and/or cool to ambient temperatures before accumulating as waste, and tightly closing the lid**. Until all reactions are completed, the contents of a container are not waste, but are instead the last step of the reaction procedure.

Figure 12.1 – Three examples of unacceptable lids for hazardous waste containers.
Photos courtesy of University of Kentucky, Environmental Health & Safety.

Store glass waste containers in rubber safety carriers, buckets, or similar containers to protect against breakage and spillage. All containers holding 4 liters or less of liquid hazardous waste, and all glass containers of liquid hazardous materials stored on the floor, require secondary containment.

Liquid wastes may be accumulated in glass reagent bottles compatible with the waste. If you generate a large volume of liquid waste, consider 5-gallon carboys for solvent accumulation. Containers of liquids must have a ten percent headspace to accommodate thermal expansion.

Solid wastes are to go into a double-lined cardboard box. Liners must be 1.5 mil or greater polypropylene bags. Tie and seal each bag individually. Zip-locking bags are available through Scientific Storeroom.

Ethidium bromide-containing solid and semi-solid waste (e.g. used gels) is also collected in double-lined bags within cardboard boxes. Save liquid ethidium bromide waste in carboys or bottles.

Reactive chemicals must be disposed in their original shipping containers, or containers provided by EHS.

Hydrofluoric acid presents a special hazard and must be stored in Teflon® containers or original containers. Refer to Chapter 6: Safe Handling of Toxic Materials for more information about hydrofluoric acid.

Biohazardous waste – Place biohazardous waste (other than sharps) in a container that is durable, closable with a lid, leak-proof, lined with an autoclavable orange or red plastic bag with the universal biohazard symbol, labeled (with a biohazard sticker), **and** (as of June 1, 2008) red and less than or equal to 15-gallons (57-L) (Fig. 12.2). Limit the use of orange or red plastic bags to infectious waste that must be autoclaved before disposal or incinerated. For autoclaving, label the bags with heat sensitive autoclave indicator tape in an X-pattern over the biohazard symbol, and securely seal the bag opening with indicator tape. Do not

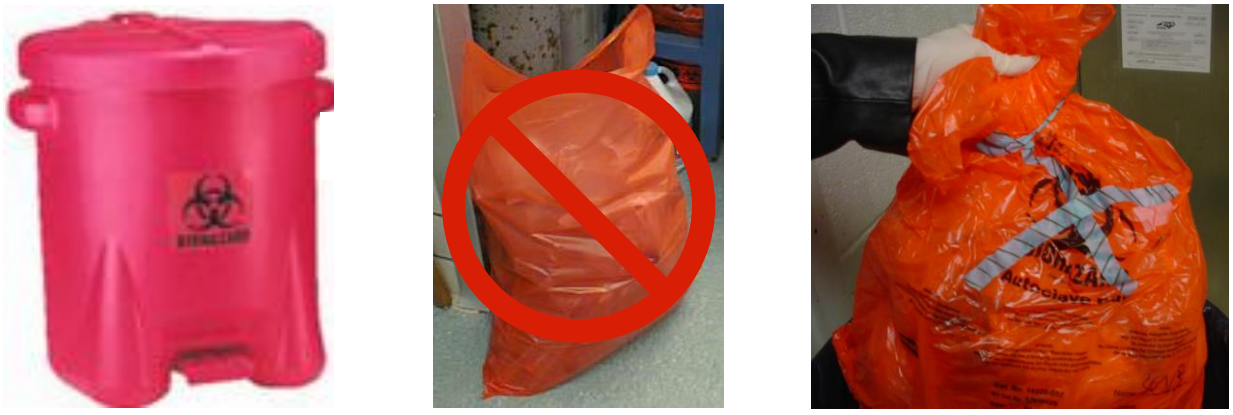


Figure 12.2 – (Left) Labeled red container with lid for accumulating biohazardous waste (other than regulated sharps). (Center) Biohazard bag outside of a hard-walled container, which is unacceptable. (Right) Infectious waste bag that was sealed, marked with heat-sensitive tape, and autoclaved.

use biohazard bags for radioactive or hazardous waste. Disposal contractors will return drums containing biohazard bags or any other labels indicating infectious materials, and the Orange County Regional Landfill will reject waste that contains biohazard bags that have not clearly been marked as autoclaved.

After autoclaving this waste, place it in the barrels marked for AUTOCLAVED or DECONTAMINATED waste (Fig. 12.3). Housekeeping will empty these barrels, but will not touch or move orange/red bagged waste from any other locations, whether it was autoclaved or not.

For procedures on infectious waste disposal that are more specific, consult the EHS Biological Waste Management website.

Figure 12.3 – Barrels for disposal of red/orange bag autoclaved waste.
Do not dispose this waste in containers not labeled for autoclaved waste.

IV. Chemical Waste Segregation

Acids and Bases – Segregate containers of acids and bases from one another while accumulating for disposal/treatment. EHS will pick up concentrated acids and bases and neutralized waste. Do not discharge acids and bases containing heavy metals to the sewer. Do not mix acids and bases containing heavy metals with other acidic or basic wastes. You should include neutralization as an end step in your laboratory procedures.

Oxidizers – Package oxidizers separately, and accumulate away from flammable materials.

Reactives – For the safety of hazardous waste personnel, exercise special care to identify reactive wastes. Although the process of using reactives usually eliminates the reactivity characteristic, some have dangerous residual properties. For example, residual metallic sodium, added to a solvent to remove water, could result in a fire or explosion if that solvent mixed with aqueous wastes. Likewise, you must label solutions containing sulfides and/or cyanides to alert personnel not to mix these with acid wastes. This mixing could release lethal amounts of toxic gases. Due to

the cost and hazards of shipping and disposing reactives, make every effort to use or react the entire contents of the container.

Used Solvents – Collect halogenated and non-halogenated solvent wastes in separate containers. Separate those wastes containing heavy metals. Those containing acids or bases are to have the pH adjusted to 6-8 prior to pickup.

V. "Unknowns" – Unidentified Chemicals

Unlabeled chemicals present a significant disposal problem. Hazardous waste disposal firms require certification of the waste composition by the generator. If the generator is unable to provide this certification based on knowledge of the chemicals in the waste, a laboratory analysis is usually required. An analysis of an unknown may cost anywhere from $30 to several hundred dollars. EHS provides periodic identification and removal of unknowns by contract with qualified disposal companies. Exercise every precaution to avoid generating unknowns. If you discover unknown chemicals in a laboratory, contact the Hazardous Materials Manager (962-5509) for assistance and handling information.

Figure 12.4 –
Unknown chemicals collected during a recent laboratory clean out of Venable Hall.

VI. Hazardous Waste Pickups

For each waste type, you must submit an online Waste Pickup Request. The link for online waste pickup is https://s4.its.unc.edu/HazMat_Pickup/. If you are requesting pickup from a research laboratory, you must have a valid ONYEN and a current registration with EHS as a Principal Investigator or Laboratory Worker. Go to http://onyen.unc.edu if you do not have an ONYEN, the ONYEN has expired, or you have forgotten your password. If the system blocks you from entering an online pickup request, contact EHS at 962-5717 for further assistance.

If you are not a Principal Investigator or Laboratory Worker, or if you wish to request waste pickup from a location other than a laboratory, choose the "Non-PI Organizations/ Locations" field on the waste pickup screen. You do not need an ONYEN to request a non-lab waste pickup. If your non-lab location is not among the drop-down menu choices under "Non-PI", contact the Hazardous Materials Manager at 962-5509 for further assistance.

Do not use older, paper versions of the Hazardous Materials Transfer Form. The online request is the only approved method for requesting waste pickup. The EHS website offers a tutorial for using the online e-510 waste disposal form: http://ehs.unc.edu/environmental/waste_disposal.shtml.

Below are condensed instructions for completing the e-510 form. These instructions are specific to the PI/Registered Lab Worker portal that you must have a valid ONYEN and password to enter. However, most of these instructions also apply to non-PI/non-lab waste pickup requests.

- Click on the "Make New Request as PI" field under the Chemical Waste Pickup Menu.
- Next, choose the name of the faculty member responsible for the laboratory and click submit.
- Room and Building. Choose the building where the waste is located from the drop-down menu., and list the room number.
- Contents. Identify waste as liquid, solid, or gas. Indicate if liquid waste is aqueous solution, organic solvent, or other.
- pH value. Complete for liquids that contain corrosives (acids or bases); otherwise, enter 7 as pH.
- Mixed chemicals. Indicate whether waste generators mixed chemical constituents before ("new") or after ("used") use. This affects proper classification of solvent wastes and may provide a basis for waste minimization, as non-hazardous materials become hazardous waste when mixed with a hazardous waste.
- Chemical composition. List constituents and their percentages. Total must add up to 100 percent. Do not use abbreviations or chemical formulas. Include percentages of water, already listed, if any.
- Container size. List size of the waste container (gallon, liter, etc.)
- Container type. Identify the container type from drop-down menu; choose "other" if your container type is not otherwise listed.
- Weight. Net weight of the contents, in kilograms (required for regulatory purposes). We estimate that a liter of liquid weighs one kilogram.
- Number of containers. Give the number of containers of equal type, size, and contents that you want to have picked up.
- Notes. List any additional information that will assist EHS, or any special pickup instructions. For example, indicate where to find the waste in the room if the location is not obvious (e.g. refrigerator, cabinet).

After submitting your request, you will see a pickup request confirmation. If all information is correct, press the confirm button at bottom of page. You will receive an e-mail indicating your request was received and is under review. After the Hazardous Materials Manager reviews and approves the request, you will receive a confirmation e-mail that includes a hyperlink to the Hazardous Material Transfer Form. You must print out this form and affix it to the waste container(s). This marks the waste for pickup.

THIS FORM MUST BE ATTACHED TO THE CONTAINER

HAZARDOUS MATERIAL TRANSFER FORM
SERIAL# E004208

Principal Investigator: [redacted]
Email: [redacted]
Telephone No. [redacted]
Waste In: Bldg KERR HALL (BEARD HALL ADDITION)
Room: [redacted]
Requested by: [redacted]
Date Request: 01/08/2004

MATERIAL DESCRIPTION

Container Size: 4L
Weight: 4.0
Contents: LIQUID
Chemical Mixed:

Chemical Composition

Chemical Description	Percent
ACETONITRILE	25.0
METHANOL	5.0
OCTANOL	5.0
WATER	65.0

Notes: USED

DOT Hazard Class: 3
EPA: D001 F003

Cut Here

Figure 12.5 –
(Left): Hazardous Material Transfer Form example.
(Right): Forms attached to waste bottles awaiting pickup.

VII. Waste Minimization

The most significant way that you can assist in the management of hazardous waste is to reduce the volume that must be disposed. Principal Investigators are encouraged to consider ways to reduce the volume of waste or preserve the reuse of materials through the redesign of experiments. Keep recyclable materials separate from other wastes. Make every effort in the lab to decontaminate, detoxify, neutralize, or otherwise make research materials non-hazardous as the last step in each experiment.

VIII. Disposal to Sewage System

Do not use the sanitary sewer for the disposal of hazardous materials, with the exception of trace quantities associated with cleaning and washing operations, e.g., glassware. The following discharges to the sanitary sewer are prohibited by the Clean Water Act:

- Materials that may create a fire or explosion hazard.
- Corrosive materials with pH less than five (5).
- Solid or viscous materials in amounts to obstruct flow or interfere with operations.
- Heated discharges which will inhibit biological activities or increase the wastewater treatment plant influent temperature to 104^{o}F and higher.
- Discharges of any toxic material in volume or strength to cause interference with waste treatment processes, or contamination of sludge or effluent from the wastewater treatment plant so as to violate its permit.
    - **Note on Biocides**: Do not release concentrated solutions to the sanitary sewer. Limit disposal to one gallon of "working strength" solution per laboratory per day. This also applies to germicides and disinfectants. Pesticides and other chemicals that are persistent in the environment cannot go to the sewer.

IX. Disposal to General Waste – Sharps

Trash placed in wastebaskets is picked up by Housekeeping personnel, transferred to dumpsters and transported to the Orange County Regional Landfill for burial. Prohibited items include batteries, liquids, radioactive materials, hazardous wastes as defined by the Resource Conservation and Recovery Act (RCRA), poisons, infectious materials, and other items that would pose a threat to waste-handling personnel or the environment.

Broken Glass and Other Sharp Objects – Place non-contaminated and/or decontaminated glassware and non-regulated sharp objects in a plastic bag within a cardboard box. EHS recommends this manner for disposal of all glass items. Housekeeping will pick up these boxes if they are sealed and identified with a label indicating: **"CAUTION, GLASS AND SHARPS, NON-HAZARDOUS MATERIAL ONLY".** You can download these labels from the EHS Safety Labels page (http://ehs.unc.edu/ih/lab/labels/).

Figure 12.6 - Disposal boxes for non-contaminated glassware or non-regulated sharp objects.

Regulated Sharps - North Carolina law requires special handling of hypodermic needles, syringes with attached needles, capillary tubes, slides and coverslips, and scalpel blades. Dispose these items in a hard-walled container. You must use one-gallon metal cans for accumulation and disposal of regulated sharps. Glass bottles are not acceptable, as they could break during handling or compaction. Metal cans and lids are available from Fisher Scientific, stock number 5001069EA. Do not overfill these cans; this could expose personnel to sharps protruding out the lid opening.

Figure 12.7 – Metal containers for disposal of regulated sharps.
(Left) Metal can labeled for disposal of non-infectious regulated sharps.
(Right) Metal can labeled for disposal of infectious sharps that has been autoclaved;
autoclave tape over the biohazard symbol indicates contents are no longer infectious.

For non-infectious regulated sharps, you can place the metal cans into a "glass and sharps" box for disposal when the can fills. You can also place these in the ordinary trash for disposal. Make sure to tighten and tape the lid before disposing the can. The can must be labeled for non-infectious waste only. For disposal of infectious regulated sharps, such as needles and scalpels contaminated with known or suspected human pathogens, you must label the metal can with a biohazard symbol. This indicates that the can must be steam sterilized (autoclaved) before disposal. Similar to the requirements for bags of infectious waste, make sure to put heat-sensitive autoclave tape in an X-pattern over the biohazard symbol on the metal can prior to autoclaving and disposal.

Do not use plastic-walled containers for disposal of infectious waste sharps. These containers cannot withstand autoclaving, and require incineration for disposal. Do not use these containers for disposal of non-infectious waste either; these containers do not belong in the waste stream that goes to the landfill. The Orange County Regional Landfill could reject an entire waste load from the University if they found a single plastic-walled sharps container in it. Please contact EHS for guidance if you currently have plastic-walled sharps containers in your lab.

Other Regulated Sharps – Place broken glass and other sharps contaminated with carcinogens or radioactive material in the containers provided for these waste streams. Metal cans are not suitable for sharps contaminated with trace carcinogens or short-lived radioactive material, since these wastes are incinerated. Plastic-walled containers with tight-fitting lids are appropriate for disposal of these waste streams; the Hospital Storeroom offers plastic three-liter urine collection containers that are ideal.

For long-lived radioactive materials, any type of hard-walled container is suitable. Refer to the UNC Radiation Safety Manual (http://ehs.unc.edu/manuals/index.shtml) for radioactive sharps disposal procedures.

X. Disposal of Compressed Gas Cylinders

Disposal of non-returnable, e.g., lecture-size cylinders that are not "empty" can be very expensive, especially for reactive gases. Consider residual gas disposal options before purchasing reactive or highly toxic compressed gases. Compressed gas suppliers generally are not licensed to receive hazardous waste, and thus cannot accept non-returnable cylinders. However, suppliers can accept reusable cylinders with residual gas. Make every effort to purchase from suppliers who have a cylinder return program.

Figure 12.8 – Non-returnable lecture gas bottles from a lab cleanout.

XI. Disposal of Infectious Waste

You must decontaminate infectious wastes before disposal to the sewerage system, general waste, chemical waste, radioactive waste or any other disposal system. Liquid infectious wastes such as human blood or pathogenic cultures must be autoclaved prior to sanitary sewer disposal. Do not attempt to disinfect this waste with bleach.

Decontaminated wastes placed into general waste must be in an autoclaved bag marked with heat sensitive tape to signal that the material has been decontaminated. Refer to Section III of this chapter or the UNC Biological Safety Manual for specific procedures.

XII. Disposal of Radioactive Wastes

The purchase, use, storage, and disposal of radioactive materials are governed by the NC Regulations for Protection Against Radiation, and policies and procedures promulgated by the UNC Radiation Safety Committee. Refer to the UNC Radiation Safety Manual for details.

XIII. Empty Chemical Containers and Recycling

Currently, a community recycling program exists for glass and plastic (HDPE and PETE) containers. Glass and plastic containers that contained hazardous materials are not acceptable in the community recycling program at this time. Many chemical containers are made from borosilicate glass, which is not compatible with most recycled glass because of the higher melting temperature. Pyrex-type glass is not acceptable for the same reason. Plastic containers are not acceptable because of residual contamination concerns. You are encouraged to re-use chemical containers as waste containers, if the waste is compatible with the container materials and any residuals that might remain in the container. Before disposing a chemical container, triple-rinse it with water and deface the label. For containers that held water-reactive chemicals that make triple rinsing inappropriate, contact EHS for advice or submit an online waste pickup request.

Hopefully, a means of recycling these chemical containers will be available in the near future.

XIV. Waste Definitions and Regulatory Terms

Asbestos Waste - Asbestos containing materials (ACM) containing more than one percent asbestos.

DOT – U.S. Department of Transportation. The DOT enforces rules involving transport of hazardous materials. All hazardous materials removed from laboratories and transported to the University's Hazardous Materials Facility must be properly identified and packaged prior to transporting. DOT hazard classes are:

- 1.1 - 1.6 Explosives
- 2.1 Flammable gas
- 2.2 Non-flammable, non-poisonous gas
- 2.3 Poisonous gas
- 3 Flammable liquids
- 4.1 Flammable solids
- 4.2 Spontaneously combustible materials
- 4.3 Dangerous when wet materials
- 5.1 Oxidizers
- 5.2 Organic peroxides
- 6.1 Poisonous materials
- 6.2 Infectious substances
- 7 Radioactive materials
- 8 Corrosive materials
- 9 Miscellaneous hazardous materials

Empty Container - A container that has held hazardous waste is not a hazardous waste if it is empty. A container is empty if:

- All wastes have been removed that can be removed using the practices commonly employed to remove materials from that type of container, e.g., pouring, pumping, and aspirating, or no more than three percent by weight of the total capacity remains in the container.
- It held an acute hazardous waste (P-Listed), but has been triple rinsed using a solvent capable of removing the chemical (note: the rinsate must be disposed as a hazardous waste).
- It is a compressed gas cylinder and its pressure approaches atmospheric.

EPA – U.S. Environmental Protection Agency. Hazardous waste must be identified, stored, recycled and/or treated and/or disposed in accord with EPA regulations. The EPA regulates all solid waste disposal including municipal landfills and sanitary sewer.

Hazardous Materials - A DOT term that refers to a liquid, solid, or gas which has properties requiring special handling precautions due to biological, physical, chemical or radiological characteristics.

Hazardous Waste - An EPA term that refers to a used and discarded hazardous material. This includes abandoned, recycled, or inherently waste-like hazardous materials. Hazardous waste is also called RCRA-regulated waste. For acute hazardous wastes, see definition of P-listed waste under RCRA-regulated Waste.

Infectious Waste - Waste capable of producing an infectious disease. For a waste to be infectious, it must contain pathogens with sufficient virulence and quantity so that exposure to the waste by a susceptible host could result in an infectious disease. Infectious waste from laboratories includes cultures and stocks of infectious agents and items contaminated with infectious agents, such as disposable culture dishes and devices used to transfer, inoculate, and mix cultures; human blood and blood products; animal carcasses, body parts, and bedding contaminated with infectious agents; sharp items, such as needles, syringes, broken glass, slides, cover slips, Pasteur pipettes, and scalpel blades, contaminated with infectious agents.

Medical Waste - As defined in North Carolina solid waste regulations, medical waste "means any solid waste which is generated in the diagnosis, treatment, or immunization of human beings or animals, in research pertaining thereto, or in the production or testing of biologicals". Note: infectious wastes are regulated medical wastes that require treatment before disposal.

Mixed Waste - A radioactive waste that also meets the definition of a RCRA-regulated waste.

Non-RCRA Regulated Waste - A solid waste, other than radioactive or RCRA-regulated waste that is subject to additional EPA requirements because disposal to the sewer or the sanitary landfill is prohibited or imprudent. Wastes in this category include batteries, carcinogens, compressed gases, controlled substances, corrosive solids, infectious waste, latex paint, medical waste, mutagens, poisons, sharps, teratogens and waste oils. This includes “Universal Wastes” (see definition below).

Radioactive Waste - Radioactive material regulated by the North Carolina Radiation Protection Division that is to be discarded.

RCRA-Regulated Waste - Waste regulated under the Resource Conservation and Recovery Act (RCRA), commonly referred to as the "hazardous waste regulations". According to RCRA definitions (40 CFR 260), a waste is a hazardous waste if it exhibits one or more of the "characteristics" of a hazardous waste or contains "listed" waste. A description of characteristic and listed wastes follows.

The four hazardous waste characteristics are ignitability, corrosivity, reactivity, and toxicity.

Ignitability - A waste exhibits the characteristic of ignitability if it is:

- a liquid with a flashpoint of less than 60^{o}C (140^{o}F);
- a solid capable of causing fire through friction, absorption of moisture or spontaneous chemical changes and, when ignited, burns so vigorously and persistently that it creates a hazard;
- a flammable compressed gas; or
- an oxidizer.

The EPA waste code for ignitability is "D001".

Corrosivity - A waste exhibits the characteristic of corrosivity if it is aqueous and has a pH $\leq$ 2 or $\geq$ 12.5. The EPA Waste Code for corrosivity is "D002".

Reactivity - A waste exhibits the characteristic of reactivity if:

- it is normally unstable and readily undergoes violent change without detonating;
- it reacts violently with water;
- it forms potentially explosive mixtures with water;
- it generates gases sufficient to endanger human health;
- it is a cyanide or sulfide bearing wastes that can generate toxic gases upon contact with an acid or base; or
- it is readily capable of detonation.

The EPA Waste Code for reactivity is "D003".

Toxicity - A waste exhibits the characteristic of toxicity if it contains any of the contaminants listed in Appendix 12-A at the concentration equal to or greater than the respective value given in that table. The Toxicity Characteristic Leaching Procedure (TCLP) is used to determine whether waste exhibits the toxicity characteristic.

Listed wastes are organized into several different "lists" by the EPA. The F-List includes non-specific source wastes and is found at 40 CFR 261.31. The K-List consists of wastes from specific industrial sources (full list at 40 CFR 261.32). The P-List and U-List are discarded commercial chemical products (full list at 40 CFR 261.33). Below are particular listed wastes common to laboratories.

Spent Solvents (subsets of F-Listed Waste):

- EPA Waste Code F002 - Halogenated solvents containing, before use, a total of ten percent or more of one or more of the following:

tetrachloroethylene	methylene chloride
trichloroethylene	1,1,1-trichloroethane
chlorobenzene	1,1,2-trichloroethane
ortho-dichlorobenzene	trichlorofluoromethane
	1,1,2-trichloro-1,2,2-trifluoroethane

- EPA Waste Code F003 - The following non-halogenated solvents, or mixtures/blends containing only these solvents.

xylene	ethyl ether
acetone	methyl isobutyl ketone
ethyl acetate	n-butyl alcohol
ethyl benzene	cyclohexanone

methanol

- EPA Waste Code F005 - Non-halogenated solvents containing, before use, a total of ten percent or more of one or more of the following:

toluene	pyridine
methyl ethyl ketone	benzene
carbon disulfide	2-ethoxyethanol
isobutanol	2-nitropropane

P-Listed Wastes - Discarded commercial chemical products, container residues, and spill residues of materials listed in Appendix 12-B are acute hazardous wastes. These wastes are "acutely toxic" or "P-listed" wastes. Note: if these materials are used (spent), they are not RCRA-regulated hazardous wastes unless they meet the definition of a characteristic hazardous waste or wastes from non-specific sources; however, they may still require disposal as a hazardous material (see definition of "non-RCRA regulated waste").

U-Listed Wastes - Discarded commercial chemical products listed in Appendix 12-C are listed wastes because of toxicity (T), reactivity (R), corrosivity (C) or ignitability (I). Note if these materials are used (spent), they are not hazardous wastes unless they meet the definition of a characteristic hazardous waste or wastes from non-specific sources; however, they may still require disposal as a hazardous material (see definition of "non-RCRA regulated waste").

Sharps - Broken glass, pipettes, scalpels, razor blades, serrated metal, hypodermic needles, slides, cover slips, capillary tubes, and any other items capable of penetrating trash bags and skin.

Solid Waste - Any discarded solid, compressed gas or liquid material other than domestic sewage. “Discarded” includes abandoned, recycled or inherently waste-like hazardous materials. All solid waste disposal is regulated by the EPA. Solid waste may be further classified and regulated as:

Hazardous or RCRA-regulated waste	Mixed Radioactive waste
Infectious waste	Non-RCRA regulated waste
Medical waste	Radioactive waste

Universal Wastes – Widely-generated wastes that are subject to the Standards for Universal Waste Management (40 CFR 273), to facilitate environmentally sound collection and proper recycling or treatment. Universal wastes include batteries, pesticides, mercury containing equipment, and lamps (fluorescent bulbs). For disposal information, contact EHS.

APPENDIX 12 - A

Table I - Maximum Concentration of Contaminants for Toxicity Characteristic

EPA hazardous waste number[1]	Contaminant	CAS No[2]	Regulatory Level (mg/l)
D004	Arsenic	7440-38-2	5.0
D005	Barium	7440-39-3	100.0
D018	Benzene	71-43-2	0.5
D006	Cadmium	7440-43-9	1.0
D019	Carbon Tetrachloride	56-23-5	0.5
D020	Chlordane	57-74-9	0.03
D021	Chlorobenzene	108-90-7	100.0
D022	Chloroform	67-66-3	6.0
D007	Chromium	7440-47-3	5.0
D023	o-Cresol	95-48-7	[4]200.0
D024	m-Cresol	108-39-4	[4]200.0
D025	p-Cresol	106-44-5	[4]200.0
D026	Cresol	.....	[4]200.0
D016	2,4-D	94-75-7	10.0
D027	1,4-Dichlorobenzene	106-46-7	7.5
D028	1,2-Dichloroethane	107-06-2	0.5
D029	1,1-Dichloroethylene	75-35-4	[3]0.7
D030	2,4-Dinitrotoluene	121-14-2	[3]0.13
D012	Endrin	72-20-8	0.02
D031	Heptachlor (and its epoxide)	76-44-8	[3]0.008
D032	Hexachlorobenzene	118-74-1	[3]0.13
D033	Hexachlorobutadiene	87-68-3	0.5
D034	Hexachloroethane	67-72-1	3.0
D008	Lead	7439-92-1	5.0
D013	Lindane	58-89-9	0.4
D009	Mercury	7439-97-6	0.2
D014	Methoxychlor	72-43-5	10.0
D035	Methyl ethyl ketone	78-93-3	200.0
D036	Nitrobenzene	98-95-3	2.0
D037	Pentachlorophenol	87-86-5	100.0
D038	Pyridine	110-86-1	[3]5.0
D010	Selenium	7782-49-2	1.0
D011	Silver	7440-22-4	5.0
D039	Tetrachloroethylene	127-18-4	0.7
D015	Toxaphene	8001-35-2	0.5
D040	Trichloroethylene	79-01-6	0.5
D041	2,4,5-Trichlorophenol	95-95-4	400.0
D042	2,4,6-Trichlorophenol	88-06-2	2.0
D017	2,4,5-TP Silvex	93-72-1	1.0
D043	Vinyl chloride	75-01-4	0.2

[1] Hazardous waste number.
[2] Chemical abstracts service number.
[3] Quantitation limit is greater than the calculated regulatory level. The quantitation limit therefore becomes the regulatory level.
[4] If o-, m-, and p-Cresol concentrations cannot be differentiated, the total cresol (D026) concentration is used. The regulatory level of total cresol is 200 mg/l.

APPENDIX 12 – B

P-Listed Wastes

ACUTELY HAZARDOUS

Hazardous Waste No.	Chemical abstracts No.	Substance
P023	107-20-0	Acetaldehyde, chloro-
P002	591-08-2	Acetamide, N-(aminothioxomethyl)-
P057	640-19-7	Acetamide, 2-fluoro-
P058	62-74-8	Acetic acid, fluoro-, sodium salt
P002	591-08-2	1-Acetyl-2-thiourea
P003	107-02-8	Acrolein
P070	116-06-3	Aldicarb
P203	1646-88-4	Aldicarb sulfone
P004	309-00-2	Aldrin
P005	107-18-6	Allyl alcohol
P006	20859-73-8	Aluminum phosphide (R,T)
P007	2763-96-4	5-(Aminomethyl)-3-isoxazolol
P008	504-24-5	4-Aminopyridine
P009	131-74-8	Ammonium picrate (R)
P119	7803-55-6	Ammonium vanadate
P099	506-61-6	Argentate(1-), bis(cyano-C)-, potassium
P010	7778-39-4	Arsenic acid H_3AsO_4
P012	1327-53-3	Arsenic oxide As_2O_3
P011	1303-28-2	Arsenic oxide As_2O_5
P011	1303-28-2	Arsenic pentoxide
P012	1327-53-3	Arsenic trioxide
P038	692-42-2	Arsine, diethyl
P036	696-28-6	Arsonous dichloride, phenyl-
P054	151-56-4	Aziridine
P067	75-55-8	Aziridine, 2-methyl-
P013	542-62-1	Barium cyanide
P024	106-47-8	Benzenamine, 4-chloro-
P077	100-01-6	Benzenamine, 4-nitro-
P028	100-44-7	Benzene, (chloromethyl)-
P042	51-43-4	1,2-Benzenediol,4-[1-hydroxy-2-(methylamino)ethyl]-, (R)-
P046	122-09-8	Benzeneethanamine, alpha, alpha-dimethyl-
P014	108-98-5	Benzenethiol
P127	1563-66-2	7-Benzofuranol, 2,3-dihydro-2,2-dimethyl-, methylcarbamate
P188	57-64-7	Benzoic acid, 2-hydroxy-, compd. with (3aS-cis)-1,2,3,3a,8,8a-hexahydro-1,3a,8-trimethyl-pyrrolo[2,3-b] indol-5-yl methylcarbamate ester (1:1)
P001	81-81-2	2H-1-Benzopyran-2-one, 4-hydroxy-3-(3-oxo-1-phenylbutyl)-, & salts, when present at concentrations greater than 0.3%
P028	100-44-7	Benzyl chloride
P015	7440-41-7	Beryllium powder
P017	598-31-2	Bromoacetone
P018	357-57-3	Brucine
P045	39196-18-4	2-Butanone, 3,3-dimethyl-1-(methylthio)-, O-[methylamino)carbonyl] oxime
P021	592-01-8	Calcium cyanide
P021	592-01-8	Calcium cyanide $Ca(CN)_2$
P189	55285-14-8	Carbamic acid, [(dibutylamino)-thio] methyl-, 2,3-dihydro-2,2-dimethyl-7-benzofuranyl ester
P191	644-64-4	Carbamic acid, dimethyl-, 1-[(dimethylamino)carbonyl]-5-methyl-1H-pyrazol-3-yl ester
P192	119-38-0	Carbamic acid, dimethyl-, 3-methyl-1-(1-methylethyl)-1H-pyrazol-5-yl ester
P190	1129-41-5	Carbamic acid, methyl-, 3-methylphenyl ester
P127	1563-66-2	Carbofuran
P022	75-15-0	Carbon disulfide
P095	75-44-5	Carbonic dichloride
P189	55285-14-8	Carbosulfan
P023	107-20-0	Chloroacetaldehyde
P024	106-47-8	p-Chloroaniline
P026	5344-82-1	1-(o-Chlorophenyl) thiourea
P027	542-76-7	3-Chloropropionitrile
P029	544-92-3	Copper cyanide
P029	544-92-3	Copper cyanide Cu(CN)
P202	64-00-6	m-Cumenyl methylcarbamate
P030		Cyanides (soluble cyanide salts), not otherwise specified
P031	460-19-5	Cyanogen
P033	506-77-4	Cyanogen chloride
P033	506-77-4	Cyanogen chloride (CN)Cl
P034	131-89-5	2-Cyclohexyl-4,6-dinitrophenol

APPENDIX 12 - B continued

Hazardous Waste No.	Chemical abstracts No.	Substance
P016	542-88-1	Dichloromethyl ether
P036	696-28-6	Dichlorophenylarsine
P037	60-57-1	Dieldrin
P038	692-42-2	Diethylarsine
P041	311-45-5	Diethyl-p-nitrophenyl phosphate
P040	297-97-2	O,O-Diethyl O-pyrazinyl phosphorothioate
P043	55-91-4	Diisopropylfluorophosphate (DFP)
P004	309-00-2	1,4,5,8-Dimethanonaphthalene, 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-, (1alpha,4alpha,4abeta,5alpha,8alpha,8abeta)-
P060	465-73-6	1,4,5,8-Dimethanonaphthalene, 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-, (1alpha,4alpha,4abeta,5beta,8beta,8abeta)-
P037	60-57-1	2,7:3,6-Dimethanonaphth[2,3-b]oxirene, 3,4,5,6,9,9-hexachloro-1a,2,2a,3,6,6a,7,7a-octahydro-, (1aalpha,2beta,2aalpha,3beta,6beta,6aalpha,7beta,7aalpha)-
P051	172-20-8	2,7:3,6-Dimethanonaphth[2,3-b]oxirene, 3,4,5,6,9,9-hexachloro-1a,2,2a,3,6,6a,7,7a-octahydro-, (1aalpha,2beta,2abeta,3alpha,6alpha,6abeta,7beta,7aalpha)-, & metabolites
P044	60-51-5	Dimethoate
P046	122-09-8	alpha, alpha-Dimethylphenethylamine
P191	644-64-4	Dimetilan
P047	1534-52-1	4,6-Dinitro-o-cresol, & salts
P048	51-28-5	2,4-Dinitrophenol
P020	88-85-7	Dinoseb
P085	152-16-9	Diphosphoramide, octamethyl-
P111	107-49-3	Diphosphoric acid, tetraethyl ester
P039	298-04-4	Disulfoton
P049	541-53-7	Dithiobiuret
P185	26419-73-8	1,3-Dithiolane-2-carboxaldehyde, 2,4-dimethyl-, O-[(methylamino)carbonyl]oxime
P050	115-29-7	Endosulfan
P088	145-73-3	Endothall
P051	72-20-8	Endrin
P051	72-20-8	Endrin, & metabolites
P042	51-43-4	Epinephrine
P031	460-19-5	Ethanedinitrile

Hazardous Waste No.	Chemical abstracts No.	Substance
P194	23135-22-0	Ethanimidothioic acid, 2-(dimethylamino)-N-[[(methylamino)carbonyl]oxy]-2-oxo-, methyl ester
P066	16752-77-5	Ethanimidothioic acid, N-[[(methylamino)carbonyl]oxy]-, methyl ester
P101	107-12-0	Ethyl cyanide
P054	151-56-4	Ethyleneimine
P097	52-85-7	Famphur
P056	7782-41-4	Fluorine
P057	640-19-7	Fluoroacetamide
P058	62-74-8	Fluoroacetic acid, sodium salt
P198	23422-53-9	Formetanate hydrochloride
P197	17702-57-7	Formparanate
P065	628-86-4	Fulminic acid, mercury(2+) salt (R,T)
P059	76-44-8	Heptachlor
P062	757-58-4	Hexaethyl tetraphosphate
P116	79-19-6	Hydrazinecarbothioamide
P068	60-34-4	Hydrazine, methyl-
P063	74-90-8	Hydrocyanic acid
P063	74-90-8	Hydrogen cyanide
P096	7803-51-2	Hydrogen phosphide
P060	465-73-6	Isodrin
P192	119-38-0	Isolan
P202	64-00-6	3-Isopropylphenyl N-methylcarbamate
P007	2763-96-4	3(2H)-Isoxazolone, 5-(aminomethyl)-
P196	15339-36-3	Manganese, bis(dimethyl-carbamodithioato-S,S')-,
P196	15339-36-3	Manganese dimethyldithio-carbamate
P092	62-38-4	Mercury, (acetato-O)phenyl-
P065	628-86-4	Mercury fulminate (R,T)
P082	62-75-9	Methanamine, N-methyl-N-nitroso
P064	624-83-9	Methane, isocyanato-
P016	542-88-1	Methane, oxybis(chloro-
P112	509-14-8	Methane, tetranitro- (R)
P118	75-70-7	Methanethiol, trichloro-
P198	23422-53-9	Methanimidamide, N,N-dimethyl-N'-[3-[[(methylamino)carbonyl]oxy]phenyl]-, monohydrochloride
P197	17702-57-7	Methanimidamide, N,N-dimethyl-N'-[2-methyl-4-[[(methylamino)carbonyl]oxy]phenyl]-
P199	2032-65-7	Methiocarb

APPENDIX 12 - B continued

Hazardous Waste No.	Chemical abstracts No.	Substance
P050	115-29-7	6,9-Methano-2,4,3-benzodioxathiepen, 6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-, 3-oxide
P059	76-44-8	4,7-Methano-1H-indene, 1,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-
P066	16752-77-5	Methomyl
P068	60-34-4	Methyl hydrazine
P064	624-83-9	Methyl isocyanate
P069	75-86-5	2-Methyllactonitrile
P071	298-00-0	Methyl parathion
P190	1129-41-5	Metolcarb
P128	315-18-4	Mexacarbamate
P072	86-88-4	alpha-Naphthylthiourea
P073	13463-39-3	Nickel carbonyl
P073	13463-39-3	Nickel carbonyl $Ni(CO)_4$, (T-4)-
P074	557-19-7	Nickel cyanide
P074	557-19-7	Nickel cyanide $Ni(CN)_2$
P075	154-11-5	Nicotine, & salts
P076	10102-43-9	Nitric oxide
P077	100-01-6	p-Nitroaniline
P078	10102-44-0	Nitrogen dioxide
P076	10102-43-9	Nitrogen oxide NO
P078	10102-44-0	Nitrogen oxide NO_2
P081	55-63-0	Nitroglycerine (R)
P082	62-75-9	N-Nitrosodimethylamine
P084	4549-40-0	N-Nitrosomethylvinylamine
P085	152-16-9	Octamethylpyrophosphoramide
P087	20816-12-0	Osmium oxide OsO_4, (T-4)-
P087	20816-12-0	Osmium tetroxide
P088	145-73-3	7-Oxabicyclo[2.2.1]heptane-2,3-dicarboxylic acid
P194	23135-22-0	Oxamyl
P089	56-38-2	Parathion
P034	131-89-5	Phenol, 2-cyclohexyl-4,6-dinitro-
P128	315-18-4	Phenol, 4-(dimethylamino)-3,5-dimethyl-, methylcarbamate (ester)
P199	2032-65-7	Phenol, (3,5-dimethyl-4-(methylthio)-, methylcarbamate
P048	51-28-5	Phenol, 2,4-dinitro-
P047	1534-52-1	Phenol, 2-methyl-4,6-dinitro-, & salts
P202	64-00-6	Phenol, 3-(1-methylethyl)-, methyl carbamate
P201	2631-37-0	Phenol, 3-methyl-5-(1-methylethyl)-, methyl carbamate
P020	88-85-7	Phenol, 2-(1-methylpropyl)-4,6-dinitro-
P009	131-74-8	Phenol, 2,4,6-trinitro-, ammonium salt (R)
P092	62-38-4	Phenylmercury acetate
P093	103-85-5	Phenylthiourea
P094	298-02-2	Phorate
P095	75-44-5	Phosgene
P096	7803-51-2	Phosphine
P041	311-45-5	Phosphoric acid, diethyl 4-nitrophenyl ester
P039	298-04-4	Phosphorodithioic acid, O,O-diethyl S-[2-(ethylthio)ethyl] ester
P094	298-02-2	Phosphorodithioic acid, O,O-diethyl S-[(ethylthio)methyl] ester
P044	60-51-5	Phosphorodithioic acid, O,O-dimethyl S-[2-(methylamino)-2-oxoethyl] ester
P043	55-91-4	Phosphorofluoric acid, bis(1-methylethyl) ester
P089	56-38-2	Phosphorothioic acid, O,O-diethyl-O-(4-nitrophenyl) ester
P040	297-97-2	Phosphorothioic acid, O,O-diethyl O-pyrazinyl ester
P097	52-85-7	Phosphorothioic acid, O-[4-[(dimethylamino)sulfonyl]phenyl] O,O-dimethyl ester
P071	298-00-0	Phosphorothioic acid, O,O-dimethyl O-(4-nitrophenyl) ester
P204	57-47-6	Physostigmine
P188	57-64-7	Physostigmine salicylate
P110	78-00-2	Plumbane, tetraethyl-
P098	151-50-8	Potassium cyanide
P098	151-50-8	Potassium cyanide K(CN)
P099	506-61-6	Potassium silver cyanide
P201	2631-37-0	Promecarb
P203	1646-88-4	Propanal, 2-methyl-2-(methyl-sulfonyl)-, O-[(methylamino)carbonyl] oxime
P070	116-06-3	Propanal, 2-methyl-2-(methylthio)-, O-[(methylamino)carbonyl]oxime
P101	107-12-0	Propanenitrile
P027	542-76-7	Propanenitrile, 3-chloro-
P069	75-86-5	Propanenitrile, 2-hydroxy-2-methyl-

APPENDIX 12 - B continued

Hazardous Waste No.	Chemical abstracts No.	Substance
P081	55-63-0	1,2,3-Propanetriol, trinitrate (R)
P017	598-31-2	2-Propanone, 1-bromo-
P102	107-19-7	Propargyl alcohol
P003	107-02-8	2-Propenal
P005	107-18-6	2-Propen-1-ol
P067	75-55-8	1,2-Propylenimine
P102	107-19-7	2-Propyn-1-ol
P008	504-24-5	Pyridinamine
P075	[1]54-11-5	Pyridine, 3-(1-methyl-2-pyrrolidinyl)-, (S)-, & salts
P204	57-47-6	Pyrrolo[2,3-b]indol-5-ol, 1,2,3,3a,8,8a-hexahydro-1,3a,8-trimethyl-, methylcarbamate (ester), (3aS-cis)-
P114	12039-52-0	Selenious acid, dithallium(1+) salt
P103	630-10-4	Selenourea
P104	506-64-9	Silver cyanide
P104	506-64-9	Silver cyanide Ag(CN)
P105	26628-22-8	Sodium azide
P106	143-33-9	Sodium cyanide
P106	143-33-9	Sodium cyanide Na(CN)
P108	[1]57-24-9	Strychnidin-10-one, & salts
P018	357-57-3	Strychnidin-10-one, 2,3-dimethoxy-
P108	[1]57-24-9	Strychnine, & salts
P115	7446-18-6	Sulfuric acid, dithallium(1+) salt
P109	3689-24-5	Tetraethyldithiopyrophosphate
P110	78-00-2	Tetraethyl lead
P111	107-49-3	Tetraethyl pyrophosphate
P112	509-14-8	Tetranitromethane (R)
P062	757-58-4	Tetraphosphoric acid, hexaethyl ester
P113	1314-32-5	Thallic oxide
P113	1314-32-5	Thallium oxide Tl_2O_3
P114	12039-52-0	Thallium(I) selenite
P115	7446-18-6	Thallium(I) sulfate
P109	3689-24-5	Thiodiphosphoric acid, tetraethyl ester
P045	39196-18-4	Thiofanox
P049	541-53-7	Thioimidodicarbonic diamide $[(H_2N)C(S)]_2NH$
P014	108-98-5	Thiophenol
P116	79-19-6	Thiosemicarbazide
P026	5344-82-1	Thiourea, (2-chlorophenyl)-
P072	86-88-4	Thiourea, 1-naphthalenyl-
P093	103-85-5	Thiourea, phenyl-
P185	26419-73-8	Tirpate
P123	8001-35-2	Toxaphene
P118	75-70-7	Trichloromethanethiol
P119	7803-55-6	Vanadic acid, ammonium salt
P120	1314-62-1	Vanadium oxide V_2O_5
P120	1314-62-1	Vanadium pentoxide
P084	4549-40-0	Vinylamine, N-methyl-N-nitroso-
P001	[1]81-81-2	Warfarin, & salts, when present at concentrations greater than 0.3%
P205	137-30-4	Zinc, bis(dimethylcarbamo-dithioato-S,S')-,
P121	557-21-1	Zinc cyanide
P121	557-21-1	Zinc cyanide $Zn(CN)_2$
P122	1314-84-7	Zinc phosphide Zn_3P_2, when present at concentrations greater than 10% (R,T)
P205	137-30-4	Ziram

[1] CAS Number given for parent compound only.

(f) The commercial chemical products, manufacturing chemical intermediates, or off-specification commercial chemical products referred to in paragraphs (a) through (d) of this section, are identified as toxic wastes (T) unless otherwise designated and are subject to the small quantity generator exclusion defined in §261.5(a) and (g).

[*Comment*: For the convenience of the regulated community, the primary hazardous properties of these materials have been indicated by the letters T (Toxicity), R (Reactivity), I (Ignitability) and C (Corrosivity). Absence of a letter indicates that the compound is only listed for toxicity.]

These wastes and their corresponding EPA Hazardous Waste Numbers are:

APPENDIX 12 – C

U-Listed Wastes

TOXIC & OTHER

Hazardous Waste No.	Chemical abstracts No.	Substance
U394	30558-43-1	A2213
U001	75-07-0	Acetaldehyde (I)
U034	75-87-6	Acetaldehyde, trichloro-
U187	62-44-2	Acetamide, N-(4-ethoxyphenyl)-
U005	53-96-3	Acetamide, N-9H-fluoren-2-yl-
U240	94-75-7	Acetic acid, (2,4-dichlorophenoxy)-, salts & esters
U112	141-78-6	Acetic acid, ethyl ester (I)
U144	301-04-2	Acetic acid, lead(2+) salt
U214	563-68-8	Acetic acid, thallium(1+) salt
See F027	93-76-5	Acetic acid, (2,4,5-trichlorophenoxy)-
U002	67-64-1	Acetone (I)
U003	75-05-8	Acetonitrile (I,T)
U004	98-86-2	Acetophenone
U005	53-96-3	2-Acetylaminofluorene
U006	75-36-5	Acetyl chloride (C,R,T)
U007	79-06-1	Acrylamide
U008	79-10-7	Acrylic acid (I)
U009	107-13-1	Acrylonitrile
U011	61-82-5	Amitrole
U012	62-53-3	Aniline (I,T)
U136	75-60-5	Arsinic acid, dimethyl-
U014	492-80-8	Auramine
U015	115-02-6	Azaserine
U010	50-07-7	Azirino[2',3':3,4]pyrrolo[1,2-a]indole-4,7-dione, 6-amino-8-[[(aminocarbonyl)oxy]methyl]-1,1a,2,8,8a,8b-hexahydro-8a-methoxy-5-methyl-[1aS-(1aalpha,8beta,8aalpha,8balpha)]-
U280	101-27-9	Barban
U278	22781-23-3	Bendiocarb
U364	22961-82-6	Bendiocarb phenol
U271	17804-35-2	Benomyl
U157	56-49-5	Benz[j]aceanthrylene, 1,2-dihydro-3-methyl-
U016	225-51-4	Benz[c]acridine
U017	98-87-3	Benzal chloride
U192	23950-58-5	Benzamide, 3,5-dichloro-N-(1,1-diethyl-2-propynyl)-
U018	56-55-3	Benz[a]anthracene

Hazardous Waste No.	Chemical abstracts No.	Substance
U094	57-97-6	Benz[a]anthracene, 7,12-dimethyl-
U012	62-53-3	Benzenamine (I,T)
U014	492-80-8	Benzenamine, 4,4'-carbonimidoyl-bis[N,N-dimethyl-
U049	3165-93-3	Benzenamine, 4-chloro-2-methyl-, hydrochloride
U093	60-11-7	Benzenamine, N-N-dimethyl-4-(phenylazo)-
U328	95-53-4	Benzenamine, 2-methyl-
U353	106-49-0	Benzenamine, 4-methyl-
U158	101-14-4	Benzenamine, 4,4'-methylenebis[2-chloro-
U222	636-21-5	Benzenamine, 2-methyl-, hydrochloride
U181	99-55-8	Benzenamine, 2-methyl-5-nitro-
U019	71-43-2	Benzene (I,T)
U038	510-15-6	Benzeneacetic acid, 4-chloro-alpha-(4-chlorophenyl)-alpha-hydroxy-, ethyl ester
U030	101-55-3	Benzene, 1-bromo-4-phenoxy-
U035	305-03-3	Benzenebutanoic acid, 4-[bis(2-chloroethyl)amino]-
U037	108-90-7	Benzene, chloro-
U221	25376-45-8	Benzenediamine, ar-methyl-
U028	117-81-7	1,2-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester
U069	84-74-2	1,2-Benzenedicarboxylic acid, diburyl ester
U088	84-66-2	1,2-Benzenedicarboxylic acid, diethyl ester
U102	131-11-3	1,2-Benzenedicarboxylic acid, dimethyl ester
U107	117-84-0	1,2-Benzenedicarboxylic acid, dioctyl ester
U070	95-50-1	Benzene, 1,2-dichloro-
U071	541-73-1	Benzene, 1,3-dichloro-
U072	106-46-7	Benzene, 1-4-dichloro-
U060	72-54-8	Benzene, 1,1'-(2,2-dichloroethylidene)bis[4-chloro-
U017	98-87-3	Benzene, (dichloromethyl)-
U223	26471-62-5	Benzene, 1,3-diisocyanatomethyl- (R,T)
U239	1330-20-7	Benzene, dimethyl-(I,T)
U201	108-46-3	1,3-Benzenediol
U127	118-74-1	Benzene, hexachloro-

APPENDIX 12 – C continued

Hazardous Waste No.	Chemical abstracts No.	Substance
U056	110-82-7	Benzene, hexahydro-(I)
U220	108-88-3	Benzene, methyl-
U105	121-14-2	Benzene, 1-methyl-2,4-dinitro-
U106	606-20-2	Benzene, 2-methyl-1,3-dinitro-
U055	98-82-8	Benzene, (1-methylethyl)- (I)
U169	98-95-3	Benzene, nitro-
U183	608-93-5	Benzene, pentachloro-
U185	82-68-8	Benzene, pentachloronitro-
U020	98-09-9	Benzenesulfonic acid chloride (C,R)
U020	98-09-9	Benzenesulfonyl chloride (C,R)
U207	95-94-3	Benzene, 1,2,4,5-tetrachloro-
U061	50-29-3	Benzene, 1,1'-(2,2,2-trichloroethylidene)bis[4-chloro-
U247	72-43-5	Benzene, 1,1'-(2,2,2-trichloroethylidene)bis[4-methoxy-
U023	98-07-7	Benzene, (trichloromethyl)-
U234	99-35-4	Benzene, 1,3,5-trinitro-
U021	92-87-5	Benzidine
U202	[1]81-07-2	1,2-Benzisothiazol-3(2H)-one, 1,1-dioxide, & salts
U203	94-59-7	1,3-Benzodioxole, 5-(2-propenyl)-
U141	120-58-1	1,3-Benzodioxole, 5-(1-propenyl)-
U090	94-58-6	1,3-Benzodioxole, 5-propyl-
U278	22781-23-3	1,3-Benzodioxol-4-ol, 2,2-dimethyl-, methyl carbamate
U364	22961-82-6	1,3-Benzodioxol-4-ol, 2,2-dimethyl-,
U367	1563-38-8	7-Benzofuranol, 2,3-dihydro-2,2-dimethyl-
U064	189-55-9	Benzo[rst]pentaphene
U248	[1]81-81-2	2H-1-Benzopyran-2-one, 4-hydroxy-3-(3-oxo-1-phenyl-butyl)-, & salts, when present at concentrations of 0.3% or less
U022	50-32-8	Benzo[a]pyrene
U197	106-51-4	p-Benzoquinone
U023	98-07-7	Benzotrichloride (C,R,T)
U085	1464-53-5	2,2'-Bioxirane
U021	92-87-5	[1,1'-Biphenyl]-4,4'-diamine
U073	91-94-1	[1,1'-Biphenyl]-4,4'-diamine, 3,3'-dichloro-
U091	119-90-4	[1,1'-Biphenyl]-4,4'-diamine, 3,3'-dimethoxy-
U095	119-93-7	[1,1'-Biphenyl]-4,4'-diamine, 3,3'-dimethyl)-

Hazardous Waste No.	Chemical abstracts No.	Substance
U225	75-25-2	Bromoform
U030	101-55-3	4-Bromophenyl phenyl ether
U128	87-68-3	1,3-Butadiene, 1,1,2,3,4,4,-hexachloro-
U172	924-16-3	1-Butanamine, N-butyl-N-nitroso-
U031	71-36-3	1-Butanol (I)
U159	78-93-3	2-Butanone (I,T)
U160	1338-23-4	2-Butanone peroxide (R,T)
U053	4170-30-3	2-Butenal
U074	764-41-0	2-Butene, 1,4,-dichloro- (I,T)
U143	303-34-4	2-Butenoic acid, 2-methyl-,7-[(2,3-dihydroxy-2-(1-methoxyethyl)-3-methyl-1-oxobutoxy]methyl]-2,3,5,7a-tetrahydro-1H-pyrrolizin-1-yl ester, [1S-[1alpha(Z),7(2S*,3R*),7aalpha]]-
U031	71-36-3	n-Butyl alcohol (I)
U136	75-60-5	Cacodylic acid
U032	13765-19-0	Calcium chromate
U372	10605-21-7	Carbamic acid, 1H-benzimidazol-2-yl, methyl ester
U271	17804-35-2	Carbamic acid, [1-[(butylamino)carbonyl]-1H-benzimidazol-2-yl]-, methyl ester
U280	101-27-9	Carbamic acid, (3-chlorophenyl)-, 4-chloro-2-butynyl ester
U238	51-79-6	Carbamic acid, ethyl ester
U178	615-53-2	Carbamic acid, methylnitroso-, ethyl ester
U373	122-42-9	Carbamic acid, phenyl-, 1-methylethyl ester
U409	23564-05-8	Carbamic acid, [1,2-phenylenebis(iminocarbonothioyl)]bis-, dimethyl ester
U097	79-44-7	Carbamic chloride, dimethyl-
U114	[1]111-54-6	Carbamodithioic acid, 1,2-ethanediylbis-, salts & esters
U062	2303-16-4	Carbamothioic acid, bis(1-methylethyl)-S-(2,3-dichloro-2-propenyl) ester
U389	2303-17-5	Carbamothioic acid, bis(1-methylethyl)-, S-(2,3,3-trichloro-2-propenyl) ester
U387	52888-80-9	Carbamothioic acid, dipropyl-, S-(phenylmethyl) ester
U279	63-25-2	Carbaryl

APPENDIX 12 – C continued

Hazard-ous Waste No.	Chemical abstracts No.	Substance
U372	10605-21-7	Carbendazim
U367	1563-38-8	Carbofuran phenol
U215	6533-73-9	Carbonic acid, dithallium(1+) salt
U033	353-50-4	Carbonic difluoride
U156	79-22-1	Carbonochloridic acid, methyl ester (I,T)
U033	353-50-4	Carbon oxyfluoride (R,T)
U211	56-23-5	Carbon tetrachloride
U034	75-87-6	Chloral
U035	305-03-3	Chlorambucil
U036	57-74-9	Chlordane, alpha & gamma isomers
U026	494-03-1	Chlornaphazin
U037	108-90-7	Chlorobenzene
U038	510-15-6	Chlorobenzilate
U039	59-50-7	p-Chloro-m-cresol
U042	110-75-8	2-Chloroethyl vinyl ether
U044	67-66-3	Chloroform
U046	107-30-2	Chloromethyl methyl ether
U047	91-58-7	bera-Chloronaphthalene
U048	95-57-8	o-Chlorophenol
U049	3165-93-3	4-Chloro-o-toluidine, hydrochloride
U032	13765-19-0	Chromic acid H_2CrO_4, calcium salt
U050	218-01-9	Chrysene
U051		Creosote
U052	1319-77-3	Cresol (Cresylic acid)
U053	4170-30-3	Crotonaldehyde
U055	98-82-8	Cumene (I)
U246	506-68-3	Cyanogen bromide (CN)Br
U197	106-51-4	2,5-Cyclohexadiene-,1,4-dione
U056	110-82-7	Cyclohexane (I)
U129	58-89-9	Cyclohexane, 1,2,3,4,5,6-hexa-chloro-, (1alpha,2alpha,3beta, 4alpha,5alpha,6beta)-
U057	108-94-1	Cyclohexanone (I)
U130	77-47-4	1,3-Cyclopentadiene, 1,2,3,4,5,5-hexachloro-
U058	50-18-0	Cyclophosphamide
U240	194-75-7	2,4-D, salts & esters
U059	20830-81-3	Daunomycin
U060	72-54-8	DDD
U061	50-29-3	DDT
U062	2303-16-4	Diallate

Hazard-ous Waste No.	Chemical abstracts No.	Substance
U063	53-70-3	Dibenz[a,h]anthracene
U064	189-55-9	Dibenzo[a,i]pyrene
U066	96-12-8	1,2-Dibromo-3-chloropropane
U069	84-74-2	Dibutyl phthalate
U070	95-50-1	o-Dichlorobenzene
U071	541-73-1	m-Dichlorobenzene
U072	106-46-7	p-Dichlorobenzene
U073	91-94-1	3,3'-Dichlorobenzidine
U074	764-41-0	1,4-Dichloro-2-butene (I,T)
U075	75-71-8	Dichlorodifluoromethane
U078	75-35-4	1,1-Dichloroethylene
U079	156-60-5	1,2-Dichloroethylene
U025	111-44-4	Dichloroethyl ether
U027	108-60-1	Dichloroisopropyl ether
U024	111-91-1	Dichloromethoxy ethane
U081	120-83-2	2,4-Dichlorophenol
U082	87-65-0	2,6-Dichlorophenol
U084	542-75-6	1,3-Dichloropropene
U085	1464-53-5	1,2:3,4-Diepoxybutane (I,T)
U108	123-91-1	1,4-Diethyleneoxide
U395	5952-26-1	Diethylene glycol, dicarbamate
U028	117-81-7	Diethylhexyl phthalate
U086	1615-80-1	N,N'-Diethylhydrazine
U087	3288-58-2	O-O-Diethyl-S-methyldithiophos-phate
U088	84-66-2	Diethyl phthalate
U089	56-53-1	Diethylstilbesterol
U090	94-58-6	Dihydrosafrole
U091	119-90-4	3,3'-Dimethoxybenzidine
U092	124-40-3	Dimethylamine (I)
U093	60-11-7	p-Dimethylaminoazobenzene
U094	57-97-6	7,12-Dimethylbenz[a]anthracene
U095	119-93-7	3,3'-Dimethylbenzidine
U096	80-15-9	alpha,alpha-Dimethylbenzylhydro-peroxide (R)
U097	79-44-7	Dimethylcarbamoyl chloride
U098	57-14-7	1,1-Dimethylhydrazine
U099	540-73-8	1,2-Dimethylhydrazine
U101	105-67-9	2,4-Dimethylphenol
U102	131-11-3	Dimethyl phthalate
U103	77-78-1	Dimethyl sulfate

APPENDIX 12 – C continued

Hazard-ous Waste No.	Chemical abstracts No.	Substance
U105	121-14-2	2,4-Dinitrotoluene
U106	606-20-2	2,6-Dinitrotoluene
U107	117-84-0	Di-n-octyl phthalate
U108	123-91-1	1,4-Dioxane
U109	122-66-7	1,2-Diphenylhydrazine
U110	142-84-7	Dipropylamine (I)
U111	621-64-7	Di-n-propylnitrosamine
U041	106-89-8	Epichlorohydrin
U001	75-07-0	Ethanal (I)
U404	121-44-8	Ethanamine, N,N-diethyl-
U174	55-18-5	Ethanamine, N-ethyl-N-nitroso-
U155	91-80-5	1,2-Ethanediamine, N,N-dimethyl-N'-2-pyridinyl-N'-(2-thienylmethyl)-
U067	106-93-4	Ethane, 1,2-dibromo-
U076	75-34-3	Ethane, 1,1-dichloro-
U077	107-06-2	Ethane, 1,2-dichloro-
U131	67-72-1	Ethane, hexachloro-
U024	111-91-1	Ethane, 1,1'-[methylenebis(oxy)] bis[2-chloro-
U117	60-29-7	Ethane, 1,1'-oxybis- (I)
U025	111-44-4	Ethane, 1,1'-oxybis[2-chloro-
U184	76-01-7	Ethane, pentachloro-
U208	630-20-6	Ethane, 1,1,1,2-tetrachloro-
U209	79-34-5	Ethane, 1,1,2,2-tetrachloro-
U218	62-55-5	Ethanethioamide
U226	71-55-6	Ethane, 1,1,1-trichloro-
U227	79-00-5	Ethane, 1,1,2-trichloro-
U410	59669-26-0	Ethanimidothioic acid, N,N'-[thiobis [(methylimino)carbonyl-oxy]] bis-, dimethyl ester
U394	30558-43-1	Ethanimidothioic acid, 2-(dimethyl-amino)-N-hydroxy-2-oxo-, methyl ester
U359	110-80-5	Ethanol, 2-ethoxy-
U173	1116-54-7	Ethanol, 2,2'-(nitrosoimino)bis-
U395	5952-26-1	Ethanol, 2,2'-oxybis-, dicarbamate
U004	98-86-2	Ethanone, 1-phenyl-
U043	75-01-4	Ethene, chloro-
U042	110-75-8	Ethene, (2-chloroethoxy)-
U078	75-35-4	Ethene, 1,1-dichloro-
U079	156-60-5	Ethene, 1,2-dichloro-, (E)
U210	127-18-4	Ethene, tetrachloro

Hazard-ous Waste No.	Chemical abstracts No.	Substance
U228	79-01-6	Ethene, trichloro
U112	141-78-6	Ethyl acetate (I)
U113	140-88-5	Ethyl acrylate (I)
U238	51-79-6	Ethyl carbamate (urethane)
U117	60-29-7	Ethyl ether (I)
U114	'111-54-6	Ethylenebisdithiocarbamic acid, salts & esters
U067	106-93-4	Ethylene dibromide
U077	107-06-2	Ethylene dichloride
U359	110-80-5	Ethylene glycol monoethyl ether
U115	75-21-8	Ethylene oxide (I,T)
U116	96-45-7	Ethylenethiourea
U076	75-34-3	Ethylidene dichloride
U118	97-63-2	Ethyl methacrylate
U119	62-50-0	Ethylmethanesulfonate
U120	206-44-0	Fluoranthene
U122	50-00-0	Formaldehyde
U123	64-18-6	Formic acid (C,T)
U124	110-00-9	Furan (I)
U125	98-01-1	2-Furancarboxaldehyde (I)
U147	108-31-6	2,5-Furandione
U213	109-99-9	Furan, tetrahydro- (I)
U125	98-01-1	Furfural (I)
U124	110-00-9	Furfuran (I)
U206	18883-66-4	Glucopyranose, 2-deoxy-2-(3-methyl-3-nitrosoureido)-,D-
U206	18883-66-4	D-Glucose, 2-deoxy-2-[[(methylnitro-soamino)carbonyl]amino]-
U126	765-34-4	Glycidylaldehyde
U163	70-25-7	Guanidine, N-methyl-N'-nitro-N-nitroso-
U127	118-74-1	Hexachlorobenzene
U128	87-68-3	Hexachlorobutadiene
U130	77-47-4	Hexachlorocyclopentadiene
U131	67-72-1	Hexachloroethane
U132	70-30-4	Hexachlorphene
U243	1888-71-7	Hexachloropropene
U133	302-01-2	Hydrazine (R,T)
U086	1615-80-1	Hydrazine, 1,2-diethyl-
U098	57-14-7	Hydrazine, 1,1-dimethyl-
U099	540-73-8	Hydrazine, 1,2-dimethyl-
U109	122-66-7	Hydrazine, 1,2-diphenyl-

APPENDIX 12 – C continued

Hazardous Waste No.	Chemical abstracts No.	Substance
U134	7664-39-3	Hydrofluoric acid (C,T)
U134	7664-39-3	Hydrogen fluoride (C,T)
U135	7783-06-4	Hydrogen sulfide
U135	7783-06-4	Hydrogen sulfide H_2S
U096	80-15-9	Hydroperoxide, 1-methyl-1-phenylethyl- (R)
U116	96-45-7	2-Imidazolidinethione
U137	193-39-5	Indeno[1,2,3-cd]pyrene
U190	85-44-9	1,3-Isobenzofurandione
U140	78-83-1	Isobutyl alcohol (I,T)
U141	120-58-1	Isosafrole
U142	143-50-0	Kepone
U143	303-34-4	Lasiocarpine
U144	301-04-2	Lead acetate
U146	1335-32-6	Lead, bis(acetato-O)tetrahydroxytri-
U145	7446-27-7	Lead phosphate
U146	1335-32-6	Lead subacetate
U129	58-89-9	Lindane
U163	70-25-7	MNNG
U147	108-31-6	Maleic anhydride
U148	123-33-1	Maleic hydrazide
U149	109-77-3	Malononitrile
U150	148-82-3	Melphalan
U151	7439-97-6	Mercury
U152	126-98-7	Methacrylonitrile (I,T)
U092	124-40-3	Methanamine, N-methyl- (I)
U029	74-83-9	Methane, bromo-
U045	74-87-3	Methane, chloro- (I,T)
U046	107-30-2	Methane, chloromethoxy-
U068	74-95-3	Methane, dibromo-
U080	75-09-2	Methane, dichloro-
U075	75-71-8	Methane, dichlorodifluoro-
U138	74-88-4	Methane, iodo-
U119	62-50-0	Methanesulfonic acid, ethyl ester
U211	56-23-5	Methane, tetrachloro-
U153	74-93-1	Methanethiol (I,T)
U225	75-25-2	Methane, tribromo-
U044	67-66-3	Methane, trichloro-
U121	75-69-4	Methane, trichlorofluoro-
U036	57-74-9	4,7-Methano-1H-indene, 1,2,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-

Hazardous Waste No.	Chemical abstracts No.	Substance
U154	67-56-1	Methanol (I)
U155	91-80-5	Methapyrilene
U142	143-50-0	1,3,4-Metheno-2H-cyclobuta[cd]pentalen-2-one, 1,1a,3,3a,4,5,5,5a,5b,6-decachlorooctahydro-
U247	72-43-5	Methoxychlor
U154	67-56-1	Methyl alcohol (I)
U029	74-83-9	Methyl bromide
U186	504-60-9	1-Methylbutadiene (I)
U045	74-87-3	Methyl chloride (I,T)
U156	79-22-1	Methyl chlorocarbonate (I,T)
U226	71-55-6	Methyl chloroform
U157	56-49-5	3-Methylcholanthrene
U158	101-14-4	4,4'-Methylenebis(2-chloroaniline)
U068	74-95-3	Methylene bromide
U080	75-09-2	Methylene chloride
U159	78-93-3	Methyl ethyl ketone (MEK) (I,T)
U160	1338-23-4	Methyl ethyl ketone peroxide (R,T)
U138	74-88-4	Methyl iodide
U161	108-10-1	Methyl isobutyl ketone (I)
U162	80-62-6	Methyl methacrylate (I,T)
U161	108-10-1	4-Methyl-2-pentanone (I)
U164	56-04-2	Methylthiouracil
U010	50-07-7	Mitomycin C
U059	20830-81-3	5,12-Naphthacenedione, 8-acetyl-10-[(3-amino-2,3,6-trideoxy)-alpha-L-lyxo-hexopyranosyl)oxy]-7,8,9,10-tetrahydro-6,8,11-trihydroxy-1-methoxy-, (8S-cis)-
U167	134-32-7	1-Naphthalenamine
U168	91-59-8	2-Naphthalenamine
U026	494-03-1	Naphthalenamine, N,N'-bis(2-chloroethyl)-
U165	91-20-3	Naphthalene
U047	91-58-7	Naphthalene, 2-chloro-
U166	130-15-4	1,4-Naphthalenedione
U236	72-57-1	2,7-Naphthalenedisulfonic acid, 3,3'-[(3,3'-dimethyl[1,1' biphenyl]-4,4'-diyl)bis(azo)bis[5-amino-4-hydroxy]-, tetrasodium salt
U279	63-25-2	1-Naphthalenol, methylcarbamate
U166	130-15-4	1,4-Naphthoquinone
U167	134-32-7	alpha-Naphthylamine
U168	91-59-8	beta-Naphthylamine

APPENDIX 12 – C continued

Hazardous Waste No.	Chemical abstracts No.	Substance
U217	10102-45-1	Nitric acid, thallium(1+) salt
U169	98-95-3	Nitrobenzene (I,T)
U170	100-02-7	p-Nitrophenol
U171	79-46-9	2-Nitropropane (I,T)
U172	924-16-3	N-Nitrosodi-n-butylamine
U173	1116-54-7	N-Nitrosodiethanolamine
U174	55-18-5	N-Nitrosodiethylamine
U176	759-73-9	N-Nitroso-N-ethylurea
U177	684-93-5	N-Nitroso-N-methylurea
U178	615-53-2	N-Nitroso-N-methylurethane
U179	100-75-4	N-Nitrosopiperidine
U180	930-55-2	N-Nitrosopyrrolidine
U181	99-55-8	5-Nitro-o-toluidine
U193	1120-71-4	1,2-Oxathiolane, 2,2-dioxide
U058	50-18-0	2H-1,3,2-Oxazaphosphorin-2-amine, N,N-bis(2-chloroethyl)tetrahydro-, 2-oxide
U115	75-21-8	Oxirane (I,T)
U126	765-34-4	Oxiranecarboxyaldehyde
U041	106-89-8	Oxirane, (chloromethyl)-
U182	123-63-7	Paraldehyde
U183	608-93-5	Pentachlorobenzene
U184	76-01-7	Pentachloroethane
U185	82-68-8	Pentachloronitrobenzene (PCNB)
See F027	87-86-5	Pentachlorophenol
U161	108-10-1	Pentanol, 4-methyl-
U186	504-60-9	1,3-Pentadiene (I)
U187	62-44-2	Phenacetin
U188	108-95-2	Phenol
U048	95-57-8	Phenol, 2-chloro-
U039	59-50-7	Phenol, 4-chloro-3-methyl-
U081	120-83-2	Phenol, 2,4-dichloro-
U082	87-65-0	Phenol, 2,6-dichloro-
U089	56-53-1	Phenol, 4,4'-(1,2-diethyl-1,2-ethenediyl)bis-, (E)-
U101	105-67-9	Phenol, 2,4-dimethyl-
U052	1319-77-3	Phenol, methyl-
U132	70-30-4	Phenol, 2,2'-methylenebis[3,4,6-trichloro-
U411	114-26-1	Phenol, 2-(1-methylethoxy)-, methylcarbamate
U170	100-02-7	Phenol, 4-nitro-

Hazardous Waste No.	Chemical abstracts No.	Substance
See F027	87-86-5	Phenol, pentachloro-
See F027	58-90-2	Phenol, 2,3,4,6-tetrachloro-
See F027	95-95-4	Phenol, 2,4,5-trichloro-
See F027	88-06-2	Phenol, 2,4,6-trichloro-
U150	148-82-3	L-Phenylalanine, 4-[bis(2-chloroethyl)amino]-
U145	7446-27-7	Phosphoric acid, lead(2+) salt (2:3)
U087	3288-58-2	Phosphorodithioic acid, O,O-diethyl S-methyl ester
U189	1314-80-3	Phosphorous sulfide (R)
U190	85-44-9	Phthalic anhydride
U191	109-06-8	2-Picoline
U179	100-75-4	Piperidine, 1-nitroso-
U192	23950-58-5	Pronamide
U194	107-10-8	1-Propanamine (I,T)
U111	621-64-7	1-Propanamine, N-nitroso-N-propyl-
U110	142-84-7	1-Propanamine, N-propyl- (I)
U066	96-12-8	Propane, 1,2-dibromo-3-chloro-
U083	78-87-5	Propane, 1,2-dichloro
U149	109-77-3	Propanedinitrile
U171	79-46-9	Propane, 2-nitro (I,T)
U027	108-60-1	Propane, 2,2'-oxybis[2-chloro-
U193	1120-71-4	1,3-Propane sultone
See F027	93-72-1	Propanoic acid, 2-(2,4,5-trichlorophenoxy)-
U235	126-72-7	1-Propanol, 2,3-dibromo-, phosphate (3:1)
U140	78-83-1	1-Propanol, 2-methyl- (I,T)
U002	67-64-1	2-Propanone (I)
U007	79-06-1	2-Propenamide
U084	542-75-6	1-Propene, 1,3-dichloro-
U243	1888-71-7	1-Propene, 1,1,2,3,3,3-hexachloro-
U009	107-13-1	2-Propenenitrile
U152	126-98-7	2-Propenenitrile, 2-methyl- (I,T)
U008	79-10-7	2-Propenoic acid (I)
U113	140-88-5	2-Propenoic acid, ethyl ester (I)
U118	97-63-2	2-Propenoic acid, 2-methyl-, ethyl ester
U162	80-62-6	2-Propenoic acid, 2-methyl-, methyl ester (I,T)
U373	122-42-9	Propham
U411	114-26-1	Propoxur

APPENDIX 12 – C continued

Hazardous Waste No.	Chemical abstracts No.	Substance
U194	107-10-8	n-Propylamine (I,T)
U083	78-87-5	Propylene dichloride
U387	52888-80-9	Prosulfocarb
U148	123-33-1	3,6-Pyridazinedione, 1,2-dihydro-
U196	110-86-1	Pyridine
U191	109-06-8	Pyridine, 2-methyl-
U237	66-75-1	2,4-(1H,3H)-Pyrimidinedione, 5-[bis (2-chloroethyl)amino]-
U164	56-04-2	4(1H)-Pyrimidinone, 2,3-dihydro-6-methyl-2-thioxo-
U180	930-55-2	Pyrrolidine, 1-nitroso-
U200	50-55-5	Reserpine
U201	108-46-3	Resorcinol
U202	[1]81-07-2	Saccharin, & salts
U203	94-59-7	Safrole
U204	7783-00-8	Selenious acid
U204	7783-00-8	Selenium dioxide
U205	7488-56-4	Selenium sulfide
U205	7488-56-4	Selenium sulfide SeS_2 (R,T)
U015	115-02-6	L-Serine, diazoacetate (ester)
See F027	93-72-1	Silvex (2,4,5-TP)
U206	18883-66-4	Streptozotocin
U103	77-78-1	Sulfuric acid, dimethyl ester
U189	1314-80-3	Sulfur phosphide (R)
See F027	93-76-5	2,4,5-T
U207	95-94-3	1,2,4,5-Tetrachlorobenzene
U208	630-20-6	1,1,1,2-Tetrachloroethane
U209	79-34-5	1,1,2,2-Tetrachloroethane
U210	127-18-4	Tetrachloroethylene
See F027	58-90-2	2,3,4,6-Tetrachlorophenol
U213	109-99-9	Tetrahydrofuran (I)
U214	563-68-8	Thallium(I) acetate
U215	6533-73-9	Thallium(I) carbonate
U216	7791-12-0	Thallium(I) chloride
U216	7791-12-0	Thallium chloride TlCl
U217	10102-45-1	Thallium(I) nitrate
U218	62-55-5	Thioacetamide
U410	59669-26-0	Thiodicarb
U153	74-93-1	Thiomethanol (I,T)
U244	137-26-8	Thioperoxydicarbonic diamide $[(H_2N)C(S)]_2S_2$, tetramethyl-
U409	23564-05-8	Thiophanate-methyl
U219	62-56-6	Thiourea
U244	137-26-8	Thiram
U220	108-88-3	Toluene
U221	25376-45-8	Toluenediamine
U223	26471-62-5	Toluene diisocyanate (R,T)
U328	95-53-4	o-Toluidine
U353	106-49-0	p-Toluidine
U222	636-21-5	o-Toluidine hydrochloride
U389	2303-17-5	Triallate
U011	61-82-5	1H-1,2,4-Triazol-3-amine
U408	118–79–6	2,4,6-Tribromophenol
Editor's Note: The entry for U408, 2,4,6-Tribromophenol, is effective November 4, 1998.		
U227	79-00-5	1,1,2-Trichloroethane
U228	79-01-6	Trichloroethylene
U121	75-69-4	Trichloromonofluoromethane
See F027	95-95-4	2,4,5-Trichlorophenol
See F027	88-06-2	2,4,6-Trichlorophenol
U404	121-44-8	Triethylamine
U234	99-35-4	1,3,5-Trinitrobenzene (R,T)
U182	123-63-7	1,3,5-Trioxane, 2,4,6-trimethyl-
U235	126-72-7	Tris(2,3-dibromopropyl) phosphate
U236	72-57-1	Trypan blue
U237	66-75-1	Uracil mustard
U176	759-73-9	Urea, N-ethyl-N-nitroso-
U177	684-93-5	Urea, N-methyl-N-nitroso-
U043	75-01-4	Vinyl chloride
U248	[1]81-81-2	Warfarin, & salts, when present at concentrations of 0.3% or less
U239	1330-20-7	Xylene (I)
U200	50-55-5	Yohimban-16-carboxylic acid, 11,17-dimethoxy-18-[(3,4,5-trimethoxybenzoyl)oxy]-, methyl ester, (3beta, 16beta,17alpha,18beta,20alpha)-
U249	1314-84-7	Zinc phosphide Zn_3P_2, when present at concentrations of 10% or less

[1]CAS Number given for parent compound only.

[Source Note: At 45 FR 78529 and 78541, November 25, 1980, revised section. At 46 FR 27473, May 20, 1981, revised (c), (d), (e), and (f). At 50 FR 665, January 4, 1985, revised introductory text; and at 50 FR 28744, July 15, 1985, revised introductory text. At 51 FR 10175, March 24, 1986, revised

CHAPTER 13

SAFE HANDLING OF PEROXIDIZABLE COMPOUNDS

Overview

This chapter describes the hazards associated with peroxide formation in chemical compounds, methods to detect peroxides, safe handling, use, and storage of peroxidizable compounds, and how to remove peroxide contamination from chemicals.

Table of Contents

This page intentionally left blank.

CHAPTER 13

SAFE HANDLING OF PEROXIDIZABLE COMPOUNDS

I. Introduction

Peroxides are chemical substances that contain the reactive peroxo unit (O_2^{2-}, or R-O-O-R). Several different organic chemicals are capable of forming peroxides. Peroxide formation in solvents and reagents has caused many laboratory accidents. Every worker must learn to recognize and safely handle peroxidizable compounds.

Peroxides form by the reaction of a peroxidizable compound with free radicals and molecular oxygen through a process called autooxidation or peroxidation. Peroxidizable compounds are insidious. Under normal storage conditions, they can form and accumulate peroxides, which may explode violently when subjected to thermal or mechanical shock. This can occur even when the containers appear to be tightly closed.

Peroxides in solution do not normally present thermal or shock hazards at concentrations up to about one percent (1%). You can safely dispose such solutions or treat them to remove peroxides. However, if you notice visible crystals in a peroxidizable liquid, or discoloration in a peroxidizable solid, peroxide concentrations greater than 1% are likely already present. Such chemicals are extremely dangerous, and might require special handling and disposal procedures. Do not handle chemicals that you suspect might have significant peroxide contamination. Leave the chemicals in place and contact EHS.

Figure 13.1 –

Following years of uninhibited peroxidation, this bottle of isopropyl ether contains a large chunk of explosive peroxide crystal. A high-hazard removal company took this bottle from the lab and detonated it with a blasting cap, visible on top of the tape. Photo courtesy of Reactive Hazards Reduction, Inc. (http://home.cyberave.com/~rhr/).

To prevent accidents caused by peroxidizable compounds, your laboratory safety procedures should emphasize:

- Recognition of chemical structures that may form peroxides (Appendix 13-A, Table I)
- Use of hazard identification labels
- Controlled inventory of peroxidizable compounds
- Use of peroxide detection tests and peroxide removal procedures
- Proper safety equipment and process procedures

II. Peroxidizable Compounds

Some of the specific compounds that form peroxides during storage are in Appendix 13-A, Table II, lists A, B and C. Compounds that form peroxides that may explode even without concentration are in List A. List B includes chemicals that are dangerous when concentrated by distillation or evaporation. List C includes substances for which peroxide formation can initiate explosive polymerization of monomeric forms.

Peroxide accumulation is a balance between the rate of peroxide formation and the rate of peroxide degradation for the particular substance in its environment. For example, certain highly reactive compounds, such as organometallics, accumulate peroxide at low temperatures because the peroxide degradation rate slows relative to the formation rate. By contrast, less reactive compounds such as hydrocarbons or ethers form fewer peroxides at low temperatures.

The more volatile the peroxidizable compound, the easier it is to concentrate the peroxides. Remember that pure compounds are more subject to peroxide accumulation, because impurities can inhibit peroxide formation or catalyze their slow decomposition.

III. Detection of Peroxides

You should routinely test ethers and other peroxide-forming solvents prior to distillation.

Peroxide Test Strips - Commercial test strips are available from Sigma-Aldrich Chemical Company (Quantofix® Test Sticks for Peroxides, catalog #37206). These strips are convenient to use; however, they do not have the universality or the sensitivity of the ferrous thiocyanate test, and have a limited shelf life.

Figure 13.2 – Quantofix® peroxide test sticks. These strips are colorimetric, and can detect peroxides at a range of 1-100 mg/L.

Ferrous Thiocyanate Test - Mix a fresh solution in the following proportions:

- 5 units of 1% ferrous ammonium sulfate [$(NH_4)_2Fe(SO_4)_2$] in water,
- 0.5 units of 1N sulfuric acid (H_2SO_4),
- 0.5 units of 0.1 molar ammonium thiocyanate (NH_4SCN); to make a 0.1M solution, dissolve 7.16 grams in 1L of distilled water.
- Decolorize with a trace of zinc dust if necessary.

Shake an equal quantity (six units) of the solvent to test with the above reagent. Appendix 13-A, Table III shows the relation between color change and peroxide content.

IV. Storage

Purchase quantities of peroxidizable compounds according to short-term needs. For instance, buy several 100ml cans of diethyl ether instead of one 1L can. Though this might be more expensive per volume, purchasing this way helps prevent expiration and product loss, and reduces the peroxidation potential. Purchases corresponding to use requirements help minimize exposure to air from multiple openings of the container. A tight cap on a nearly full bottle provides effective protection against peroxide formation.

You can keep peroxide accumulation low by storage in reasonably full containers (25% maximum headspace) with TIGHT caps that you replace promptly after use. Further protection is available when you flush the headspace over peroxidizable compounds with nitrogen (inert gas) before closing the container. Vinyl monomers (Appendix 13-A, Table I, List C) containing certain inhibitors are exceptions and require air in the headspace.

Oxidation inhibitors are useful, and recommended by several chemical manufacturers. Hydroquinone, alkyl phenols, aromatic amines, and other oxidation inhibitors are effective in preventing peroxide formation during storage of peroxidizable compounds. If you add an inhibitor, make sure it is compatible with use or purity requirements of the compounds. Follow a program of periodic testing and replenishing inhibitor levels during storage of peroxidizable materials.

As part of the Laboratory Safety Plan, your research group must maintain an inventory of peroxidizable compounds and review it twice a year. Discard those compounds that are out of date. The EHS Safety Labels Page (http://ehs.unc.edu/ih/lab/labels/) includes a printable label on which you can enter the date you received a peroxidizable material, date opened, and date to evaluate, treat, or discard.

Evaluate List A (Appendix 13-A, Table II) materials for peroxide content at least every three months after opening, followed by re-dating if safe, treating or discarding. Before disposing any List A materials, review the properties of the material (preferably with EHS consultation) to ensure safe disposal.

Do not store List B (Appendix 13-A, Table II) materials in your lab for longer than 12 months after opening, unless a suitable test shows they have not accumulated peroxide. If List B materials give

a significantly positive test (red by the ferrous thiocyanate test) you must retain them, treat to remove peroxide, repackage, show by test to be peroxide-free, and then re-date the label.

List C (Appendix 13-A, Table II) materials should not be stored for longer than 12 months, unless test results show them to be peroxide-free. Commercial vinyl monomers usually contain additives that inhibit peroxidation. Generally, you should store inhibited vinyl monomers under air rather than nitrogen or other inert atmosphere, because customary inhibitors are phenolic compounds, which require oxygen for their action. Isolation of uninhibited (and hazardous) vinyl monomer is usually not necessary, since most vinyl monomers can polymerize without removal of inhibitor by proper adjustment of initiator concentration.

Uninhibited List C materials can be a significant hazard. Do not store more than 500 grams of uninhibited monomers for longer than 24 hours. Smaller samples (less than 10 g) may be stored longer than 24 hours with discretion. Generally, storage of uninhibited vinyl monomers should be under nitrogen and below room temperatures. For storage in excess of 24 hours, add a suitable inhibitor, with its name and quantity on the label.

In addition, each container of peroxide-forming chemicals must have the following dates written on the label:

Date Received

Date First Opened

Date to be Discarded

You may use the label available from the EHS Safety Labels website to enter these dates. When you chemically remove peroxides, make a notation on the label to indicate the new disposal date.

Store peroxide-forming chemicals together in full, airtight, opaque containers at temperatures below 30^{o}C and in the dark. Use only refrigerators designated "explosion-proof".

V. Removal of Peroxides

You can easily remove peroxide impurities in water-insoluble solvents (ether, hydrocarbons) by shaking with the following solution:

60 g of ferrous sulfate
6 mL of concentrated sulfuric acid
110 mL of distilled water

Water is introduced by this method. Therefore, post-drying is required if you need a dry solvent. If you want to treat more than 500ml of solvent, an additional batch of peroxide-removal solution might be necessary. Test all solvents for peroxides after these procedures, to ensure adequate removal has occurred.

VI. Disposal

Immediately set aside and **DO NOT USE** any peroxide-forming chemicals that have formed crystals, precipitate, solids or an oily viscous layer, or any rusted, damaged, undated or suspicious containers of peroxide-forming chemicals. Call EHS at 962-5507 for assistance. Put up a sign near the container to warn other personnel not to touch it, until it can be removed from your lab by trained personnel.

Never attempt to force open a rusted or jammed cap, or a cap encrusted with scale, on a container of peroxide-forming chemicals. Never attempt to clean by scraping or rubbing glassware or other containers if an oily deposit or crusty residue is present.

Empty containers of ethers and other peroxide-formers must be triple-rinsed with water before discarding.

VII. Distillation and Evaporation Precautions

You should routinely test ethers and other peroxide-forming solvents prior to distillation or evaporation. One common error is distilling too close to dryness. Leave at least a 10% volume of liquid in the container to ensure safety.

VIII. Safety Audit

Perform a safety audit before starting each chemical experiment in the laboratory. This includes a review of possible hazards from the use of peroxidizable chemicals in the experiment. Peroxidation may have already occurred in one or more of the starting materials; it may occur during the process, or in the storage of the products. In every chemical process, consider the following factors relative to (a) the starting materials, (b) the process itself, and (c) the products:

- Structure - Are peroxidizable structures present or being formed?

- Process conditions - Will the process condition favor initiation of peroxidation and accumulation of peroxides?

- Storage - Will storage containers and conditioners reduce peroxide initiation and accumulation, and are all products properly inhibited and labeled?

If the audit indicates that peroxidation or peroxides are present, follow all the described procedures for handling, testing, and removal from this Chapter.

Peroxidation in a chemical process may not only be a serious hazard due to the explosion potential, but it also may affect the results of an experiment because of lower yield and unwanted impurities. Exercise the precautions outlined in this Chapter to ensure your safety and the success of your experiments.

APPENDIX 13-A

Table I

Peroxide-Forming Structures

Organic structures (in approximate order of decreasing hazard)

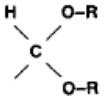
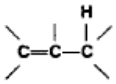
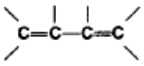
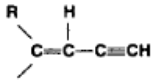
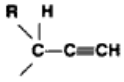
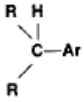
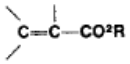
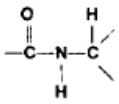
	Formula 1:	
1.		Ethers with alpha hydrogen atoms (isopropyl ether, ethyl ether, glyme)
	Formula 2:	
2.		Acetals with alpha hydrogen atoms (acetal, benzylacetal)
	Formula 3:	
3.		Olefins with allylic hydrogen atoms (butylene, cyclohexene)
	Formula 4:	
4.		Chloroolefins and fluoroolefins (tetrafluoroethylene)
	Formula 5:	
5.		Vinyl halides, esters, and ethers (vinylidene chloride, vinyl chloride, vinyl acetate)
	Formula 6:	
6.		Dienes (butadiene, chloroprene)
	Formula 7:	
7.		Vinylacetylenes with alpha hydrogen atoms (diacytylene, vinylacetylene)
	Formula 8:	
8.		Alkylacetylenes with alpha hydrogen atoms (3-methyl-1-butyne)
	Formula 9:	
9.		Alkylarenes that contain tertiary hydrogen atoms (isopropyl benzene)
	Formula 10:	
10.		Alkanes and cycloalkanes that contain tertiary hydrogen atoms (ethylcyclohexane)
	Formula 11:	
11.		Acrylates and methacrylites (methyl methacrlate, acrylonitrile)
	Formula 12:	
12.		Secondary alcohols (sec-butyl alcohol, diphenylmethanol)
	Formula 13:	
13.		Aldehydes (benzeldehyde)
	Formula 14:	
14.		Ketones with alpha hydrogen atoms (diisopropyl ketone, MEK)
	Formula 15:	
15.		Ureas, amides, lactams with hydrogen atom on carbon atom attached to nitrogen (N-ethylacetamide, N-isopropylacetamide)

Table II

Common Compounds That Form Peroxides During Storage

List A – Red Label (Three Months) Peroxide Hazard on Storage	List B – Yellow Label (Twelve Months) Peroxide Hazard on Concentration	List C – Yellow Label (Twelve Months) Hazard Due to Peroxide Initiation of Polymerization*
Isopropyl ether	Ethyl ether	Styrene
Divinyl acetylene	Tetrahydrofuran	Butadiene
Vinylidene chloride	Dioxane	Tetrafluoroethylene
Potassium metal	Acetal	Chlorotrifluoroethylene
Sodium amide	Methyl-i-butyl ketone	Vinyl acetylene
	Ethylene glycol dimethyl ether (glyme)	Vinyl acetate
		Vinyl chloride
	Vinyl ethers	Vinyl pyridine
	Dicyclopentadiene	Chlorobutadiene (chloroprene)
	Diacetylene	9,10-Dihydroanthracene
	Methyl acetylene	Indene
	Cumene	Dibenzocyclopentadiene
	Tetrahydronaphthalene	
	Cyclohexene	
	Methylcyclopentane	
	t-Butyl alcohol	

*When stored as a liquid, the peroxide-forming potential increases and certain of these monomers (especially butadiene, chloroprene, and tetrafluoroethylene) should then be considered as List A compounds.

Table III

The Ferrous Thiocyanate Test

Relation Between Color Change and Peroxide Content of a Compound

COLOR	Percent of Peroxide as H_2O_2
Barely discernible pink	0.001
Pink to cherry red	0.002
Red	0.008*
Deep red	0.04*

*A percentage of 0.008 or greater is considered hazardous.

This page intentionally left blank.

CHAPTER 14

SAFE HANDLING OF LABORATORY ANIMALS

Overview

This chapter covers the hazards associated with laboratory animal handling, mandatory and recommended control practices, the institutional structures that UNC-Chapel Hill has in place to assure animal welfare, and requirements for using hazardous agents in laboratory animals.

Table of Contents

This page intentionally left blank.

CHAPTER 14

SAFE HANDLING OF LABORATORY ANIMALS

I. Introduction

Personnel involved in the care and use of research animals work in an environment that presents many unique hazards related:

- to the equipment, materials and practices used in routine animal husbandry;
- directly or indirectly to animal contact; and
- to the techniques or materials (e.g., biohazardous substances) used during the course of animal experimentation.

Regardless of the source of hazard, you must take several basic measures to reduce the risk of personal exposure. These include understanding the hazards you are likely to encounter during animal care and use, using properly designed and maintained facilities and equipment to minimize exposures, wearing appropriate personal protective equipment (PPE), and demonstrating the technical proficiency necessary to accomplish experimental manipulations or animal care procedures in a safe and humane fashion.

II. Regulatory Structure for Animal Handling at UNC-Chapel Hill

In compliance with Federal regulations and institutional policies and procedures, several institutional entities address health and safety issues pertaining to vertebrate animal care and use. The **Office of Animal Care and Use (OACU)** oversees all campus use of lab animals, and provides required training courses for research animal handlers and caretakers. The **Institutional Animal Care and Use Committee (IACUC)** at UNC-Chapel Hill consists of selected UNC faculty and staff members and non-UNC affiliated community members. IACUC reviews all research protocols involving the use of vertebrate animals.

If you plan to use vertebrate animals in your work, IACUC requires successful completion of the online IACUC Orientation course, as well as additional courses for specific techniques or species. Refer to the IACUC Training and Compliance website (http://research.unc.edu/iacuc/training_overview.php) for more information. OACU, IACUC and the **Division of Laboratory Animal Medicine (DLAM)** work in collaboration with EHS and the **University Employees Occupational Health Clinic (UEOHC)** to ensure that appropriate expertise is involved in program guidance and the timely exploration and resolution of new problems.

As part of your mandatory orientation course, you are required to submit the Research Animal Handlers and Animal Caretakers Questionnaires to the UEOHC when completed. The UEOHC performs a risk assessment based upon relevant individual health history or concerns, the species

of animals you use, the extent of animal contact, and the experimental agents or procedures used in the animal studies. UEOHC also requires that you submit a completed Worker Registration Form (https://s4.its.unc.edu/LabRadWorker/) to EHS.

Based upon this assessment, the UEOHC might recommend additional vaccinations, modifications in the use of PPE, or possibly even work re-assignment to other types of duties. In addition, the UEOHC serves as a primary care provider for workplace injuries and accidents involving laboratory animals or laboratory animal facilities. Contact the UEOHC promptly at 966-9119 if you have health-related concerns due to working with laboratory animals.

III. Common Injuries Associated with Animal Husbandry and Care

Below are examples of recorded injuries and accidents to personnel working in laboratory animal facilities:

- Burn injuries due to working around cage washers, autoclaves, or other sources of hot water or live steam;
- Crush injuries or lacerations from moving caging equipment, operating sanitation equipment, or working with intractable large animals;
- Musculoskeletal injuries (strains, sprains or fractures) due to the use of improper technique in lifting or moving heavy equipment, or improper restraint and handling of large animals;
- Slip and fall injuries from walking on wet flooring;
- Hearing impairment resulting from work around loud machinery or animals;
- Visual impairment from direct trauma (equipment), splash exposure (detergents, disinfectants, or particulate matter) or exposure to ultraviolet light resulting in corneal damage;
- Skin irritation or contact dermatitis from exposure to chemicals used in cleaning, latex or talc allergy, or in experimental procedures in the animal facility;
- Respiratory exposure to irritating vapors, aerosols or particulates from working with disinfectants and bedding materials;
- Needlestick exposures from attempts to recap hypodermic needles, improper injection technique, or delay or improper disposal of used needles.

Personal awareness of hazardous conditions or factors in the environment is critical to avoiding these types of injuries. You should develop the habit of assessing the environments in which you work. Consult with EHS, DLAM, or OACU personnel about the identified hazards in particular work areas, and effective work practices proven to prevent incidents.

IV. Safety in DLAM Facilities

DLAM operates animal housing areas, procedure rooms, and support areas in several campus buildings. DLAM facility supervisors can provide a useful orientation about the available resources and use of their facilities. In each DLAM facility, Material Safety Data Sheets (MSDS) for all agents used in the animal care operation are available for review.

All DLAM facilities provide mandatory outerwear, which you must put on before entering animal housing areas or procedure rooms. Mandatory items include gloves, facemask, shoe coverings, and disposable lab coats (Figure 14.1). Most facilities also require a hair covering, and some require (and provide) disposable coveralls in place of the lab coats. This outerwear is primarily for the protection of the housed animals, but it also provides barrier protection to the wearer by preventing deposition of animal allergens onto the wearer's clothes or hair.

Additional equipment is necessary when personnel could be exposed to zoonotic pathogens or aggressive animal behavior (Section V). Sturdy, closed-toe shoes are strongly encouraged in DLAM facilities, and are required in laboratory environments. Based on the types of research, animals, or exposure potentials, other animal housing areas might require face shields, splash goggles, respirators, fully encapsulating suits, or other equipment. Obey all PPE postings in DLAM and satellite animal facilities. Consult with DLAM facility supervisors to determine if there are entry restrictions to particular rooms due to animal infections such as pinworms. Obey all room order postings, which help prevent personnel who have been in "dirty" areas of the facility from entering "clean" animal rooms.

Figure 14-1:

Example of the minimum level of protective equipment required in most DLAM facilities:

- ✓ Hair covering
- ✓ Facemask
- ✓ Disposable lab coat
- ✓ Gloves
- ✓ Shoe coverings

V. Animal Related Hazards

A. Bites and Scratches

Bites and scratches represent a significant portion of laboratory animal associated hazards. These injuries are readily preventable through proper animal handling technique and the use of proper PPE. You should always wear a long sleeve lab coat or use other sleeve protection (e.g., Tyvek® Sleeves) when handling rabbits or larger animals to avoid scratch injury, and in some cases special gloves (e.g., stainless steel mesh or heavy leather gauntlets) to prevent bites. Prior to animal handling, eliminate unusual noises, defective equipment, slippery surfaces and conditions conducive to entrapment or distraction of the animal handler. Inappropriate animal handling may induce discomfort, pain, and distress in the animal. This can provoke a fractious response, introduce undesirable experimental variables, and provide an opportunity for the animal to inflict injury upon the handler. OACU Training and Compliance personnel can provide supervised instruction for those undertaking new animal handling procedures in addition to their regularly scheduled training courses.

Special attention and training is necessary if you are involved in the handling and restraint of large animals, especially non-human primates. In addition to posing a bite and scratch hazard, non-human primates can be challenging and difficult to handle safely because of their remarkable strength, dexterity, intelligence, and tenacity. Non-human primates have caused injuries when they have grabbed and pulled neckties, loose-fitting lab coats, or long hair of unsuspecting personnel. When compatible with the experimental conditions of animal use and/or the clinical condition of the animal, consider chemical immobilization of many non-human primate species to enable safe animal handling and to reduce the risk of injury.

DLAM posts specific PPE requirements in the housing areas for working with macaque monkeys. These requirements include the DLAM outerwear mentioned earlier, plus safety (splash) goggles; a face shield is also required for close contact with conscious animals. During the quarantine period, before the monkeys are known to be free from tuberculosis, you must use a NIOSH certified, fitted N95 respirator at a minimum. Refer to Chapter 5 for more details about respiratory protection.

Animal bites continue to be a common occurrence among research personnel, and you should take them seriously even when there is little tissue damage. If a laboratory animal bites you, seek prompt medical review of the wound and tetanus immunization status by UEOHC. Complete accident form, Form 19, and supervisor form. If warranted, the animal will receive a veterinary evaluation.

Animal bites also prompt a veterinary review of the animal handling circumstances to ensure that you used proper animal handling techniques. A specific, detailed protocol is in effect for bites, scratches, or mucous membrane exposures involving some monkey species due to the Herpes B virus, an agent that can cause fatal infection. Other specific viral agents that can be involved as wound contaminants include rabies virus (all mammals), Hantavirus

(rodents), lymphocytic choriomeningitis virus (rodents) and orf virus (sheep and goats). Numerous bacterial agents and at least one fungal agent have also been recorded as wound contaminants resulting in serious localized or systemic infections.

B. Animal Associated Allergy

An estimated 10 to 30 percent of individuals who work with laboratory animals may eventually develop allergy to laboratory animals manifested by reddened, itchy eyes, nasal symptoms, and skin rashes. Individuals with pre-existing allergy to other agents have a predisposition to develop an additional sensitivity to animal allergens. Asthma, characterized by cough, wheezing, chest tightness and shortness of breath, develops as a further complication in approximately ten percent (10%) of individuals with animal-associated allergy. Anaphylaxis, a generalized allergic reaction presenting as diffuse itching, hives, and facial and oral swelling, can develop. Anaphylaxis can produce life-threatening consequences from laryngeal edema, airway obstruction, and shock in certain individuals with massive allergen exposure, often through saliva.

Although rodents, rabbits, and cats are most often incriminated in cases of laboratory animal-associated allergy, other mammals and birds also can be involved. Work practices that minimize contact with animal proteins reduce risk for development of allergy. For example, various levels of PPE are available for personnel working with laboratory animals to reduce exposure to allergen. You should wear long sleeve outer garments (e.g., lab coat or disposable coverall) to reduce the exposure of skin to urine, dander, and other allergens. Filtering facepiece respirators may help reduce the exposure of the respiratory tract to allergen; however, personnel with known inhalant allergy should consider the use of a full-face respirator or a powered-air purifying respirator (PAPR), both of which provide ocular as well as respiratory protection.

Allergy history is an important element of the health review conducted by UEOHC for personnel involved with laboratory animal care and use. If you have or suspect that you are developing an animal-associated allergy, consult with the UEOHC to determine the optimal allergy management strategy.

C. Zoonoses

Zoonoses are diseases that are transmissible from animals to humans. Laboratory animal species potentially harbor numerous zoonotic agents, including viruses, bacteria, fungi, protozoa and internal and external parasites, but the reported cases of zoonotic transmission to individuals with laboratory animal contact have been infrequent and sporadic. However, many zoonotic disease episodes likely have remained unreported, and those reported involved serious disease and even fatalities. For these reasons, individuals with laboratory animal contact should be aware of these diseases and take appropriate precautionary measures. The likelihood of encountering zoonoses varies with the species of laboratory animal, its source, and history of veterinary care. Consult with the UEOHC staff if you become ill and/or feel you have contracted a disease from a laboratory animal. Below are examples of major zoonoses.

1. **Rodents and Rabbits:** The modern conditions of production and care for most laboratory rodents and rabbits have led to the eradication of zoonoses in most of these species. Although contamination of these animals through environmental sources, contact with wild rodents or other infected animals, or through tumors, cell lines, or other biologics used experimentally happens, it is rare. In most circumstances, only wild-caught, laboratory maintained rodents are a high risk for the transmission of zoonotic diseases. Be familiar with several zoonoses associated with rodents and rabbits.

   Two serious systemic viral zoonoses have been associated with the use of laboratory rodents. Lymphocytic choriomeningitis virus causes a flu-like disease with neurological complications, and Hantavirus infection produces a disease marked by renal failure and respiratory complications. Other than the bite-associated bacterial infections from rodents (e.g., rat-bite fever) there are few bacterial zoonoses in these species. The rabbit is a potential source for human bacterial pathogens, especially those that cause human diarrheal disease such as salmonellosis.

   Rodents and rabbits are also a source for human ringworm infection, usually recognized as a reddened, annular lesion of the skin of the affected individual. A similar focal dermatitis results from infestation with rabbit fur mite and, rarely, other mite species of rodents. The dwarf tapeworm infestation of rodents also is capable of infecting man. The complete absence or extremely low incidence of these agents in laboratory animal populations has obviated our need to adopt intensive health surveillance measures for individuals who work with these species. However, all personnel should use appropriate PPE when working with these species and report unusual illnesses or conditions possibly related to animal contact. The minimal personnel protective equipment recommended for working with small rodents includes particle facemask, latex (or nitrile or other) disposable gloves, safety glasses and a clean lab coat.

2. **Dogs and Cats:** Source control and sound programs of veterinary care at the vendors' facilities and at UNC-CH ensure the eradication of most zoonotic infections in these animal species prior to their experimental utilization. Due to financial limitations, it is not practical to rule out all potential zoonoses. In some cases, subclinical infections may go undetected and untreated, posing a risk for the personnel who work with these animals. These can include intestinal bacterial infections (salmonellosis, yersiniosis, and campylobacterosis), systemic bacterial infections (brucellosis, cat-scratch fever, leptospirosis and Q-fever) and intestinal parasitic infections (giardiasis and toxoplasmosis). The dog and cat can also harbor dermatophytes that cause human ringworm and other external parasites capable of infesting humans.

   Proper use of PPE can minimize exposure to these zoonotic hazards, and should include long pants (or similar leg protection), lab coat or coverall, facemask, safety glasses and disposable gloves. If you work with laboratory cats not specifically bred

for research purposes, consider participation in the rabies vaccination program available through UEOHC**.**

3. **Non-human Primates:** The list of zoonotic diseases in non-human primates is long and includes numerous viral (e.g., Herpes B virus, hepatitis A and B, measles and SIV), bacterial (e.g., tuberculosis, salmonellosis, and shigellosis) and protozoal (e.g., giardiasis and amebiasis) diseases, and there are many documented cases of zoonotic transmission. Consequently, non-human primates must undergo an extensive quarantine period to preclude the presence of many of these zoonoses before experimental work with these animals can proceed. Even after release from quarantine, rigorous disease surveillance continues for some agents such as tuberculosis. Personnel must participate in periodic tuberculin testing through UEOHC if they have any non-human primate contact. Personnel who work with macaques must undergo special training concerning the prevention and management of potential exposure to B virus, an agent that has caused many fatalities among laboratory personnel.

   University policies expect strict adherence in the use of PPE of all personnel with non-human primate contact. Personnel handling non-macaque monkey species must wear a lab coat (or equivalent), particle face mask, eye protection, disposable gloves and shoe covers when entering housing areas. The more stringent PPE requirements for personnel using macaque monkeys are listed above under the section on **Bites and Scratches**.

4. **Birds and Livestock:** Q fever has proven to be an important zoonosis associated with livestock in laboratory animal facilities. Although all ruminants and many other animals are potential carriers, infection of laboratory personnel has most often been associated with pregnant sheep that copiously shed the organisms. The disease causes a flu-like illness, which can progress to a serious systemic infection with heart involvement. Orf, a pox viral disease of sheep and goats, can also infect humans through contaminated wounds producing firm, nodular lesions. Livestock and birds can harbor bacterial zoonoses causing diarrhea in humans. Birds also can shed the agent psittacosis (*Chlamydia psittaci*), a serious respiratory and systemic disease of humans. Proper use of PPE is essential to minimize exposure to these potential zoonotic hazards. Use respiratory protection compatible with that described for the prevention of tuberculosis when working with pregnant ruminants (Q fever) or birds harboring *Chlamydia psittaci*.

   A more recent, emerging concern is avian influenza virus, with H5:N1 virus receiving the most attention. H5:N1 virus is an influenza A virus subtype that occurs mainly in poultry and wild birds, is highly contagious among birds, and can be deadly to them. H5:N1 does not usually infect people, but infections with these viruses have occurred in humans. Most of these cases have not resulted from person-to-person contact, but instead resulted from people having direct or close contact with H5:N1-infected poultry or H5:N1-contaminated surfaces. Therefore, proper handling, sanitation, and use of PPE can prevent transmission of virus from bird to human.

VI. Use of Hazardous Agents in Animal Experimentation

Many studies involve the use of hazardous agents in laboratory animals. Often the use of a hazardous substance is incidental to the research, whereas in other circumstances it is an integral component of the study intended to produce a particular experimental effect. Examples of the former include inhalant anesthetic agents (e.g., ether, sevoflurane, halothane or isoflurane), analgesic agents (e.g. secobarbital and other controlled substances, acetaminophen), and adjuvants (particularly Complete Freund's adjuvant, FCA). Examples of the latter include carcinogens, teratogens, mutagens, toxicants, microbial pathogens, radionuclides, and organisms modified through recombinant DNA techniques. EHS representatives on the IACUC review team note the uses of hazardous agents in animals during protocol review, and verify or establish the conditions under which one can use the hazardous materials safely. In some cases, it may be necessary for the institution to engage outside expert consultants and work with the investigator to develop a more elaborate safety protocol and ensure appropriate personnel training before the animal studies can proceed.

Depending on the type of hazardous agent used in animal experimentation, you might have to include the following forms in your animal use applications. These forms are on the OACU/IACUC Forms website (http://research.unc.edu/iacuc/forms.php). To expedite review and approval of hazardous agent use, send copies of these forms directly to EHS (CB #1650) when completed.

A. Use of Chemical Hazards in Laboratory Animals Form

Use this form if you will use hazardous chemical substances in live, vertebrate animals. You do not need to fill out this form for substances that you use on animal tissues post-mortem. Consult product labels, MSDSs, or hazardous chemical databases to determine whether your experimental agent requires completion of this form according to the criteria below, or contact EHS for a determination.

In general, the following chemical substances will require the completion of the Use of Chemical Hazards in Laboratory Animals form:

- Any substance that meets the definition of a toxic substance from the OSHA Hazard Communication Standard, meaning that it possesses any of these three characteristics:
  - oral LD50 <500 mg/kg in albino rats;
  - skin absorption LD50 <200 mg/kg in albino rabbits; or
  - inhalation LC50 <2000 parts per million or 20 mg/L in albino rats.
- All substances that are known or suspected human carcinogens. This includes formaldehyde-based fixatives used for animal tissue perfusion while the animal is still alive.
- All inhalation anesthetic agents (e.g. isoflurane, sevoflurane, methoxyflurane, halothane,

- nitrous oxide, ether).

These forms are not required for agents used strictly for animal analgesia, or for injectable anesthetic agents (e.g. ketamine, xylazine, tribromoethanol) used for anesthesia. However, if you use these substances as experimental test agents, rather than for analgesia/anesthesia, and they are either toxic or carcinogenic as defined above, then you must complete a form. Many analgesics and anesthetics are also controlled substances; refer to Chapter 9: Controlled Substances for more information on the safe use of controlled substances.

B. Use of Biohazardous Materials in Laboratory Animals Form

Use this form if you will work with any of the following materials in live, vertebrate animals:

- Human blood or body fluids, or other potentially infectious materials, including cell lines and neoplastic tissues.
- Microbial agents capable of causing human illness or infection, including various species of bacteria, viruses, protozoa, rickettsia, etc. Note: If you are using purified, isolated microbial components such as exotoxins or endotoxins (LPS), rather than the entire microbe, the Use of Chemical Hazards in Laboratory Animals form would be more appropriate.
- Microbial vectors (such as phages, adenoviruses) used for delivery of genetic materials.

Work with viral vectors and recombinant DNA, gene transfer experiments, and transgenic animals require the approval of the **Institutional Biosafety Committee (IBC)**. To expedite IBC review, send the appropriate form(s) to EHS before the end of each month, so the IBC can review them at its meeting at the beginning of the month. Refer to **Chapter 2: Laboratory Safety Plan** for more information about the following forms.

- For recombinant DNA, viral vectors, gene transfer experiments, and transgenic animals created within your lab, use the Schedule G: Recombinant DNA form at http://ehs.unc.edu/ih/lab/docs/ScheduleG.doc.
- For transgenic animals created in other labs or institutions, use the Schedule H: Use of Transgenic Animals or Plants form at http://ehs.unc.edu/ih/lab/docs/ScheduleH.doc.

C. Use of Radioactive Materials in Laboratory Animals Form

Complete this form if you will use radionuclides *in vivo*. This includes short-lived isotopes such as $^{99}Tc_m$ with a radioactive half-life ($T_{1/2}$) of 6 hours, as well as longer-lived isotopes (e.g. ^{3}H, ^{32}P, ^{35}S, ^{135}I). You do not need to complete this form in order to use sealed source radiation-producing equipment on animals, such as X-ray machines or ^{137}Cs γ-irradiators.

For additional requirements for using radionuclides or radiation-producing equipment, consult the EHS Radiation Protection Manual (http://ehs.unc.edu/manuals/index.shtml).

This page intentionally left blank.

CHAPTER 15

SAFE HANDLING OF BIOLOGICAL HAZARDS

Overview

This chapter is an overview of the requirements for working with biological hazards. You can find more detailed information about working with biological hazards in the UNC Exposure Control Plan (Bloodborne Pathogens), the UNC Biological Safety Manual and on our website http://ehs.unc.edu/ih/biological/.

Table of Contents

This page intentionally left blank.

CHAPTER 15

SAFE HANDLING OF BIOLOGICAL HAZARDS

I. Introduction

Biohazardous agents are infectious microorganisms, or their toxins, which cause or may cause human disease. This chapter will cover some basic information about biohazardous agents, including those found in human blood and other potentially infectious materials (OPIM). For more information on this topic, consult the UNC Biological Safety Manual, located at http://ehs.unc.edu/manuals/biological/. Contact EHS at 962-5507 if you wish to receive a printed copy of the Biological Safety Manual.

II. Laboratory Safety Plan: Schedule F

The Principal Investigator is responsible for registering the human and animal pathogens used in his/her research and teaching laboratories with EHS. This occurs by completing the "Schedule F: Biological Hazards" section in the Laboratory Safety Plan (http://ehs.unc.edu/ih/lab/docs/ScheduleF.doc) and submitting a copy to EHS. Refer to Chapter 2 for further requirements when submitting a new or updated Laboratory Safety Plan. The Principal Investigator is responsible for assessing the risk for the agents used in the laboratory and for selecting appropriate safeguards. Use the Laboratory Safety Plan to describe the procedures used to ensure the safe handling of biohazardous agents, an assessment of the potential risks, the need for medical surveillance, and procedures for handling accidental spills and waste disposal methods. Consult the UNC Biological Safety Manual for assistance in the risk assessment process; EHS is also available to assist in selecting appropriate safeguards.

III. Use of Human Blood and Other Potentially Infectious Materials

A. Regulation. The OSHA Bloodborne Pathogens Standard (29 CFR Part 1910.1030) requires that each employer develop a written **Exposure Control Plan** designed to eliminate or minimize exposures to employees. EHS makes the University's Exposure Control Plan available to each employee identified as having occupational exposures to human blood or other potentially infectious materials and upon request. You can also find it online at http://ehs.unc.edu/ih/biological/bbp.shtml. Compliance with the Exposure Control Plan is a condition of employment for all employees with occupational exposures.

B. Occupational Exposure. This is defined as reasonably anticipated skin, eye, mucous membrane, or parenteral contact with human blood or other potentially infectious materials (OPIM, defined below) that may result from the performance of an employee's duties. OPIM includes:

1) The following human body fluids: semen, vaginal secretions, cerebrospinal fluid, pleural fluid, pericardial fluid, peritoneal fluid, amniotic fluid, saliva in dental procedures, or any body fluid visibly contaminated with blood. Under circumstances in which

differentiation between body fluid types is difficult or impossible, all body fluids should be considered potentially infectious materials;

2) Any unfixed tissue or organ from a human, living or dead; and

3) Human cell lines

4) Cell or tissue cultures containing Human Immunodeficiency Virus (HIV), organ cultures, and HIV- or Hepatitis B Virus (HBV)-containing culture medium or other solutions;

5) blood, organs, or other tissues from experimental animals infected with HIV or HBV.

C. Hepatitis B Vaccination. For employees who have known or reasonably-anticipated occupational exposure to human blood or OPIM, the Hepatitis B vaccination must be made available after the employee has received information and training regarding the vaccine, and within 10 working days of initial assignment. Employees are exempt if they previously received the complete hepatitis B vaccination series, antibody testing has revealed that the employee is immune, the vaccine is contraindicated for medical reasons or the employee has signed a declination form. You can obtain more information about the vaccination in the UNC Exposure Control Plan or from the University Employee Occupational Health Clinic (UEOHC) at 966-9119.

IV. Information for Researchers Using Recombinant DNA

University policy requires Principal Investigators comply with the National Institutes of Health "Guidelines for Research involving Recombinant DNA Molecules", regardless of the funding source supporting that research. Follow this link, http://www4.od.nih.gov/oba/rac/guidelines_02/NIH_Guidelines_Apr_02.htm, for these Guidelines.

Principal Investigators conducting experiments involving rDNA that are not exempt from the Guidelines, including creation of transgenic animals or plants, must submit a Schedule G (http://ehs.unc.edu/ih/lab/docs/ScheduleG.doc) to the UNC Institutional Biosafety Committee (IBC) for approval. Use of transgenic animals requires submission of a Schedule H (http://ehs.unc.edu/ih/lab/docs/ScheduleH.doc) for IBC approval. Information about which experiments require approval and form submission instructions can be found on the EHS website (http://ehs.unc.edu/ih/biological/dna.shtml).

V. Signage for Laboratories Using Biological Hazards

Laboratories in which employees handle biosafety level 2 (including laboratories handling human blood, OPIM and human cell lines) or biosafety level 3 agents must be posted with the Universal Biohazard Sign, the assigned biosafety level and the Principal Investigator's name and contact information. EHS provides this signage for laboratory doors.

Figure 15.1 – Example of the Universal Biohazard Symbol.
This version is available on the EHS Safety Labels Page
(http://ehs.unc.edu/ih/lab/labels/docs/biohazard.pdf)

VI. Training

A. **Bloodborne Pathogen Training.** This training is required annually for all employees with occupational exposures to human blood, OPIM, or human cell lines. The self-study training module for bloodborne pathogens is the primary method of initial and annual training, and is located at http://ehs.unc.edu/training/self_study/bbp/index.shtml. EHS can also conduct instructor-led training on bloodborne pathogens. Contact EHS at 962-5507 for information and scheduling.

B. **Biosafety Level 2 Training.** This training is highly recommended for employees working with agents that require biosafety level 2 practices and containment. This is an instructor-led course and the schedule for this training is available at http://ehs.unc.edu/training/schedule.shtml#bio.

VII. Exposure Reporting

Employees that have had an incident that results in occupational exposure to biohazardous agents (e.g., needlestick or cut with contaminated object, splash to mucous membranes, contact with non-intact skin, large spill, etc) must follow appropriate exposure procedures. Wash exposed skin and sites of parenteral exposure thoroughly with soap and water. Flush eyes with water at an eyewash station for at least 15 minutes. If exposed, flush the mouth with clean water.

Employees are to report all incidents to the UEOHC. To ensure prompt attention, University employees are to call:

- During daytime hours (8:30 a.m.-4:30 p.m., M-F): Call the UEOHC, 966-9119, for consultation and assessment.

- After-hours: Call Healthlink, 966-7890, for consultation and assessment.

The employee's supervisor must complete a Form 19, "Employer's Report of Injury to Employee" (http://www.comp.state.nc.us/ncic/pages/form19.pdf) directly following the incident. EHS will investigate the circumstances of the exposure incident, and make a report with recommendations to avoid further exposure incidents. As with all injuries, the employee must complete an Employee Accident Report Form, and the supervisor must complete a Supervisor Accident Report Form. Both are on the EHS Forms page: http://ehs.unc.edu/ehs/forms.shtml.

VIII. Infectious Waste Disposal.

North Carolina Medical Waste Management Regulations define "regulated medical waste" as:

(1) blood and body fluids in individual containers in volumes greater than 20 mL, which must be treated by incineration or sanitary sewage;
(2) microbiological waste, which must be treated by incineration, steam sterilization or chemically; and,
(3) pathological waste, which must be incinerated.

For laboratories that have access to autoclaves, steam sterilize (autoclave) blood samples before disposal. If this is not feasible, the NC Medical Waste Management Regulations permit the disposal of blood down the sanitary sewer after treating with a 10% solution of sodium hypochlorite (bleach). When using this option, take care to avoid splashing, and flush the drains with generous amounts of water.

Microbiological wastes are cultures and stocks of infectious agents, including HIV, and items contaminated with these cultures. Microbiological waste must be autoclaved prior to disposal. Refer to the UNC Biological Safety Manual (Chapter 15, Appendix 15-A) for detailed autoclaving and disposal procedures, or Chapter 12 of this Laboratory Safety Manual for basic procedures.

Pathological waste includes human tissues or body parts. Pathological waste either is autoclaved (small tissues only) or incinerated.

CHAPTER 16

BIOLOGICAL SAFETY CABINETS

Overview

This chapter describes the containment principles of biological safety cabinets (BSCs), the various classes and types of BSCs and their uses, how to select the correct type of BSC for your needs, how to get approval for installation of a BSC, and their installation and certification requirements.

Table of Contents

This page intentionally left blank.

CHAPTER 16

BIOLOGICAL SAFETY CABINETS

I. Introduction

Laboratory techniques may produce aerosols, which can contain hazardous research materials, such as infectious agents that laboratory workers could inhale. Biological safety cabinets (BSC) are one type of primary barrier to contain potentially infectious research materials in order to prevent exposure of laboratory personnel and contamination of the general environment. Some biological safety cabinets also provide a clean work environment to protect cell cultures or sterile apparatus. Discussion of another type of primary barrier, the laboratory hood, is in Chapter 17.

II. Principles of Containment

Containment of hazardous aerosols in biological safety cabinets occurs by air barriers, physical barriers, and high-efficiency particulate air (HEPA) filtration. Air barriers provide containment by providing directional airflow from the laboratory, past the researcher, and into the cabinet via the work opening. Hazardous aerosols generated during experimental procedures inside the cabinet become captured and carried by the flow of air, and trap within HEPA filters. Some BSCs provide protection for experimental procedures by providing uniform, unidirectional HEPA filtered air, referred to as laminar airflow, continuously flowing over the work area. Laminar airflow minimizes turbulence inside the cabinet, allowing for immediate removal of contaminants generated by the procedures. Disruption of the airflow patterns in the cabinet can compromise the integrity of the containment provided by air barriers, and objects within the cabinet can disrupt airflow patterns. Therefore, air barriers provide only partial containment, and you should not use them solely to contain highly toxic or infectious materials.

Physical barriers are impervious surfaces such as metal sides, glass panels, rubber gloves and gaskets, which physically separate the experimental procedures from the researcher. Biological safety cabinets incorporating physical barriers (e.g. Class III BSCs), and not relying on air barriers, can be used for higher risk agents since compromised containment is less likely.

HEPA filters have a filtration efficiency of 99.97% for thermally generated monodisperse dioctylphthalate (DOP) 0.3 μm diameter particles. Because of their high efficiency, HEPA filters in biological safety cabinets can remove virtually all particulates, including hazardous microbiological and chemical aerosols, in the air stream passing through the filter. All biological safety cabinets have exhaust filters that remove contaminants as air discharges from the cabinet. Some types (discussed below) also have supply HEPA filters to provide clean air to the work area. HEPA filters are not effective in capturing chemical vapors, and are not considered protective against gases or vapor-phase solids/liquids.

III. Classification of Biological Safety Cabinets

There are three classes of biological safety cabinets, designated as Class I, Class II, and Class III. Class I and II cabinets have a protective air barrier across the work opening that separates the laboratory researcher from the work area. Class II cabinets also provide a HEPA filtered, clean work area to protect the experiment from room contamination. There are several variations of Class II cabinets, described below. Class III cabinets have a physical barrier between the operator and the work area. Arm length rubber gloves sealed to glove ports on the cabinet provide the operator with access to the work area. The distinctive features of the three classes of cabinets follow. Refer to Table 16-1 for a comparison of the characteristics and applications for the types of BSCs described below, or visit http://www.cdc.gov/od/ohs/biosfty/primary_containment_for_biohazards.pdf.

A. Class I Cabinets (Figure 16-1)

- The Class I cabinet is ventilated for personnel and environmental protection, with an inward airflow away from the operator. It is similar in air movement to a laboratory hood.
- The minimum average face velocity through the work opening is 75 feet per minute (fpm).
- The cabinet exhausts air through a HEPA filter to prevent discharge of most particles to the outside atmosphere.
- This cabinet is suitable for work with low and moderate risk biological agents, where no product protection is required.
- Because of the popularity of Class II cabinets and the product protection they provide, use of Class I cabinets has declined.

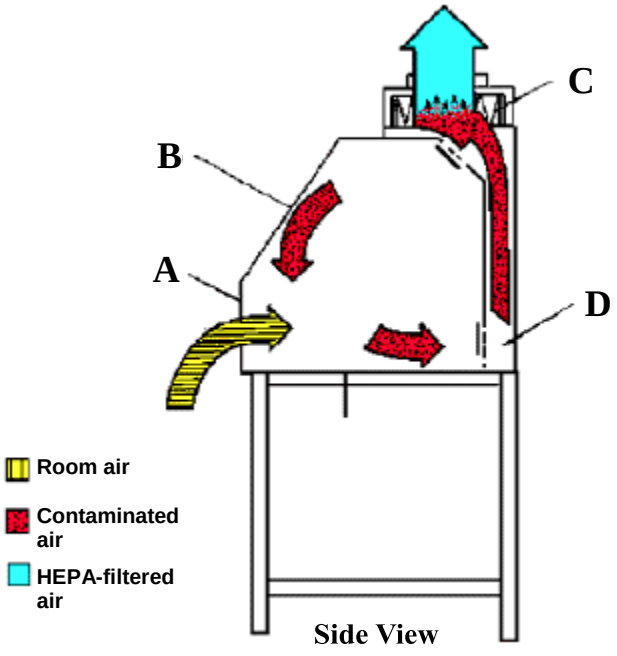


Figure 16.1 –Class I Biological Safety cabinet
A. front opening; **B.** sash; **C.** exhaust HEPA; **D.** exhaust plenum

B. Class II Cabinets

- The Class II cabinet ventilates air for personnel, product, and environmental protection, and has an open front and inward airflow for personnel protection.
- Product protection comes from HEPA filtered laminar airflow from a diffuser located above the work area. The downflow air splits at the work surface, and exits the work area through grilles located at both the rear and front of the work surface, respectively.
- The cabinet has HEPA filtered exhausted air for environmental protection.
- Types of Class II biological safety cabinets are designated A1, A2, B1, and B2,.

1. Class II, Type A1 (Formerly Type A) Cabinets (Figure 16-2)

- The work opening is 8 to 10 inches (20-25 cm) high.
- The type A cabinet may have a fixed work opening, a sliding sash, or a hinged window.
- A fan located within the unit provides the intake, recirculated supply air, and the exhaust air.
- The BSC fan maintains a minimum average inflow velocity of 75 fpm through the work area access opening.
- Approximately 70% of the cabinet air recirculates through a HEPA filter into the work area from a common plenum, while approximately 30% of the air enters through the front opening and an amount equal to the inflow is exhausted from the cabinet through a HEPA filter.
- The cabinet may exhaust HEPA filtered air back into the laboratory or exhaust to the environment through an exhaust canopy.

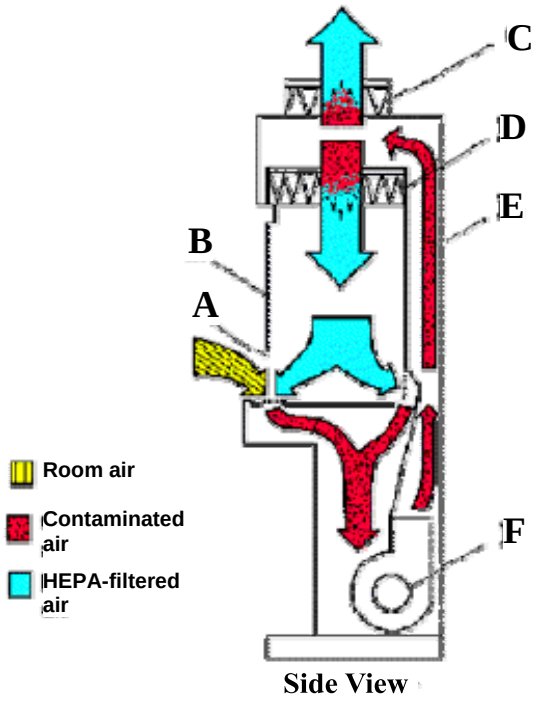


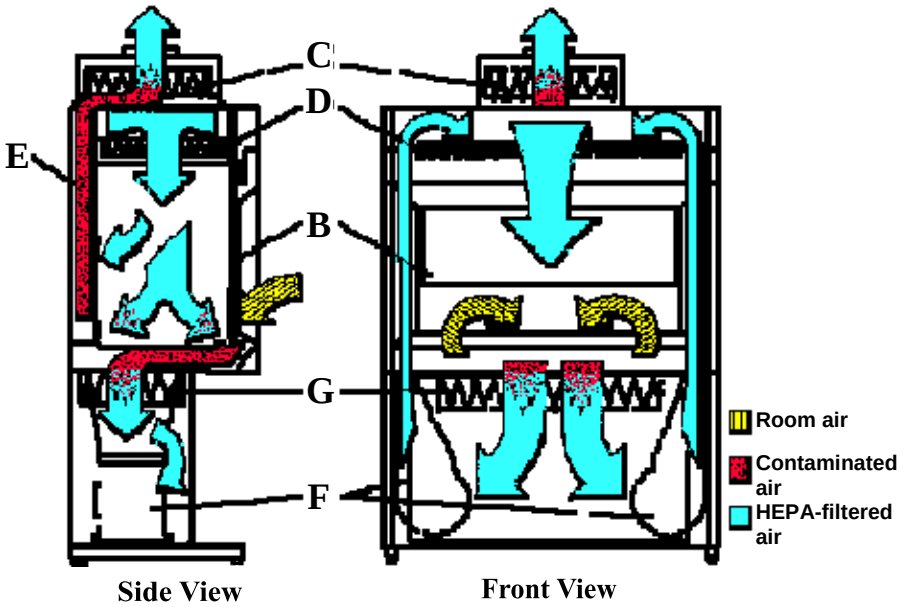
Figure 16.2 –Class II, Type A1 cabinet
A. front opening; **B.** sash; **C.** exhaust HEPA filter; **D.** rear plenum; **E.** supply HEPA filter; **F.** blower

- The cabinets may have positive pressure contaminated plenums. Contaminated plenums under positive pressure must be gas tight.
- Type A1 cabinets are suitable for work with low to moderate risk biological agents in the absence of volatile toxic chemicals and volatile radionuclides.

2. Class II, Type B1 Cabinets (Figure 16-3)

- The work opening is 8 inches (20 cm) high, with a sliding sash that one can raise for introduction of equipment into the cabinet.
- Type B1 cabinets have a minimum average inflow velocity of 100 fpm through the work area access opening.
- The HEPA filtered downflow air is composed largely of uncontaminated recirculated inflow air.
- Supply fans located in the base of the cabinet, below the work surface, draw air through a grille at the front of the work surface, and supply HEPA filters located directly below the work surface. The fans then force the filtered air through plenums in the sides or the rear of the cabinet and recirculate the air through a diffuser above the work surface. Some cabinets have a secondary supply filter located above the work surface.
- Approximately 70% of the contaminated downflow air is exhausted through a HEPA filter and a dedicated duct and then discharged outside the building.
- The remote exhaust fan is generally located on the roof of the building.
- All biologically contaminated ducts and plenums are under negative pressure or surrounded by negative pressure ducts and plenums. The type B1 cabinet is suitable for work with low to moderate risk biological agents. They are also useful for

Figure 16.3 –Class II, Type B1 cabinet
A. front opening; **B.** sash; **C.** exhaust HEPA filter; **D.** supply HEPA filter;
E. negative pressure exhaust plenum; **F.** blower; **G.** additional HEPA filter for air supply;
Note: The cabinet exhaust needs to be connected to the building exhaust.



biological materials treated with minute quantities of toxic chemicals and trace amounts of radionuclides.

3. Class II, Type B2 ("Total Exhaust") Cabinets (Figure 16-4)

- The type B2 cabinet has a sliding sash with an 8-inch (20 cm) opening.
- The type B2 cabinet maintains a minimum average inflow velocity of 100 fpm through the work area access opening.
- No air recirculates within the cabinet.
- A supply fan draws air from the laboratory and forces it through a supply HEPA filter located over the work area.
- A remote exhaust fan, generally located on the roof, pulls all inflow air and supply air through a HEPA filter, and discharges it outside the building. As much as 1200 cubic feet per minute may be exhausted from a 6 ft. cabinet.
- The cabinet has all contaminated ducts and plenums under negative pressure or surrounded by directly exhausted (not recirculated through work area) negative pressure ducts and plenums. .
- Type B2 cabinets are suitable for work with low to moderate risk biological agents. They are also useful for biological materials treated with toxic chemicals and radionuclides.

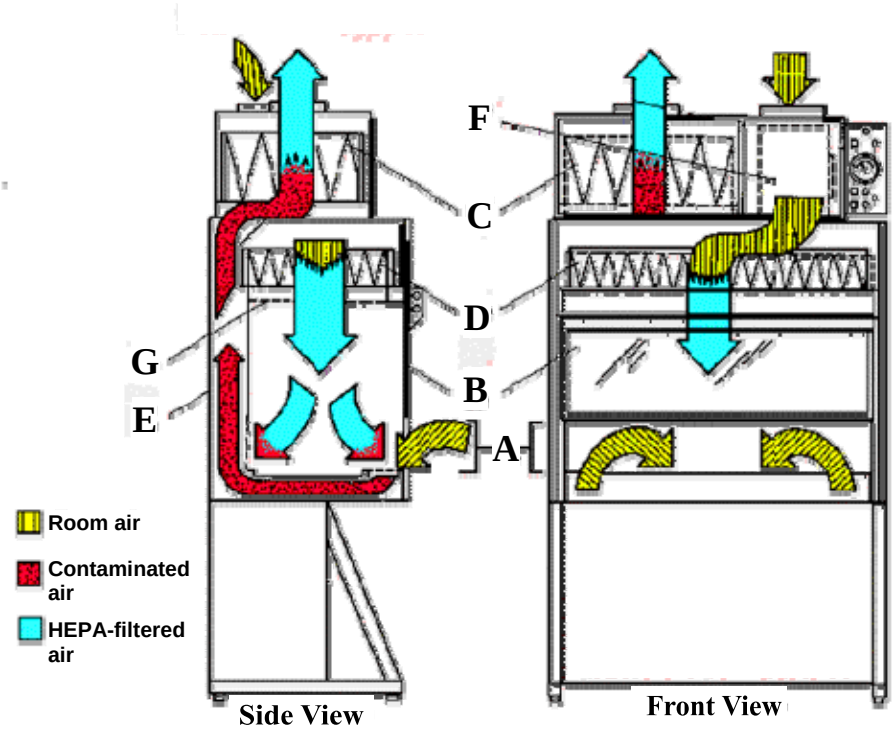


Figure 16.4 –Class II, Type B2 cabinet
A. front opening; **B.** sash; **C.** exhaust HEPA filter; **D.** supply HEPA filter; **E.** negative pressure exhaust plenum; **F.** supply blower; **G.** filter screen. **Note:** The carbon filter in the building exhaust is not shown. The cabinet exhaust needs to be connected to the building exhaust system.

4. Class II, Type A2 (Formerly B3) Cabients (Figure 16-5)

- Type A2 cabinets have a minimum of 100 fpm average inflow velocity.
  - All biologically contaminated ducts and plenums are under negative pressure or surrounded by negative pressure ducts and plenums
  - They may exhaust HEPA filtered air back into the laboratory or to the environment through and exhaust canopy.
- Type A2 cabinets are suitable for work with low to moderate risk biological agents. Type A2 cabinets used for work with minute quantities of volatile toxic chemical and trace amounts of radionuclides must be exhausted through properly functioning exhaust canopies. If the cabinet is not ducted, you cannot work with chemicals in the cabinet.

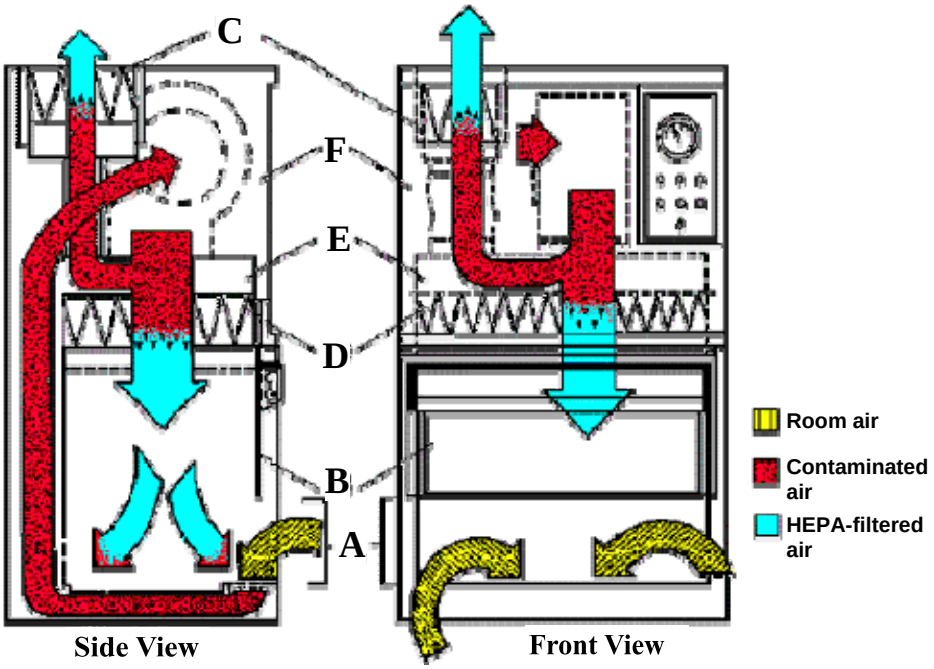


Figure 16.5 –Class II, Type B3 cabinet
A. front opening; **B.** sash; **C.** exhaust HEPA filter; **D.** supply HEPA filter;
E. positive pressure plenum; **F.** negative pressure plenum
Note: The cabinet exhaust needs to be connected to the building exhaust system.

C. Class III Cabinets (Figure 16-6)

- The Class III cabinet is totally enclosed, ventilated, and of leak-tight construction.
- Users conduct operations in the cabinet through attached arm-length rubber gloves, which serve as physical barriers.
- The cabinet maintains negative air pressure of at least 0.5 inches water gauge (120Pa).
- The BSC fan draws supply air into the cabinet through HEPA filters.
- Treatment of exhaust air is by double HEPA filtration, or by HEPA filtration and incineration.
- Class III cabinets are used in maximum containment laboratories (BSL-3) and may be used with agents of low, moderate, and high risk.

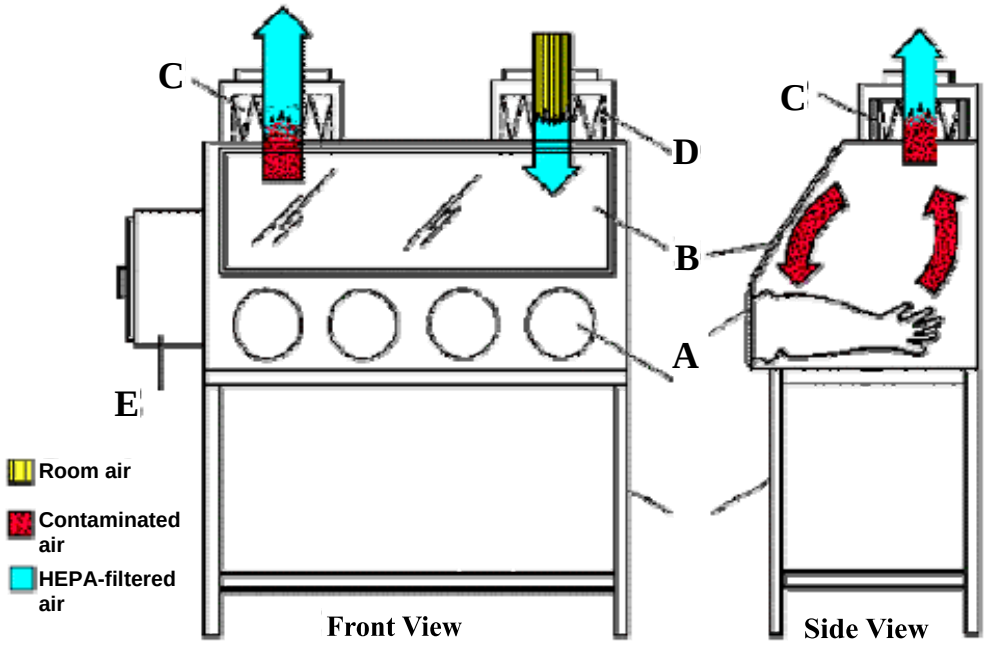


Figure 16.6 – Class III cabinet
A. glove ports with O-ring for attaching arm-length gloves to cabinet; **B.** sash; **C.** exhaust HEPA filter; **D.** supply HEPA filter; **E.** double-ended autoclave or pass-through box
Note: A chemical dunk tank may be installed which would be located beneath the work surface of the BSC with access from above. The cabinet exhaust needs to be connected to the building exhaust system.

IV. Laminar Flow Clean Benches (Figure 16-7)

Horizontal and vertical laminar flow clean benches are sometimes mistaken for biological safety cabinets. Clean benches provide product protection but no personnel protection. The horizontal flow clean bench discharges HEPA filtered air across the work surface onto the operator. The less common vertical flow clean bench discharges air downward from a HEPA filter above the work surface. The airflow leaves the work area through the front opening where the operator is located. With both versions of the clean bench, work performed on the work surface could expose the operator to contaminants. Researchers often use clean benches for assembly of sterile apparatus. Do not use clean benches for handling cell cultures, drug formulations, radionuclides, biological hazards, or chemicals. Exposure to some of these materials from manipulation on a clean bench can cause hypersensitivity. Clean benches are to be posted with a label such as http://ehs.unc.edu/ih/lab/labels/docs/clean_bench.pdf or similar.

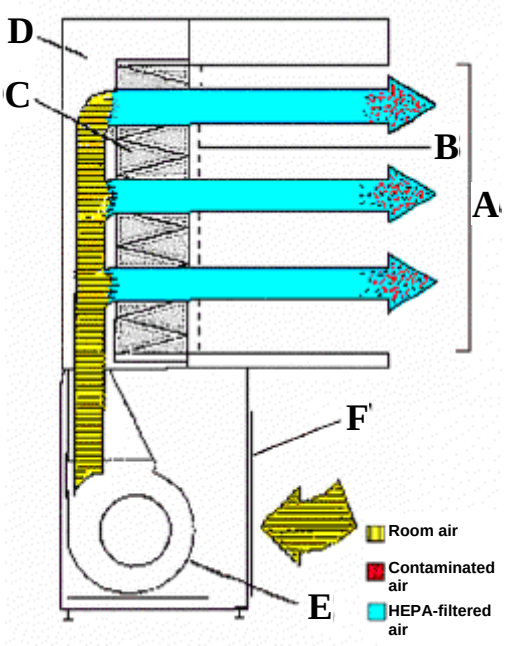


Figure 16.7a –Horizontal Flow Clean Bench
A. front opening; **B.** supply grille; **C.** supply HEPA filter; **D.** supply plenum; **E.** blower; **F.** grille

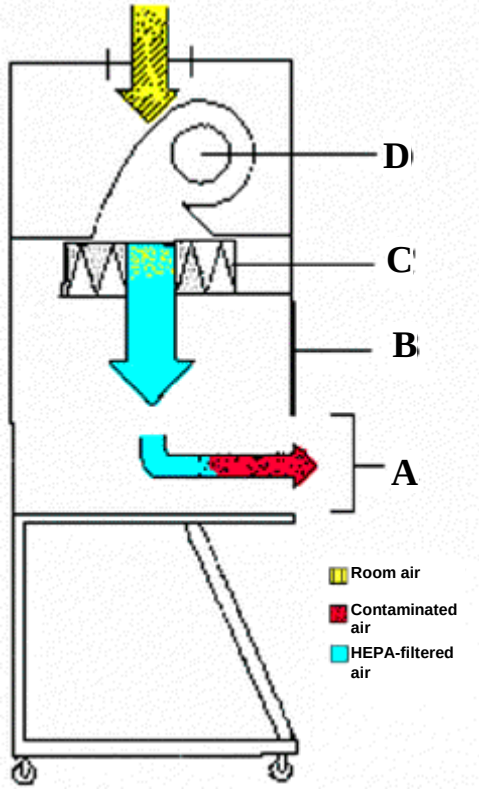


Figure 16.7b –Vertical Flow Clean Bench
A. front opening; **B.** sash; **C.** supply HEPA filter; **D.** blower

Table 16-1. Comparison of Biological Safety Cabinet Characteristics and Applications

Class, Type	Work Opening	Inflow Velocity (fpm)	Percentage Recirculated Air	Percentage Exhausted Air	Exhaust Volume (cfm) (approximate)	Exhaust Requirement	Application
Class I	Fixed	75	0%	100%	4 ft - 200 6 ft - 300	Exhausted to the outside (remote fan) or to the room through a HEPA filter (integral fan)	Biosafety Level 1-3; small amounts of toxic chemicals or radionuclides (if exhausted to outside)
Class II, type A1	fixed, sliding, or hinged	75-100	70%	30%	4 ft - 300 6 ft - 400	Exhausted to room through HEPA filter or to the environment through an exhaust canopy	Biosafety Level 1-3
Class II, type B1	Sliding	100	30%	70%	4 ft - 250 6 ft - 400	Exhausted to outside, with remote fan; duct is hard connected	Biosafety Level 1-3; small amounts of toxic chemicals or radionuclides
Class II, type B2	sliding, hinged	100	0%	100%	4 ft - 600 6 ft - 1000	Exhausted to outside, with remote fan; duct is hard connected	Biosafety Level 1-3; small amounts of toxic chemicals or radionuclides
Class II, type A2	sliding, hinged	100	70%	30%	4 ft - 300 6 ft - 400	Exhausted to room through HEPA filter or exhausted to outside, with remote fan, utilizing canopy connection	Biosafety Level 1-3; small amounts of toxic chemicals or radionuclides
Class III	Glove ports	N/A	0%	100%	**a**	Exhausted to outside, through 2 HEPA filters, with remote fan; duct is hard connected	Biosafety Level 1-4; small amounts of toxic chemicals or radionuclides

a Class III cabinets should have approximately 20 air changes per hour or enough ventilation to accommodate the heat load. The cabinet must maintain a negative pressure of 0.5 in. w.g. and should maintain 100 fpm through a glove port, if a glove is accidentally removed.

V. Selection of Biological Safety Cabinets

The selection of the class or type of BSC depends on the degree or nature of the hazard associated with the experiment, the aerosol-producing potential of the laboratory procedures, and the requirement to protect the experiment from airborne contamination. EHS must review and approve all purchases and installations of biological safety cabinets. Complete Appendix 16-A, "Questionnaire for Review of Purchase Requisitions for Biological Safety Cabinets" and send it to EHS (CB #1650) for review. This ensures selection of the proper cabinet for the intended use, and installation for proper functioning, maintenance, and certification.

Table 16-1 provides a summary and comparison of BSC characteristics and application. In general, the Class II, type A1, A2 BSC (non-ducted) is sufficient when the work involves infectious agents and cell culture work in the absence of volatile toxic chemicals and radionuclides. When small amounts of volatile chemicals or radionuclides are involved, the Class II, type B (types B1, B2) is more appropriate. Select a Class III cabinet when the work involves the handling of high-risk microbiological agents, concentrated amounts of carcinogens, or highly toxic chemicals.

NSF International - The Public Health and Safety Company™ lists the models of the various cabinet manufacturers that meet its standard criteria described in NSF Standard No. 49 for "Class II (laminar flow) Biohazard Cabinetry". This standard includes design and construction requirements as well as performance specifications such as vibration; temperature rise; noise level, and personnel, product, and cross-contamination protection determined by a spore aerosol challenge. Selection of an NSF-approved model assures the purchaser that the model meets minimum construction and performance standards.

Most manufacturers offer user options such as ultraviolet (UV) or germicidal lights. UV lights are not recommended by NSF 49, but if installed they must be cleaned weekly to remove dust which can reduce their germicidal effectiveness. They must also be installed in a manner that does not reduce the required performance of the cabinet. . Take precautions to prevent exposure of the eyes and skin to damaging effects of UV light. Keep the protective sashes in place, and do not place your hands or arms within a cabinet when the UV (purple) lamp is on. Turn off UV lamps when the room is occupied.

To accommodate special applications, the manufacturer can modify the design of biological safety cabinets. Examples include altering the front sash to accommodate microscope eyepieces, or adapting the work surface to include a centrifuge or animal waste handling capabilities.

VI. Installation and Certification of Biological Safety Cabinets

A. Installation

The cabinet should be located in a space that is free from drafts and traffic. Air conditioning vents, opening doors, and personnel traffic can produce air currents, which may penetrate the air barriers at the front opening of the cabinet. The ideal location for BSCs is a "dead-end" area of the laboratory. Nearby HVAC vents should be directed away from the BSC. Provide a clearance of 12-14 inches (30-35 cm) above Class II, type A1, A2, cabinets to allow access for accurate exhaust flow measurements and filter replacement.

The Class II, type A1 or A2 BSC is built to exhaust air back into the laboratory; therefore, it is generally best not to connect a duct to the cabinet. If a duct is connected by a canopy, the remote exhaust fan must be the correct size to match precisely the exhaust air volume from the cabinet. The canopy duct must not interfere with requirements for certification tests and filter replacement. Make sure the exhaust filter is accessible.

Type A or A2 cabinets with a canopy connected and exhausted by a remote fan should have an audible and visual alarm to indicate a loss of exhaust airflow.

The exhaust fan should interlock with the cabinet fan switch, so that both fans are either "on" or "off" at the same time. If the cabinet fan is "off" on a Class II, type A1 or A2 cabinet but the exhaust fan is "on", the exhaust fan will pull room air contaminants through the cabinet and the supply filter in the opposite direction of normal cabinet operation. The clean side of the supply filter is therefore contaminated. When someone turns "on" the cabinet, the airflow through the supply filter is now flowing in the correct direction, and contaminants can dislodge from the filter media into the clean work area of the cabinet.

Class II, type B1 and B2 cabinets by design must duct to the outside using a remote exhaust fan, usually located on the roof. Once the cabinet is set or certified in its acceptable airflow range, audible and visual alarms shall be required to indicate a 20% loss of exhaust volume within 15 seconds. The internal cabinet fans shall be interlocked to shut off at the same time the alarms are activated.

To size the exhaust fan correctly, consult the cabinet manufacturer to obtain the pressure drop through the cabinet with fully loaded filters. For some older models, the exhaust filter is located on the roof just upstream from the fan. The maintenance technician uses a bag-in / bag-out filter assembly so that he/she does not have to handle a contaminated filter directly. Upstream and downstream certification test ports and isolation dampers for formaldehyde gas decontamination are also necessary.

B. Certification

A BSC certifier tests and evaluates the performance of each BSC after initial installation in the laboratory, prior to use, whenever moved, and periodically thereafter. The following are typical

field tests: downflow velocity profile for the supply air, work access opening airflow, HEPA filter leak test, cabinet integrity test, and airflow smoke patterns.

NSF Standard No. 49 describes certification field tests. NSF also accredits BSC certifiers. Recertification of the cabinet is necessary when the HEPA filters are changed, maintenance repairs are required, or when a cabinet is relocated. BSCs require decontamination with formaldehyde gas before maintenance work or filter changes, after gross spills of biohazardous materials, and before moving the cabinet.

VII. Procedures for the Proper Use of a Class II Biological Safety Cabinet

Any laminar flow BSC is only a supplement to good microbiological techniques, not a replacement. If users do not properly understand or operate cabinets, they will not maintain an adequate protective barrier between the operator and the experiment. Listed below are procedures for proper use of BSCs.

- Turn the cabinet fan and the fluorescent light on. Turn off the UV light. Confirm that the drain valve is closed.

- Wipe the work surface with 70% ethanol or other appropriate disinfectant. Let the unit run for 5 -10 minutes to clean itself before beginning work.

- Plan the work operation in advance. Place everything needed for the complete procedure in the cabinet before starting. Nothing should pass through the air barrier, either in or out, until the procedure is complete. Arrange materials in a logical manner such that clean and contaminated materials are segregated. Remove from the cabinet all materials or equipment not necessary for the particular procedure.

- Avoid placing materials on the air intake grille, at the front of cabinet as this disrupts the protective air barrier.

- Keep equipment at least four inches (10 cm) inside the cabinet work area. Perform manipulations of hazardous materials as far back in the work area as possible.

- After the procedure is completed, decontaminate all equipment in direct contact with the research agent with an appropriate disinfectant. Run the cabinet at least three minutes with no activity to purge airborne contaminants from the work area.

- After removal of all materials and equipment, wipe the work surface with 70% ethanol or other appropriate disinfectant. Clean any spilled culture media that may support fungal growth and cause contamination in subsequent experiments.

- Turn off the cabinet fan. Some researchers prefer to let the cabinet run continuously. You may turn on the UV light if the BSC is so equipped and there are barriers in place to prevent inadvertent UV exposure to other lab personnel.

CHAPTER 17

LABORATORY HOODS

Overview

This chapter describes safe work practices when using laboratory hoods, answers frequently asked questions about this important engineering control equipment, and spells out the Laboratory Hood and Ventilation Policy at UNC-Chapel Hill.

Table of Contents

This page intentionally left blank.

CHAPTER 17

LABORATORY HOODS

I. Introduction

The University of North Carolina at Chapel Hill is committed to providing engineering controls that minimize exposure to hazardous materials to students, faculty and staff who work in laboratories. These controls include biological safety cabinets (Chapter 16) and laboratory hoods. Laboratory hoods are also known as "chemical hoods", "fume hoods" or simply "hoods".

If you believe your hood is not working properly, contact Environment, Health & Safety at 962-5507 and ask to have your hood evaluated. You must review the UNC Laboratory Hood Policy listed later in this Chapter if you are considering the installation of a new hood.

Laboratory hoods are only effective if the hood operates properly AND the user exhibits good work practices. Refer to the section below entitled *Laboratory Hood Work Practice Guidelines* for more information.

II. Frequently Asked Questions

What do I do if my hood alarm activates?

The alarm on the laboratory chemical hood notifies you that the hood is not performing as desired, which could lead to overexposure to chemicals. If the alarm triggers, take the following steps:

- Shut down your experiment;
- Close the sash;
- Call UNC Facilities Services immediately at 962-3456. When dialing from campus phones, this number is easy to remember: 2-3456.

If the alarm sounds due to a scheduled power outage and someone turns it off, post the hood as "Out of Service" (Appendix 17-A) until power is restored. Turn the alarm back on before conducting further work in the hood.

Why does my alarm always go off when the laboratory door is open?

Please keep in mind that when doors are propped open, the airflow in the laboratory is affected and the hood may go into alarm. If you believe your alarm is too sensitive, notify EHS for a calibration assessment. Never tamper with the alarm by taping over openings.

Can I use radioactive material in my laboratory hood?

The Radiation Safety Committee, appointed by the Chancellor, formulates radiation policies and procedures. Responsibility for carrying out these policies and procedures rests with the Radiation Safety Officer who directs the Radiation Safety Section of the Department of Environment, Health and Safety. Hoods must receive individual authorization by the Radiation Safety Section. EHS provides the radiation caution signs that indicate which hoods it has authorized for use with radioactive materials. Hoods must have this posting before you use radioactive materials in them. Radiation Safety Section contact information can be found at http://www.ehs.unc.edu/radiation/index.shtml.

Can I do my virology/bacteriology work in my laboratory hood?

In general, virology and bacteria work shall ***not*** occur in a laboratory chemical hood. When working with cultures, use a biological safety cabinet. For information about biological safety cabinets at UNC, refer to Chapter 16: Biological Safety Cabinets.

How do I make modifications to my existing hood or exhaust system?

Students, faculty, staff and Facilities Services personnel must not modify hoods by drilling, cutting or removing the hardware originally provided with the hoods. Such modifications are likely to degrade hood containment performance and result in hood leakage. Installing a standard latticework of "monkey" bars at the rear of the hood is an exception. The installer must follow the hood manufacturer's recommendations when installing these support bars in the hood. EHS must review and approve in advance any other proposed hood modifications, and post-test following modification.

Do not add shelving to the hood, nor block the rear slots or front airfoil at any time. Ensure the sash and panels are in place before operating.

III. Laboratory Hood Work Practice Guidelines

A. Do not work in a malfunctioning hood.

This hood has been inspected by the UNC-CH **Dept. of Environment, Health & Safety** ---2-5507

Date	Linear hood face velocity with 18" opening (fpm)	Inspected by
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Generally, a face velocity of 100-125 linear feet per minute is recommended for use with radioactive materials and toxic chemicals.

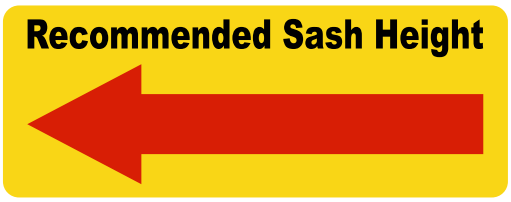
Figure 17.1 –
(Left) Hood marked out of service until repairs are completed.
(Right): Example of EHS inspection sticker.

B. Check the EHS inspection sticker on the hood (usually on the sash) to ensure it has been inspected within the past 12 months. EHS measures the face velocity of all hoods annually, notes any deficiencies, and refers them to UNC Facilities Services for correction. Recommended face velocities are between 100-125 feet per minute (fpm).

C. Test the airflow alarm prior to using the hood to ensure it is operating properly:

Test button

Figure 17.2 –
Three common examples of hood airflow alarm devices.



D. Check the sash height:

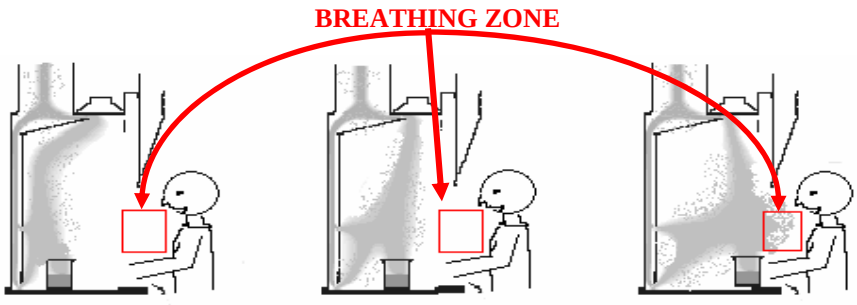
(1) EHS affixes these stickers to vertical-sash laboratory hoods to remind users not to work with the sash above 18". Try to keep the sash closed unless you are setting up or actively using the hood.

(2) You can raise and lower a correctly operating hood sash smoothly and with minimal effort. If you have difficulty operating the sash, or you cannot lower it completely, contact EHS. Do not place equipment, cords, tubing, etc. so that you cannot lower the sash quickly and completely.

(3) The recommended best practice for a combination sash hood (horizontal sliding panels within a vertical sliding sash) relies on completely closing the vertical sash while working through the horizontal sliders. Regular use of the horizontal sliding panels with the vertical sliding sash closed reduces chemical exposure and reduces energy expense. The vertical sliding sash should only be open during set up, not while manipulating objects in the hood with reactions present.

Figure 17.3 – Combination sash hoods.
(Left): Correct position of a combination sash while performing experiments.
(Right): Only raise the vertical sash when setting up experiments.

E. Work at least 6" into the hood to keep chemicals and vapors from exiting:

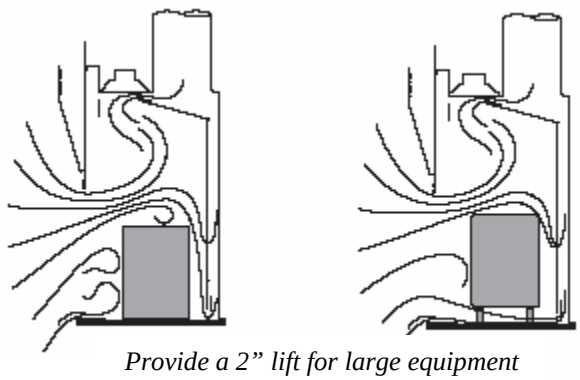


F. Do not work with your head breaking the front plane of the hood! Sashes at the proper working height generally create a physical barrier between the operator's head and the inside of the hood. Working with your head in the hood often means that the sash is too high, or that the horizontal panels are opened too wide on a combination sash hood. Consult the EHS ergonomist for furniture or equipment recommendations if you feel you cannot perform your duties at the laboratory hood without placing your head within the hood.

Figure 17.4 –
Laboratory worker with his head between the horizontal sashes on a combination sash hood.

G. Take steps to maximize containment:

(1) Place blocks under large equipment to allow air to flow underneath the equipment.



Provide a 2" lift for large equipment

(2) Keep the work area and bottom baffles clear from clutter.

H. Use chemical storage cabinets for long-term storage, not your hood. Items in a hood will impede and disturb the exhaust airflow and potentially reduce or eliminate the safety factor.

I. Reduce cross drafts, foot traffic past the hood, and quick movements in and around the hood. The recommended 100 fpm for hood face velocity is only a little more than one mile per hour (1.14 mph; 1.83 kph). Other sources of air movement can easily overcome this.

J. Remove electrical units or other spark sources from the hood when flammable liquids or gases are present. Do not place power strips or surge protectors in the hood. Plug in all electrical equipment outside of the hood.

K. The use of a laboratory hood does not negate the University policy on eye protection. Eye protection is required for all faculty, staff, students, and visitors in laboratories during experimental procedures that could produce liquid or solid projectiles.

IV. Snorkel Ducts

Several laboratories are equipped with snorkel ducts, which consist of a bell mouth and an articulated connection to the exhaust system (Figure 17.5). The main difference between your laboratory chemical hood and the snorkel is that the latter does not fully surround the reaction at the point of release. For this reason, snorkels are not a substitute for a laboratory hood when handling toxic chemicals. Snorkels are far less effective in capturing dusts, mists, or fumes, and can typically only capture contaminants released within 6 inches (15 cm) of the unit. Snorkels are extremely susceptible to cross drafts.

A good use for laboratory snorkels is the capture and removal of thermal updrafts from benchtop heated processes, or as local ventilation for benchtop apparatuses such as gas chromatographs. Snorkels generally operate at 45 feet per minute (fpm).

Figure 17.5 –
Snorkel duct systems.

V. Laboratory Hood and Ventilation Policy

If your research group is currently considering the installation of additional hoods, or replacement of existing hoods, you should carefully read this policy.

The University of North Carolina at Chapel Hill (University) is committed to providing students, faculty and staff who work in laboratories with engineering controls that minimize their exposure to hazardous materials. The National Academy of Sciences has found that, "Laboratory hoods are the most important component used to protect laboratory workers from exposure to hazardous chemicals and agents used in the laboratory."[1] A hood is also an excellent physical barrier against chemical splashes and small explosions. OSHA's Laboratory Standard relies on having a properly working hood.

This Policy addresses the design, acquisition, installation, maintenance and testing of hoods used as engineering controls for chemicals, toxins and radionuclides in University laboratories. Most importantly, this Policy outlines procedures to ensure that hoods at the University perform properly.

A. System Design

The design of laboratory hood and ventilation systems must consider their physical environment and integration into the building's supply and exhaust systems. System components include the hood, supply air, exhaust requirements, general room ventilation and Variable Air Volume (VAV) controls.

(1) Capital/Formal Projects

Capital/formal projects involving laboratories (both major and download) typically include major revisions to, or replacement of, existing HVAC systems, ductwork, hoods and control systems. For capital/formal projects, detailed specifications for the design, purchase, installation, testing and balancing of laboratory chemical hoods and ventilation systems are in the *UNC-Chapel Hill Design and Construction Guidelines* (http://www.fpc.unc.edu/DesignGuidelines.asp).

As described in the *Guidelines*, a rigorous, detailed review process for the entire ventilation system must occur early in the project. Design and construction must follow coordinated, sequential steps to ensure that all components of the system are considered, and will perform properly.

(2) Other/Informal Projects

Facilities Services Architectural and Engineering Services manages other (informal) projects. For projects involving laboratory ventilation or the installation of new or replacement laboratory hoods:

[1] *Prudent Practices in the Laboratory,* Washington, D.C.: National Academy Press, 1995, p. 178.

- To determine whether a building can adequately support a proposed laboratory hood, an engineering assessment of existing mechanical and electrical systems must occur before adding or removing hoods from a laboratory. This requirement applies to all hood replacements and ducted biological safety cabinets.
- As much as practicable, specifications should rely on the *UNC-Chapel Hill Design and Construction Guidelines*.
- After installation and prior to use, the hood must pass these tests:
  - The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 110 test, except for a Sulfur Hexafluoride (SF_6) challenge. Contact EHS for recommended testers.
  - Smoke puff tests at the bottom of the closed doors for laboratories designed to require normally closed corridor doors. (To pass, no smoke can escape into the corridor.)
  - A Sulfur Hexafluoride (SF_6) challenge according to ASHRAE 110 is highly recommended.
  - The cost of these tests shall be included in the cost of the project.
- A Professional Engineer shall seal all hood and ventilation design drawings and specifications.

B. Hood Selection and Purchase

University Materials & Disbursement Services requires the approval of the Directors of Facilities Services and Environment, Health and Safety (EHS) (or their designees) for the purchase of a ducted biological safety cabinet or a laboratory hood. Investigators who wish to bring hoods with them from a previous location must receive approval prior to shipment.

All newly installed hoods shall be equipped with a flow-monitoring device (e.g., static pressure gauge and alarm) to continuously monitor hood throat suction. Gauges shall be selected to operate at 50% of full range. Contact EHS for recommendations.

This Policy does not permit the purchase and installation of an auxiliary air hood.

The EHS Director must approve the purchase and installation of all non-ducted hoods. EHS will not approve non-ducted hoods for use with volatile chemicals. Approval will be granted only in exceptional cases, and only when particulate handling (e.g., weighing solids) is its sole use.

C. Installation and Startup

Hood installation and startup requires the following authorizations:

(1) **Authorization for Installation:** The Directors of Facilities Services and Environment, Health and Safety, or their designees must approve the installation of any laboratory hood at the University.

(2) **Authorization for Startup:** To prevent the exposure of students, faculty and staff to volatile radionuclides, carcinogens, reproductive hazards and other toxins, EHS will not

permit hazardous materials in a new laboratory until its hood and ventilation system is performing according to the project's design and manufacturer's specifications. The EHS Director will make this decision based on the available information, including tests by the contractor, Facilities Services staff, and EHS.

(3) Until the EHS Director authorizes the startup of a new hood:

a. In an occupied laboratory, the EHS will post an "Out of Service/Do Not Use" sign on the hood.

b. EHS will not authorize the new laboratory for radioactive material use.

c. EHS will not allow chemicals in the new laboratory.

d. EHS will instruct laboratory staff not to move any hazardous materials into the new laboratory.

e. Additionally, EHS will not authorize a new laboratory for biohazardous materials unless its biological safety cabinet is operating according to the project's design and manufacture's specifications.

(4) Third party commissioning is required for Variable Air Volume (VAV) laboratory hood systems.

D. Hood Modifications

Students, faculty, staff and Facilities Services personnel must not modify hoods by drilling, cutting or removing the hardware originally provided with the hoods. Such modifications are likely to degrade hood containment performance and result in hood leakage. Installing a standard latticework of "monkey" bars at the rear of the hood is an exception. The installer must follow the hood manufacturer's recommendations when installing these support bars in the hood. EHS must review and approve in advance any other proposed hood modifications, and post-test following modification.

E. Inspection and Preventive Maintenance

As with all mechanical systems, inspections and regular preventive maintenance are critical to ensure that the laboratory exhaust systems operate without unscheduled interruptions in service. Facilities Services personnel keep records of all inspections and corrective actions for each laboratory building. Depending on the item, inspections occur quarterly, semiannually or annually.

Laboratory occupants must receive advanced notification of fan stoppage.

Responsibility: Facilities Services.

F. Annual Hood and System Testing

Each hood requires annual retesting and recertification. Testing shall occur with HVAC systems operating at 100%. Qualified and trained personnel shall conduct testing. At a minimum, EHS will follow these test procedures:

- Visual inspection for hood damage, modifications or congestion.
- Face velocity measurements at the designated working sash position. (To pass, the average velocity must not be below 90% or above 150% of criteria. For most hoods at the University as of 2006, the face velocity the criterion is 100 fpm at 18 inches sash height.)
- Hood alarm test, if applicable.

Hoods that pass the annual testing will have labels affixed stating the following:

- Test Date
- Initials of inspector
- Face velocity readings at the standard operating sash opening (usually 18 inches unless otherwise specified)

EHS will contact Facilities Services to repair hoods that fail one of the first three tests. Hoods with face velocities below 80% of criteria will receive the posting: "Out of Service/Do Not Use". Hoods posted as "Out of Service/Do Not Use" must be emptied and cleaned immediately, to prevent chemical exposures for laboratory occupants and personnel who will repair the hood system.

Report all hood alarms to Facilities Services (2-3456) for repair.

Responsibilities: EHS will test and label the hood during the laboratory's annual inspection. If indicated, the inspector will contact Facilities Services to initiate repairs based upon their findings. After repairs, EHS or Facilities Services, as appropriate, will perform follow-up testing.

G. Ventilation System Repair

Laboratory personnel must call Facilities Services Work Management (2-3456) as soon as they notice a problem with the hood, or laboratory ventilation system.

All system outages (planned or unplanned) require that laboratory notification, posting and appropriate shutdown procedures be followed. Maintenance personnel shall follow all applicable OSHA standards (e.g., hazard communication, lockout-tagout, personal protective equipment) depending upon whether or not they have to access the interior of the exhaust systems.

Facilities Services must notify Directors or Department Chairs of the affected laboratories and EHS of all ventilation outages that will exceed four hours in duration.

Responsibilities:

- Facilities Services will coordinate all responses to requests for ventilation system repair.
- Hood users are responsible for contacting Facilities Services (and their supervisor) if the hood alarm or gauge indicates poor hood performance between annual inspections. Follow the posted shut down procedures and place a sign on the hood: "Out of Service/Do Not Use".

H. Key References:

- ANSI/AIHA Z9.5 (most current)
- ASHRAE 110 1995 (or most current)
- UNC-Chapel Hill Design and Construction Guidelines (most current)

This hood has been posted

Out of Service

by _____

(name & contact information)

Do Not Use

EHS (962-5507) was notified on _____ .

(date)

Facilities Services (962-3456) was notified on _____.

(date)

CHAPTER 18

SAFE USE OF NANOMATERIALS

Overview

This chapter discusses the unique properties of nanomaterials, solid superatomic materials with at least one dimension in the range of one to 100 nanometers. Subsequent sections discuss the potential safety and health concerns from nanomaterials (based on cell culture and animal studies), the routes of exposure, and guidance on how to prevent exposures to nanomaterials.

Table of Contents

This page intentionally left blank.

CHAPTER 18

SAFE USE OF NANOMATERIALS

I. Introduction

Nanomaterials are any solid superatomic materials with at least one dimension (length, width, or depth) between one and 100 nanometers (nm). This size range (1-100 nm) is referred to as "nanoscale". Nanomaterials can exhibit unique physical and chemical properties not seen in larger molecules of the same composition, properties described later in this Chapter. Substantial private and public investments are flowing into the exploration and development of products that can take advantage of the unique properties of nanomaterials. Researchers and EHS staff must consider the potential health, safety, and environmental risks that might result during this research and development boom caused by the promise of nanotechnology.

Fortunately, the health and safety of nanomaterials is a high research priority for the U.S.'s principal occupational health research agency, the National Institute for Occupational Safety and Health (NIOSH). NIOSH has a strategic plan and research agenda. In fact, they supported many of the health effects studies quoted in this chapter. Consult their Nanotechnology Page (http://www.cdc.gov/niosh/topics/nanotech/) for more information.

II. Size and Types of Nanomaterials

One meter consists of 1000 millimeters (mm). One millimeter equals 1000 micrometers (μm), and one micrometer equals 1000 nm. Thus, 1 nm = $1x10^{-9}$ m.

How do nanomaterials compare in size to other objects regarded as "small"? Dust mites have a diameter of approximately 200 μm. Human hairs have a diameter of 60-120 μm. Thus, both are 1000 or more times larger than nanoscale. The smallest known bacterial species, such as the genus *Mycoplasma*, have a diameter of approximately 300 nm (.3 μm), which is still greater than nanoscale. Some smaller viruses (e.g. Parvoviruses, diameter ~25 nm) exist at nanoscale, but most viruses are larger. Typical double-stranded DNA has a diameter of ~2.5 nm.

Nanomaterials are among the smallest materials that can exist, because the smallest unit of elemental matter that retains the properties of the element (the atom) is not much smaller than nanoscale. Due to the uncertain position of the electron cloud around the central nucleus, scientists can only estimate the diameter of atoms. However, most estimates of atomic diameter range from .05 to .25 nm (0.5 to 2.5 Angstroms).

Nanomaterials divide roughly into two main categories: ambient (or "natural") nanoparticles, and engineered/manufactured nanomaterials. This distinction is mostly arbitrary, and serves to remind that nanomaterials existed long before humankind knew of them, or made any efforts to manufacture them. The rest of this Chapter will use the term "nanoparticles" when referring specifically to nanoscale natural (non-engineered) substances. The term "nanomaterials" will be

used as a blanket term for all nanoscale substances. In most scientific uses, the terms are interchangeable.

Ambient nanoparticles are also known as "ultrafine" particles in standard industrial hygiene terminology. Sources include diesel engine exhaust, welding fumes, and other combustion processes. Most grinding and crushing processes are incapable of producing nanoparticles, unless fine bead mills are used. Ultrafine/nanoparticles have a larger surface area per unit volume than an equal volume of same composition larger particles. This can lead to different physical, chemical, and biological response properties.

Other natural nanoparticles include smaller viruses and rickettsia, and intracellular proteins, nucleic acids, and organelles.

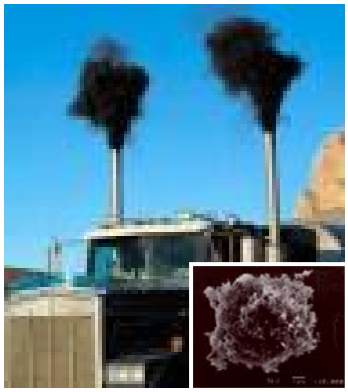


Figure 18.1 –
(Left) Diesel engines produce particulate soot, which includes ultrafine amorphous carbon (inset).

(Right) Welding produces metal fumes, many of which are ultrafine/nanoscale (inset).

Engineered or manufactured nanomaterials are deliberately created and used for a structural/functional purpose. Engineered nanomaterials can include both homogeneous materials and heterogeneous structures with specific applications in computing, medicine, and other disciplines. The development of the scanning tunneling microscope allowed the controlled manipulation and assembly of matter at the atomic scale. The next section will examine several examples of engineered nanomaterials.

III. Uses of Nanoparticles / Nanomaterials

This section is not remotely inclusive, but gives you a few examples of nano-based products that are currently available, and others that are in development.

A. Consumer Products. Several commercially available products already use nanoparticles for their desirable properties. 3M makes a dental composite called Filtek™ that consists of nanosilica particles. Other companies use nanofibers to impart stain and wrinkle resistance to fabrics. Tennis balls manufactured with nanoclay particle cores hold air pressure longer than conventional balls. Zinc oxide nanoparticles are now common in many sunscreens and cosmetics, the advantage being that the nanoparticles are transparent (unlike the larger particles) so the products are clear rather than white. Of course, nanotechnology also has a

rich present and future in computing and technological applications, to create smaller and more powerful chips. In the coming years, the number of these nano-based consumer products is expected to grow exponentially.

B. Laboratory Products. Many nanotech-based products are already used in research laboratories, and you might already have some of these in your lab. New scintillation fluids contain proprietary fluor nanoparticles that do not require organic solvents as the carrier. The advantage is that used scintillation cocktail is only radioactive waste, rather than mixed radioactive and ignitable waste, saving disposal costs. Sturdy fluorescent probes are now available, using quantum dot semiconductor particles. Recently, scientists were able to combine polyguanine with silica nanoparticles to create a new electrochemical immunosensor for TNF-α[1]. New uses for nanomaterials in the laboratory are nearly unlimited.

C. Uses in Medicine. The ability to employ nanoparticles and create nanomaterials holds great potential in the field of medicine, as many diseases result from damage at the molecular or cellular level. Therefore, the ability to deliver pharmaceuticals and therapeutic gene "payloads" at the cellular level, with nanomaterials acting as the delivery system, holds great promise. For example, calcium phosphate nanoparticles can deliver DNA to particular cells targeted for gene therapy[2]. A recent breakthrough in imprint lithography allows the production of monodisperse nanoscale particles that can effectively contain delicate payloads[3]. In the near future, it might be possible for engineered nanomaterials to take over the function of damaged/defective subcellular organelles such as mitochondria[4].

D. Carbon Nanotubes. Carbon nanotubes (CNTs) also deserve attention, since they are a basic building block for many current and future products. These allotropes of carbon assemble themselves into cylindrical sheets. Single-walled CNTs have a diameter of approximately 1.3 nm, while multi-walled CNTs have larger diameters that are still within nanoscale.

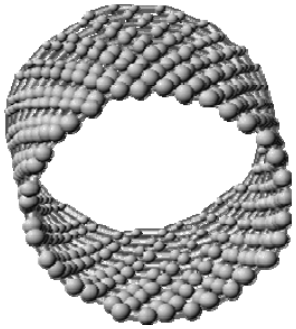


Figure 18.2 –

Representation of a single-walled carbon nanotube.

[1] Wang J, Liu G, Engelhard MH, and Lin Y. Sensitive Immunoassay of a Biomarker Tumor Necrosis Factor-a Based on Poly(guanine)-Functionalized Silica Nanoparticle Label. *Analy Chem* 78(19): 6974-6979 (2006).
[2] Roy I, Mitra S, Maitra A, and Mozumdar S. Calcium Phosphate Nanoparticles as Novel Non-Viral Vectors for Targeted Gene Delivery. *Intl J of Pharmaceutics* 250(1): 25-33 (2003).
[3] Euliss LE, DuPont JA, Gratton S, and DeSimone J. Imparting Size, Shape, and Composition Control of Materials for Nanomedicine. *Chem Soc Reviews* 35: 1095-1104 (2006).
[4] Datta R and Jaitawat SS. Nanotechnology – The New Frontier of Medicine. *Med J Armed Forces India* 62(3): 263-268 (2006).

CNTs can be up to several millimeters long, and possess tensile strength more than twenty times greater than carbon steel. CNTs also are efficient conductors of heat, excellent electron emitters, and can assemble into strong ropes of increasing diameter through VanDerWaal's forces. All of these are highly desirable material properties. Currently, CNTs are used in diverse applications such as lightweight carbon fiber bicycle pieces, water desalination filters, concrete strengthening, and solar cells. Their field emission properties have been harnessed to produce scanning X-ray imaging systems[5]. As the production and use of carbon nanotubes in laboratory research environments increases, the potential for exposure to CNTs also increases. The next section will cover known and suspected health effects from CNTs and other nanomaterials.

IV. Potential Health Hazards of Nanomaterials

As stated earlier, nanomaterials have a larger surface area to volume ratio compared to larger materials of the same composition. Nanomaterials, like many other solids, can have biological impacts based on their structure. Below is a summary of known and suspected health hazards from nanomaterials, based on recent research in animal models and *in vitro* assays.

A. Respirable Exposures

Inhalation is the most likely exposure route in laboratory settings, and the most extensive health effects studies have involved the inhalation route. From the time when carbon nanotubes were first seen through transmission electron microscopy, investigators noticed a startling physical similarity to asbestos (Figure 18.3). Both exist as fibers; with a length/width aspect ratio of at least 3:1, and both can exist at nanoscale (asbestos fibers as small as 2.5 nm diameter can occur naturally). Several decades of experimental data and retrospective epidemiological evidence have shown that asbestos exposure can lead to pulmonary fibrosis, mesothelioma, and increased risk of lung cancer, which is strongly synergistic when combined with smoking. Can CNTs cause similar health effects?

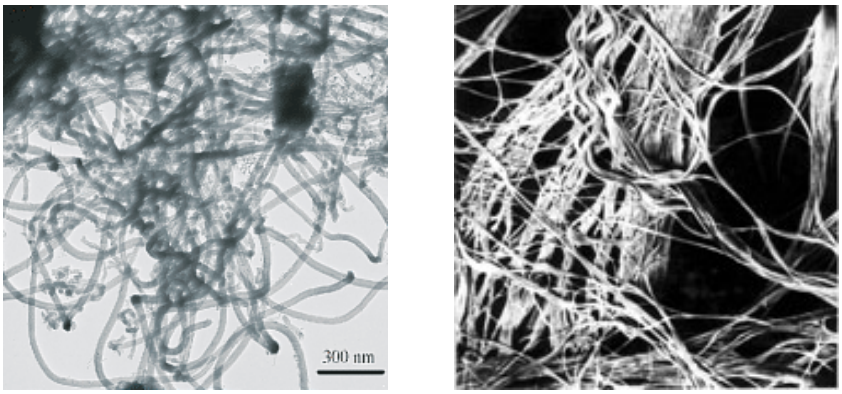


Figure 18.3 –
Transmission electron micrographs of
carbon nanotubes (left) and asbestos (right).

[5] Zhang J, Yang G, Rajaram R, Guan E, Lee Y, LaLush D, Chang S, Lu JP, and Zhou O. A Stationary Scanning X-ray Imaging System based on Carbon Nanotube Field Emitters. *Med Physics* 33(6): 2159 (2006).

CNTs can, like asbestos, reach the gas exchange (alveolar) regions of the deep lung, and trigger inflammation and oxidative stress. Studies in mice have shown that single-walled CNTs can produce pulmonary granulomas, whereas equivalent mass doses of ultrafine carbon black did not[6,7]. This implies that the shape and surface chemistry properties of CNTs impart an increase in pulmonary toxicity.

Respiratory studies for other nanomaterials are also informative. Extensive research on diesel exhaust particulates has led to their characterization by the International Agency for Research on Cancer as a reasonably anticipated human lung carcinogen. For titanium dioxide (a substances used at nanoparticle size in cosmetics, sunscreens, and self-cleaning windows), 25 nm diameter particles produced more potent lung damage than 250 nm diameter particles[8]. Since both sizes of particles are capable of reaching the deep lung, there must be another factor such as surface area to volume ratio, solubility, or agglomeration creating the toxicity difference. Nanoparticles that agglomerate tend to deposit in the nasopharyngeal region or the upper airways.

Discrete nanoparticles that reach the deep lung might be small enough to penetrate through alveolar epithelial cells, enter the capillaries, and translocate to other organs[9]. For discrete nanoparticles that remain in the nasopharyngeal region, translocation to the brain via axonal transport through the olfactory nerve has been shown in rats[10].

In summary, animal studies indicate the following potential concerns from exposures to nanomaterials through the inhalation route:

- CNTs might possess asbestos-like properties;
- For all nanomaterials, equivalent mass doses of the same materials might exhibit higher toxicity at nanoscale size;
- Previously unobserved translocation routes (via alveoli to bloodstream, via olfactory nerve to brain) might exist.

[6] Shvedova et al. Unusual Inflammatory and Fibrogenic Pulmonary Responses to Single-Walled Carbon Nanotubes in Mice. *Am J Physiology – Lung, Cell, & Mol Physiol* 289: L698-L708 (2005).
[7] Lam CW, James JT, McCluskey R, Arepalli S, Hunter RL. Pulmonary Toxicity of Single-Wall Carbon Nanotubes in Mice 7 and 90 Days after Intratrachial Installation. *Toxicol Sci* 77: 126-134 (2004).
[8] Oberdörster, G. *Phil. Trans. Roy. Soc. London Series A* 358(1775):2719-2740 (2000).
[9] Oberdörster et al. Extrapulmonary translocation of ultrafine carbon particles following whole-body inhalation exposure of rats. *J Toxicol Environ Health 65* Part A(20): 1531-1543 (2002).
[10] Oberdörster et al. Translocation of inhaled ultrafine particles to the brain. *Inhal Toxicol 16*(6-7): 437-445 (2004).

B. Skin Exposures

Skin penetration might be a viable exposure route for nanomaterials, though it is too soon to know whether it represents an important exposure route. Studies of titanium dioxide nanoparticles (found in some cosmetics and sunscreens) found that these particles did not penetrate beyond the epidermis[11]. Another study has shown that quantum dot nanomaterials with varying physicochemical properties were able to penetrate the intact skin of pigs[12]. Localized effects are also possible, as shown *in vitro* when CNTs were absorbed into skin cells leading to cytokine production and oxidative stress[13].

So far, no animal studies have shown adverse effects due to skin penetration by nanomaterials, or localized skin reactions to nanomaterials. Research is ongoing.

C. Ingestion Exposures

Very little is known about potential adverse effects from exposure to nanomaterials by ingestion. Ingestion might be the least likely exposure route in a laboratory or workplace setting. Ingestion could occur directly by mouth, or indirectly through mucociliary clearance of upper airways. It is presumed that nanomaterials could reach just about any organ or tissue after ingestion, if they are capable of penetrating skin cells, alveolar epithelium, and blood vessel walls.

V. Potential Safety Hazards of Nanomaterials

Safety hazards with nanomaterials vary based on the composition of the materials. However, a few general observations are possible. For flammable or combustible solids (e.g. some metals), nanoscale materials could present a higher fire-explosion risk compared to coarser particles of the same material[14]. Decreased particle size can increase the combustion potential and combustion rate, and reactive/catalytic properties can exist at nanoscale that do not exist at larger scales. Gold is relatively inert as a macromolecule, but gold nanoparticles can catalyze the conversion of carbon monoxide to carbon dioxide.

The greater activity of nanoscale materials forms the basis for research into nanoenergetics. For example, nanoscale thermite powders composed of aluminum and molybdenum trioxide ignite more than 300 times faster than corresponding micrometer-scale material[15].

[11] The Royal Society, The Royal Academy of Engineering. *Nanoscience and Nanotechnologies*. London, UK: The Royal Society and the Royal Academy of Engineering: www.nanotec.org.uk/finalReport.htm (2004).
[12] Ryman-Rasmussen JP, Riviere JE, Monteiro-Riviere NA. Penetration of Intact Skin by Quantum Dots with Diverse Physicochemicals Properties. *Toxicol Sci* 91(1): 159-165 (2006).
[13] Monteiro-Riviere et al. Multi-walled carbon nanotube interactions with human epidermal keratinocytes. *Toxicol Lett* 155(3): 377-384 (2005).
[14] Health and Safety Executive. Horizon scannon information sheet on nanotechnology. Sudbury, Suffolk, United Kingdom: Health and Safety Executive. www.hse.gov/pubns/hsin1.pdf (2004).
[15] Granier JJ and Pantoya ML. Laser Ignition of Nanocomposite Thermites. *Combustion Flame* 138:373-382 (2004).

VI. Protective Measures

This section details the ways that you can protect yourself when working with nanomaterials. Though there are still gaps in the safety and health knowledge literature, this section describes prudent use and handling practices that can protect you not just from nanomaterials, but other potentially harmful substances in the lab.

The most significant exposure route in laboratory settings would be inhalation, and this is the route with the most toxicity data. Respirable exposures would be most likely during the creation or handling of nanomaterials in aerosol, powder, or colloidal suspension. Nanomaterials in composites are not as likely to result in respirable exposures unless they are cut, ground, or degraded. As with all potential exposures, the best place to start is the OSHA "hierarchy of controls", which goes from engineering controls to work practice controls to personal protective equipment. Engineering controls always come first, since they have the potential to remove the exposure from the work area. Do not consider using personal protective equipment until you have considered all engineering and work practice controls.

A. Engineering Controls

It is a sound assumption that local exhaust ventilation systems (such as laboratory hoods) would effectively remove nanomaterials from the air, based on research about the capture of ultrafine particles by these systems.

To avoid re-entrainment of nanomaterials, EHS recommends High-Efficiency Particulate Air (HEPA) systems in conjunction with local exhaust ventilation. Filtration systems must be able to capture at least 99.97% of monodispersed 300 nm aerosols in order to qualify for HEPA rating. The 300 nm diameter is the most penetrating particle size. Particles smaller than 300 nm (including the nanoscale of 1-100 nm) are actually captured more effectively due to diffusion or electrostatic attraction, and particles larger than 300 nm are captured by impaction and interception. Thus, HEPA filters should effectively capture nanomaterials, however, the filter must sit properly in the housing, or nanomaterials will bypass it and take the path of least resistance.

B. Work Practice Controls

The most effective work practice control is product substitution, with a safer product used in place of a more hazardous one. For nanomaterial research, this is generally not feasible, since the experiment requires the unique nanoscale properties. However, other work practice controls are feasible. Try to use "wet" materials whenever possible, since dry materials are much more likely to cause respirable exposures. Make sure to clean up work areas effectively; use wet methods (not dry sweeping!) and consider the purchase of a HEPA vacuum. As with all laboratory substances, designate food and drink areas far from where you handle materials. If necessary, provide for adequate hand washing, showering, and clean clothes storage areas. Good work practice controls can minimize your exposure potentials from all major routes (respirable, skin contact, and ingestion).

C. Personal Protective Equipment

Earlier, under the Engineering Controls section, it was noted that HEPA filtration systems on ventilation systems could remove more than 99.97% of airborne nanomaterials. Similarly, **properly fitted** elastomeric respirators with HEPA cartridges (Figure 18.4a) should be able to prevent respirable exposure to airborne nanomaterials. Proper fit is critical, since a poor face seal means the particles and their airstream take the path of least resistance through the seal gaps into the breathing zone. See Chapter 5: Protective Clothing and Equipment for more information about the medical evaluation and fit testing requirements for tight-fitting respirators. Remember that you cannot consider respiratory protection or any other personal protective equipment until feasible engineering and work practice controls are exhausted.

Filtering facepiece respirators such as the N-95 (Figure 18.4b) are capable of filtering nanomaterials, but are prone to gaps and inward leakage. These respirators are not personal protective equipment from exposure to nanoaerosols.

Figure 18.4a (left) –
Elastomeric respirator with HEPA cartridges.

Figure 18.4b (right) –
N-95 filtering facepiece respirator.

There is currently very little data to indicate whether skin protective equipment such as gloves, Tyvek® sleeves and suits, etc., cam protect from nanomaterials. Most available data is from bloodborne pathogen protective equipment, which is challenge-tested with a 27 nm bacteriophage per ANSI (the American National Standards Institute).

Currently, it is unknown whether the skin is a significant route of exposure to nanomaterials. Until more data becomes available, you should use gloves and sleeves to prevent skin contact, and change gloves frequently.

VII. Conclusion

Nanomaterials exhibit unique properties that could challenge traditional perceptions about particle behavior and industrial hygiene, and more research is ongoing. At this time, it appears that traditional prudent approaches to avoid exposures (engineering controls, work practice controls, personal protective equipment) would also work for nanomaterials.

Please contact EHS if you have any questions about nanomaterial safety, or if you want to request an evaluation of your work conditions.

Revisions to Laboratory Safety Manual

Page	Date	Comment
i	June 2008	Updated Laboratory Safety website address.
1-11	June 2008	Updated website address for Workers' Compensation forms.
1-17	June 2008	Removed references to University Scientific Storeroom.
2-4	June 2008	Updated instructions for completing Worker Registration Form.
3-4	June 2008	Updated website address for label.
3-5	June 2008	Updated website address for label.
3-6	June 2008	Updated website address for labels.
4-4	June 2008	Removed references to University Scientific, Dental, and Chemistry Storerooms.
4-7	June 2008	Revised paragraph on chemical storage.
4-7	June 2008	Updated website address for labels.
5-3	June 2008	Removed reference to University Scientific and Chemistry Storerooms.
5-3	June 2008	Removed information referring to the loaning of eye protection.
5-5	June 2008	Removed reference to University Scientific and Chemistry Storerooms.
5-5	June 2008	Revised procedure for cleaning safety glasses.
7-4	June 2008	Updated website address for Laboratory Safety Plan.
7-5	June 2008	Updated website address for labels.
8-3	June 2008	Updated website address for Laboratory Safety Plan.
8-4	June 2008	Updated website address for label.
11-3	June 2008	Updated website address for Cameo.
12-5	June 2008	Removed reference to University Scientific Storeroom.
12-5	June 2008	Updated biohazardous waste collection policy.
12-6	June 2008	Updated link to biohazardous waste information website.
12-10	June 2008	Removed references to University Scientific Storeroom.
12-10	June 2008	Updated website address for labels.
13-5	June 2008	Updated website address for labels.
14-11	June 2008	Updated website address for Schedules G and H.
15-1	June 2008	Updated website address for EHS Biological Safety.
15-3	June 2008	Updated website address for Biological Safety Manual.
15-3	June 2008	Updated website address for Schedule F.
15-4	June 2008	Updated website address for Schedules G and H.
15-4	June 2008	Updated website address for IBC approval information.
15-5	June 2008	Updated website address for label.
15-6	June 2008	Updated website address for Workers' Compensation forms.
16-4	June 2008	Updated website address for CDC document on biosafety containment.
16-10	June 2008	Updated website address for label.
2-3	August 2008	Updated website address for Laboratory Safety Plan.
12-6	February 2009	Revised paragraph on chemical waste segregation for acids and bases.
12-7	February 2009	Revised paragraph on chemical waste segregation for used solvents.

This page intentionally left blank.