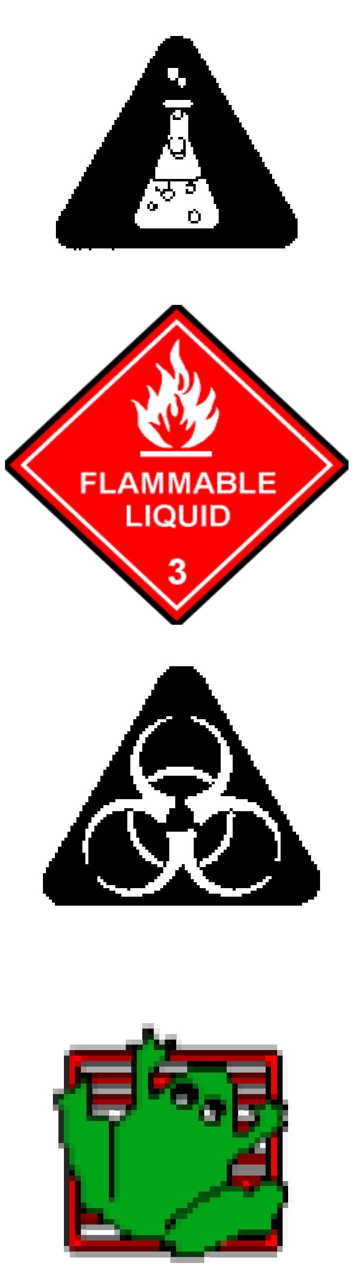
Smithsonian Institution



Laboratory Safety Manual

"There are no safe chemicals or safe equipment; the people and their work practices make a laboratory safe."

Adapted from the American Chemical Society

Issued: 1-28-05

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INTRODUCTION

Laboratory safety is largely dependent on the human factors of safe work practices and a well-trained lab staff. Laboratory protocols involve a wide variety of processes and chemicals that are not always routine and repetitive, nor can they always be conducted in a full enclosure hood. Therefore, reducing the potential for injuries and illnesses in a laboratory is critically dependent on scrupulous attention to safe work practices, multiple forms of controls, and frequent training.

This **SI Laboratory Safety Manual** has been prepared to assist Principal Investigators in developing specific **Laboratory Safety Plans** (LSPs). All laboratory operations are required by **SI policy** and the Occupational Safety and Health Administration **(OSHA) Standard 29 CFR 1910.1450**, *Occupational Exposure to Hazardous Chemicals in Laboratories* to have a LSP. The creation and periodic revision of your LSP should involve all members of the laboratory team, and in doing so, will heighten safety awareness at all levels. The Manual also provides a concise review of the basic tenets of laboratory safety expected for interns, volunteers, managers, and other staff with occasional or intermittent laboratory duties. This Manual alerts its readers to the range of issues that a specific LSP should address whatever its specific purpose.

Appendix A provides an outline for a LSP, which can be tailored to address the specific protocols of each laboratory. The Manual chapters themselves provide technical guidance to support the development of each LSP section, and as a resource supplement to the SI Safety Handbook, SD 419. The Office of Safety and Environmental Management (OSEM) also offers group Lab Safety Workshops, and technical assistance to individual laboratories, departments, and facilities in the development of their LSPs.

The Manual will be periodically reviewed by the facility-appointed Laboratory Safety Officers and members of the SI science community. Updates and new fact sheets will be added as needed to the document and as postings to the OFEO/OSEM website (ofeo.si.edu) as accessed through *Prism.* Comments and suggestions are welcome, and should be forwarded to OSEM through your facility Laboratory Safety Officer or Safety Manager.

SCOPE

All employees, visiting researchers (including those with short-term appointments or interagency agreements), volunteers, interns, or contractors assigned to laboratory work must be advised of the provisions of their LSP before working with chemicals or processes in the laboratory, and are expected to utilize the specified safe work practices.

A laboratory is defined as any Smithsonian workplace for testing, analysis, research, instruction, or similar activities that involve the use of small quantities of multiple, hazardous chemicals on a non-production basis, where such chemical processes operate on a scale that can easily and safely be done by one person, and where the added possibility of biohazards and radioactive hazards also exists.

ACKNOWLEDGEMENTS

The Office of Safety and Environmental Management expresses gratitude to the following members of the SI scientific and management community for their collaborative input and expert review of the SI Laboratory Safety Manual.

- The Office of the Undersecretary for Science
- The Office of the Undersecretary for Art
- The Office of the Deputy Secretary
- Dr. Wayne Coats, Smithsonian Environmental Research Center (SERC)
- Liza Hamill, Safety Manager, SERC
- Dr. Mary Ballard, Smithsonian Center for Materials Research and Education
- Dr. Lee Weigt, Laboratories of Analytical Biology
- Elizabeth Dietrich, Manager, Museum Support Center (MSC)
- Jessica Meltzer, Safety Manager, MSC
- Dr. Amelia Logan, Mineral Sciences, National Museum of Natural History (NMNH)
- David Schmidt, Vertebrate Zoology, NMNH
- Stanley Yankowski, Botany, NMNH
- William Boykins, Paleobiology, NMNH
- The NMNH Laboratory Safety Committee

Chapter 1

ELEMENTS of a SITE-SPECIFIC LABORATORY SAFETY PLAN

The most effective way to reinforce safe work practices is to involve every lab worker at every level in the writing and review of a Laboratory Safety Plan (LSP). Such a Plan is required by SI policy, and is also known as a "Chemical Hygiene Plan", under OSHA. **The main principle is to make this as practical, accessible, and user-friendly as possible!**

For instance:

- A facility with 5 or less laboratories may find it easier to write a separate LSP for each one. A facility with numerous departments, each having multiple labs, may find it more convenient to write a broader departmental LSP, which includes sections for each particular Department's experiments and processes.

- The LSP can be written in whatever format is most practical for your laboratory (c.f.: inserting safety warning text boxes into the protocol itself, or creating a complete document to post in the lab). Whatever format is followed, the final product(s) is/are to be written with the assistance of, and reviewed and approved by, the Laboratory Safety Officer (LSO) appointed by the facility Director.

Your LSP is to include the following sections. Technical guidance for each section is provided in the noted Manual Chapters. *A template for a typical LSP is included as Appendix A of this Manual, to help guide you through the steps.*

- ✓ Designation of authority and responsibilities (Chapter 2).

- ✓ Activities that require special restrictions and/or approvals, due to their highly hazardous nature. (Chapter 5)

- ✓ Hazard identification, exposure evaluation, and safe work procedures for each experiment or protocol (Chapters 3-14)

- ✓ Methods to ensure integrity and maintenance of controls, including personal protective equipment and local exhaust ventilation systems. (Chapters 10 and 11, as a minimum).

- ✓ Requirements for employee initial and periodic hazard awareness training (Chapter 15).

Chapter 2

RESPONSIBILITIES

Facility/Museum Directors retain overall responsibility for implementing the provisions of this Manual and the SD419 Safety Handbook to ensure the safe use and disposal of hazardous materials used in laboratory work within their jurisdiction. The Director is also responsible for designating a Laboratory Safety Officer (LSO) to manage the development and implementation of the facility's site-specific Laboratory Safety Plan(s) (LSPs), and for transmitting design and modification plans for laboratory space for review through the SD410 process.

Laboratory Safety Officers are to be knowledgeable, by formal training and practical experience, in chemical or biological laboratory protocols and the associated sciences. The LSO shall provide technical guidance in developing and reviewing the facility LSPs, including suitability of physical location, and shall have approval authority for the final LSP. The LSO also ensures that the facility LSPs are re-evaluated annually, or more often as processes change or in the event of a change in LSO appointment.

Laboratory Directors, Principal Investigators (PIs), and Supervisors are to be knowledgeable of the potential health and safety hazards associated with their work, including the means to control or eliminate such hazards, per the provisions of this Manual, and for the implementation of a site-specific LSP for laboratory work under their control.

Employees are to adhere to assigned LSPs and other precautions set forth by supervisory personnel, report any unsafe conditions to their supervisor, and notify supervisors or Occupational Health Services Division (OHSD)/OSEM of a significant change in the employee's health status which would warrant additional safety precautions to prevent adverse occupational exposure.

The **Office of Safety and Environmental Management** (OSEM), upon request or as warranted, will offer direction, medical consultation, and technical assistance in occupational safety, fire safety, industrial hygiene, environmental management, and occupational health, and to museum/facility safety coordinators, laboratory safety officers, hazardous waste coordinators, and radiation safety coordinators in implementing the requirements of this Manual. OSEM will also be responsible for reviewing and updating the contents of this Manual at least annually to reflect current codes and regulations, as well as best practices.

The **Office of Facilities Engineering and Operations** (OFEO) will: (1) ensure prompt correction of mechanical and utility system deficiencies identified through annual maintenance, testing, or inspections; (2) report scheduled outages of ventilation, electrical, and other building systems to laboratory supervisors; and (3) train custodial and maintenance workers as to the precautions to be taken when working in a laboratory environment and/or on laboratory equipment.

Chapter 3

RISK ASSESSMENT

Risk assessment requires an understanding of both the ***hazards*** (inherent potential for causing injury or illness) of the chemicals and equipment, and the ***probability that harm will occur*** under the intended work conditions and with the intended levels of controls. Identifying all the health and safety hazards in a research or conservation lab is more challenging than for an industrial process because of the variety of chemicals in use, in storage, or as part of the collections themselves. The assessment should address the hazards associated with the properties and reactivity of materials being used and potential end products, hazards associated with the operation of equipment, and hazards with proposed reactions.

A. MAJOR HAZARD CLASSIFICATIONS: Your LSP should identify whether any of the following hazards apply to your laboratory processes:

- **Fire Hazard**
  Flammability is one of the most common chemical hazards. To handle a flammable material safely, you must know its flammability characteristics: flash point, upper and lower limits of flammability, and ignition temperatures. This information appears on each chemical's Material Safety Data Sheet (MSDS).

- **Explosion Hazard**
  There are substances that are explosive in response to heat, light, friction, static discharge, mechanical shock, or contact with a catalyst. With some substances, very tiny amounts of impurity are sufficient to begin a reaction that can quickly transition to detonation. Hazards include old, degraded chemicals and peroxide-forming agents like picric acid.

  A laboratory work area is considered to contain an explosion hazard if any of the following apply:
  - ✓ Materials stored have a National Fire Protection Association (NFPA) reactivity rating of 4.
  - ✓ Use or formation of materials with an NFPA reactivity hazard rating of 4.
  - ✓ Presence of highly exothermic reactions such as polymerizations, oxidations, nitrations, peroxidations, hydrogenations, or organo-metallic reactions.

- **Reactive Hazard**
  Certain chemicals, when mixed, produce new and volatile or toxic chemicals, usually rapidly and violently leading to fire or explosion. Examples include water-reactive chemicals (elemental sodium or potassium), oxidizers (perchloric acid, ammonium nitrate), and reducing agents (ammonia, metals)

- **Electrical Hazard**
  Electrical shock or similar injuries can occur from contact with energized circuits or equipment.

- **Toxicity**
  Toxicity is the potential of a substance to cause injury to the body. To properly evaluate the degree of toxicity, you need to know the quantity demonstrated to be toxic (usually expressed in terms of Lethal Dose or Lethal Concentration) in experimental studies, whether the effect is acute or chronic, the routes of entry into the body (ingestion, inhalation, absorption, or injection), and symptoms and target organs of over-exposure.

- **Radiation Hazard**
  Ionizing, non-ionizing, or laser radiation sources are used as tools for research, and, in some cases, can be a byproduct of the research. Acute exposure to radiation at high levels can rapidly cause serious health effects, even death. Chronic exposures can lead to delayed health effects, including possible cancers.

- **Biohazard**
  Biohazards include organisms (viral, fungal, and bacterial) or products of those organisms that present a risk to humans, including animal-to-human transmission.

B. RESOURCES FOR HAZARD IDENTIFICATION

- **SI Resources**
  Your primary resources for this process are your facility LSO, OSEM training workshops, and Safety Risk Analysis tools and checklists. **Appendix B** is an annotated list of safety publications that are available through the SI Library Museum Support Center branch.

- **Material Safety Data Sheets (MSDS)**
  U.S. manufacturers are required by law to produce an MSDS on every chemical and hazardous material they produce. The MSDS is the lab's initial source of details on health effects, fire ratings, reactivity and storage precautions, personal protective and control recommendations, first aid and medical response, and disposal. MSDSs are often sent with chemical shipments, and are often available on manufacturer's web sites.

- **Container Labels**
  The chemical warning label affixed by the manufacturer to each container also contains details similar to the MSDS and should never be removed or changed while chemical remains in the container (NOTE: the external Department of Transportation (DOT) shipping label is NOT as specific and only lists the most urgent information).

- **Toxicology and Safety Information Web Sites**
  The MSDSs are often not updated as new toxicological data is published. The texts and web sites listed in **Appendix C** are excellent references for most current toxicological and safety-related data.

- **Collections-Based Hazards**
  A compendium of collections-based hazards can be found on http://ofeo.si.edu/safety_health/Environmental%20Management%20Programs.html, under "Collections management work practices"

- **Radiation safety**, and **laser safety**, are addressed fully in SD419 Chapters 30 and 34, respectively, as well as in selected resources in **Appendix C**.

- **Biohazards**, including work with **microbiological and zoonotic agents**, are best characterized in "Biosafety in Microbiological and Biomedical Laboratories", 4th (or most current) Edition, and in the references in **Appendix C**.

C. SAFETY RISK ANALYSIS TOOLS

- A Job Safety Analysis (JSA) can be adapted to reviewing laboratory bench protocols for potential hazards.
- Strike a balance between breaking down your work processes into an unnecessarily large and detailed number of steps, and making the breakdown so general that critical steps are not included.
- Use this Manual and its references to highlight the hazards associated with each step, being careful to consider the potential for new hazards created should the experiment take a wrong turn or incompatible chemicals be mixed accidentally.
- Using the step-by-step breakdown, and the list of hazards, decide what actions are needed to prevent accidents, injuries, or occupational illness.
- Be specific; saying exactly what needs to be done, such as: "Wear blue nitrile gloves (found in PPE storage drawer) and non-vented safety goggles", instead of "Wear gloves and eye protection".

(Suggestion: Create a table of the major steps in your protocols and list the following information for quick reference, based on references in this Manual and in SD419 Safety Handbook.)					
Major Steps in Process	Anticipated Health or Safety Hazards	Required PPE for Each Step	Required Work Practices, including local exhaust.	Special notes on compatible / safe storage & handling	Special Precautions for Highly Hazardous Materials.

D. CHEMICAL EXPOSURE DETERMINATIONS

The actual health risk from a particular chemical is a function of both its toxicity (its inherent hazard) and the exposure dose actually absorbed by the user.

- *Toxicity* is the capacity of a material to produce injury or harm when the chemical has reached a sufficient concentration (dose) at a certain site in the body.
- *Exposure dose* is the amount of chemical that has been absorbed by the body and could therefore reach that site to do harm.
- The *risk* of working with that chemical is the probability that this exposure dose will occur.

OSEM is responsible for conducting environmental and personal exposure assessments, and should be contacted to schedule monitoring (202-275-1167). Exposure monitoring is required by certain OSHA standards, as listed in **Appendix D**.

- **Airborne (inhalation exposure) samples and skin/glove wipe samples** can be used to determine exposure by looking at the concentration of the chemicals in the work environment, available to be inhaled, ingested, or absorbed. Airborne concentrations can be measured via calibrated personal sampling pumps and appropriate collection media, worn by the employee through the course of the work activity.

- **Radiation dose** is measured through ambient instrumentation and by personal dosimetry through the SI Radiation Dosimetry Program (see Chapter 12 of this Manual).

- **Biological Monitoring** (exhaled breath, urine and blood) is useful if significant exposure can occur through routes other than inhalation. This testing reflects absorption by all routes of entry and offers information beyond that provided by air sampling alone.

HOWEVER, *routine exposure monitoring in a chemical laboratory is often not practical when use of many different chemicals, in short time increments, creates short-term exposure peaks that are difficult to detect through traditional monitoring. The emphasis in laboratory safety and health is in designing safe work practices and engineering controls that minimize exposures to the lowest reasonably achievable.*

Chapter 4

MEDICAL MONITORING

Medical monitoring is conducted on exposed individuals to evaluate any adverse health effects of those exposures. The major purpose is the early detection of disease or conditions for which treatment can prevent further illness. It can also be a valuable tool in hazard control, by detecting when an initially effective control or work practice has lost effectiveness, or by detecting previously unknown exposures, possibly from a source outside of the work environment (e.g., lead exposure from the home).

Occupational Health Services Division/OSEM will provide medical consultations and examinations to affected employees:

- Whenever an employee develops signs or symptoms of exposure to a hazardous chemical or biological agent to which the employee may have been exposed in the laboratory.
- Whenever a spill, leak, explosion, or other occurrence results in the likelihood of a serious overexposure to a hazardous chemical or biological agent.
- When an employee requests a medical consultation due to health concerns related to assigned tasks and/or change in personal medical history, such as pregnancy, special medications, or diagnosed hypersensitivities or other illnesses.
- When exposure monitoring results trigger medical surveillance requirements under a particular OSHA standard (see **Appendix D**), or when other regulations mandate medical consultations, such as for the use of respiratory protection, or for animal handlers.

Chapter 5

SPECIAL RESTRICTIONS

The LSP is to state which activities are prohibited when working alone, or whether special provisions are required to be made for a person to work alone during any phase of the activity.

A. Highly Hazardous Materials

"**Highly hazardous**" refers to chemical carcinogens, reproductive toxins including teratogens and mutagens, acutely toxic substances, and highly reactive materials, as defined by OSHA and per **Chapter 9H** of this Manual. Use of materials deemed "highly hazardous" requires the most rigorous review and approval by the LSO. No modifications to LSPs involving highly hazardous materials can be made without re-approval by the LSO.

B. Working Alone

Individuals using highly hazardous chemicals, which could cause immediate serious injury or incapacitation as a result of an accident, should not work alone. Another individual capable of coming to the aid of the worker should be in visual or audio contact.

- If working alone is absolutely necessary, the worker should have a phone immediately available and should be in contact with another person (who knows that he or she is being relied upon) at least every 30 minutes.

- The laboratory supervisor or PI is responsible for determining whether the work requires special precautions, such as having two people in the same room for particular operations.

C. Unattended Experiments

Laboratory operations involving hazardous substances are sometimes carried out continuously or overnight with no one present. It is the responsibility of the worker to design these experiments so as to prevent the release of hazardous substances in the event of interruptions in utility services such as electricity, cooling water, and inert gas. Carefully examine how chemicals and apparatus are stored, considering the possibility for fire, explosion or unintended reactions.

- Unattended heating operations shall be provided with an automatic shutdown to prevent system failure resulting in fire or explosion.

- Office of Protection Services is to be notified of unattended experiments involving hazardous substances and provided with necessary points of contact and response instructions per the facility emergency response plan.

- Laboratory lights should be left on, and signs should be posted identifying the nature of the experiment and the hazardous substances in use, and the contact information for the responsible individual in the event of an emergency.

Chapter 6

LABORATORY POSTINGS and EMERGENCY RESPONSE

- **All entrances** to laboratory work areas in which highly hazardous materials are present shall be identified and posted with warning signs indicating any particular instructions for securing the laboratory and shutting-down equipment in case of an emergency, and the names and phone numbers of the Principal Investigator and emergency contact per the facility's own disaster response plan. Including this information on the cover page of your LSP, then posting a copy of the LSP on the door, is one way to accomplish this.

- In case of a fire, medical emergency or other disaster, laboratory occupants are to follow the **facility's disaster and emergency response plan**, which lists the phone numbers to call to report an incident.

- In the event of a chemical spill, try to turn off any reaction apparatus, especially heat sources, notify supervisors immediately and follow the response steps in your facility's "**Hazardous Chemicals Emergency Spill And Leak Control Procedures, Reporting Person's Check List".**

- Lab Safety Plans are to be reviewed for the need for any **specialized medical antidote treatment** needed upon exposure and on the way to seeking emergency medical help.

    - For instance, exposure to hydrofluoric acid may require immediate application of calcium gluconate. OHSD will provide training, upon request, to laboratories using this acid.

    - Similarly, labs using macro quantities of cyanide should consider keeping the antidotes (amyl nitrate and thiosulfates) on hand. OHSD stands prepared to offer training and consultation in response to cyanide exposures and the use of antidotes.

Chapter 7

GENERAL OPERATIONS & MAINTENANCE PRACTICES

There are multiple safe lab practices that apply to most laboratory activities. It is the responsibility of the principal investigator, supervisor, and each employee to understand and follow these guidelines, for their safety and that of their co-workers. It is the PI who determines who is "authorized" or qualified to work on certain equipment and/or make adjustments to equipment.

A. GENERAL LAB SAFETY

- Before beginning any new operation, reduce the potential for accidents by obtaining information from reference materials regarding hazards, instituting appropriate protective procedures, and planning the proper positioning of equipment.

- Chemicals shall not be brought into a laboratory work area unless the design, construction, and fire protection of the facility are suitable for the quantities and hazards of chemicals being introduced.

- Portable fire extinguishers shall be installed, located, and maintained throughout all laboratory units in accordance with NFPA 10 – *Standard for Portable Fire Extinguishers* and NFPA 45 - *Standard on Fire Protection for Laboratories Using Chemicals*.

- All heating of flammable and combustible liquids shall be conducted so as to minimize fire hazards.

- To the extent feasible, operations are not to be left unattended. In the event operations must be left unattended, leave lights on, place an appropriate sign on the door, and provide for containment of toxic substances.

- Any work involving an apparatus which may release toxic chemicals (vacuum pumps, distillation columns, etc.) should be conducted in a hood or vented into a local exhaust device.

- Chemicals and apparatus are to be placed back from edges of tables or benches.

- Access must be kept clear to safety showers and eye washes; exits and emergency equipment must not be blocked; and stairwells and hallways must not be used to store material.

- Equipment is to be used only for its designed purpose. Only authorized personnel are allowed to make repairs or adjustments on equipment.

- Damaged glassware is not to be used. Extra care is to be used with Dewar flasks and other evacuated glass apparatus, which should be shielded or wrapped to contain chemicals and fragments should implosion occur.

- Ensure all employees are educated on “Stop, Drop, and Roll” should their clothing catch on fire.

- Ensure gas shut-off valves are properly marked and readily accessible.

- Hands and areas of exposed skin are to be washed well and often while in the lab and before leaving. All food, beverages, cosmetics, and medications are to be stored outside the laboratory. Lab sink areas are not to be used for washing/storing food and beverage utensils, coffee makers, microwaves, etc. The lab sink and eye wash station water supply are not to be used for drinking water due to the potential for chemical contamination.

- Skin that could be exposed to chemical splash is to be covered. Shoes must cover the entire foot. Long hair and loose clothing are to be secured to prevent them from coming in contact with contaminated materials or moving equipment parts. Hanging jewelry or absorbent watch straps should not be worn.

B. GUIDELINES FOR CUSTODIAL AND MAINTENANCE WORKERS

- Your supervisor and the facility LSO should be providing you with an overview of lab safety in the zones to which you are assigned. If you have any questions or concerns about the safety of working in your assigned areas, ask your supervisor and the scientists/occupants of the laboratory space for more information.

- Any container (box, bottle, beaker, etc.) that holds a chemical must be clearly labeled as to content and appropriate warnings. Do not touch, move, or handle containers of chemicals in a lab.

- If chemicals or equipment needs to be moved for you to perform your work in the lab, have your supervisor and the laboratory supervisor arrange for this to be done first.

- If this cannot be done, or there is still a chance that you may contact hazardous chemicals in the course of your work, wear appropriate personal protective equipment as assigned by your supervisor (gloves, goggles, etc.).

- If the contents of any container are spilled, do not touch or clean up! Leave the area at once, close the door, and notify your supervisor and fellow lab occupants immediately (who should then follow the facility Spill Response Plan).

- Always wear barrier gloves when emptying trash containers! Be cautious for broken glass. If you see chemical containers, needles, or any objects that you are in doubt about handling, leave them in the laboratory and notify your supervisor.

- Maintenance personnel: Before working in a laboratory or chemical fume hood, notify the laboratory supervisor or lab occupant about the work to be performed. **NEVER turn off the hood, electrical power, equipment, or disturb any lab operations without first getting approval from the laboratory supervisor or principal occupant!!! Do NOT work in or on a fume hood used for perchloric acid or radioactive materials without first contacting OSEM for safe work practices.**

Chapter 8

GENERAL SAFETY REQUIREMENTS

A. MECHANICAL AND EXPERIMENTAL APPARATUS

- Inspect all equipment before use. Ensure that defective equipment is not left for someone else to use.

- All mechanical equipment, including refrigerators and freezers, shall be installed in accordance with National Fire Protection Association (NFPA) and National Electric Code (NEC) requirements, properly grounded, and Underwriter Laboratories (UL) listed. The power supply shall be properly fused and protected. Three-prong to two-prong adapters shall not be used. Refer to SD 419, Chapter 9, Electrical Safety, for detailed requirements.

- In general, all mechanical equipment shall be furnished with adequate safety guards that prevent access to electrical connections and moving parts. Laboratory personnel shall receive training in the safe use of this equipment. Refer to SD 419, Chapter 8, Machine Guarding, for detailed requirements.

- Electric power failure or shutdown may cause exhaust hoods to cease functioning. When this occurs, cylinders of toxic or flammable gas must be turned off, reactions producing toxic fumes must be shut down, bacteriological or virological techniques producing pathogenic aerosols must be stopped, and associated systems sealed off insofar as is possible and safe.

- Reactions shall not be carried out under pressure in closed containers unless the container has been tested and certified as able to withstand the pressure. Pressurized apparatus must have appropriate relief devices. Refer to SD 419, Chapter 21, Fired and Unfired Pressure Vessels, for detailed requirements.

- Safety shielding shall be used for any operation having the potential for explosion, such as when a reaction is carried out for the first time or under non-routine, non-ambient conditions. Shielding must be adequate to protect all personnel in the area.

- Pressure vessels should not be opened until the internal and atmospheric pressures have been equalized.

B. ELECTRICAL SAFETY

- All electrical installations, including wiring, apparatus, lighting, etc. shall comply with the requirements of NFPA 70 - *The National Electrical Code (NEC).*

- Electrical receptacles, switches, and controls shall be located so as not to be subject to liquid spills.

- All 125 volt receptacles installed within 6 feet of a sink will be provided with Ground Fault Circuit Interrupter (GFCI) protection.

- Flammable liquids should be kept away from electrical equipment.

- Do not use electrical equipment while standing on a wet surface or when hands are wet.

- Electrical panels in the laboratory must be easily accessible. Do not store materials on the floor in front of panels.

- Avoid working on live circuits. Connect power only to perform necessary tests and disconnect when finished.

- When building new equipment or repairing the 115 volt alternating current (AC) portion of an existing chassis, cover the bare connections with insulation or install a protective shield.

- Completely de-energize a system before conducting any electrical work with exposed circuits or contacts having a potential to ground of greater than 30 volt alternating current (AC) or 6 volt direct current (DC). Adequate safeguards must be in place to prevent the system from accidentally being re-energized.

- Replacement parts should have the same or higher voltage/current ratings as originals.

- Safety interlocks are not to be bypassed unless necessary to service equipment. When necessary, care should be taken to avoid voltage hazards and to remove the bypass when finished.

- Laboratory work areas, laboratory units, and laboratory hood interiors generally shall be considered as "unclassified" electrically, with respect to Article 500 of NFPA 70 – the NEC. It may, however, be necessary under special conditions to classify a portion or all of a laboratory work area as a hazardous location.

- Only trained personnel may repair and maintain electrical equipment. High voltage electrical work shall be performed by qualified electricians only.

C. COMPRESSED GAS CYLINDERS

- The handling, storage, and use of oxygen, fuel, or any compressed or liquefied gas cylinder shall be in accordance with the policy specified in SD 419, Chapter 17, Compressed Gases.

- Storage of compressed or liquefied gas cylinders in a laboratory shall be limited to those cylinders needed for the experiment in progress. When stored or in use at a laboratory, the maximum quantity of flammable or oxidizing gases within a laboratory unit shall be per NFPA 45. For laboratory work areas of 500 $ft.^2$ or less, the maximum cylinder volume shall not exceed 6.0 $ft.^3$ of flammable or oxidizing gases. Cylinders must be secured in an upright position with an approved strap and bracket or chain device, and protective caps in place when stored.

- Cylinders must be transported securely on carts. Cylinders must be capped when they are being moved or not in use.

- A compressed gas cylinder is considered to be in use if:
  a) It is connected through a regulator to deliver gas to a laboratory operation.
  b) It is connected to a manifold being used to deliver gas to a laboratory operation.
  c) It is a single reserve cylinder secured alongside the cylinder in item (a).

- Do not drop cylinders or allow them to strike against each other.

- Cylinders and other containers of compressed gases must be kept below 125^{o}F. Contact with a direct flame is not permitted under any circumstances. Direct sunlight must be avoided.

- Do not rely on color codes for identification of gas; use the tag or decal.

- Stand away from the face of regulator when opening the valve. Free gases should be turned on slowly and fully. Liquefied gases should be turned on partially.

- Toxic gases shall be ordered in the smallest quantity possible for the nature of the experiment. Use of cylinders shall only be under a laboratory hood, vented gas cabinet or with special safety-vented regulators connected to a local exhaust system for direct discharge to the atmosphere. Consult with OSEM before starting use.

- Only personnel experienced/trained in the use of compressed gases may handle toxic or explosive gases.

- Use special safety vented regulators for highly-toxic and hazardous gases, with the vent piped to a hood or other local exhaust system for direct discharge to the atmosphere in the event of a leaking regulator.

- Oily gauges should **never** be used with oxygen. Gauges used with oxygen should bear the warning: **"Oxygen - Use No Oil".**

D. CRYOGENIC SAFETY

- **Cryogenic Fluids.** Be aware that there is a possibility of explosion, spilling, frostbite, and an escape of asphyxiating gases when using cryogenic fluids.

- In all cases of low temperature operations, the names of persons knowledgeable of the operation of the equipment are to be posted in an obvious location near the equipment.

- When handling liquefied gases, the eyes must be protected with a full face shield. Insulating gloves must be worn when handling anything that is, or that may have come into contact with, the liquid. Gloves must be loose-fitting. Leg wear must not be tucked inside foot wear when liquids are poured from or used in open containers.

- Only authorized personnel are to be allowed to repair or make adjustments to cryogenic systems.

- All cryogenic storage vessels shall be chosen to withstand the weights and pressures of the material used, and shall have adequate venting to prevent pressure buildup.

- Cryogenic fluids are to be used in equipment and systems that are free from contaminating materials that could create a hazardous condition upon contact with the cryogen. Mixtures of gases and fluids must be closely controlled to prevent the formation of flammable or explosive mixtures.

- Evacuated glassware (commonly Dewar flasks) must be shielded against implosion.

Chapter 9

HAZARDOUS MATERIAL STORAGE AND HANDLING

Laboratory chemical storage and handling hazards can be effectively managed if you:

- Maintain good ***inventory control*** and purchase/use the least amount possible.
- ***Label*** all stored and in-process chemicals clearly and completely.
- Adopt ***safe handling*** practices.
- Use ***secondary containment*** and practice your ***spill response*** plan.
- ***Segregate incompatible chemicals*** and ***store in appropriate cabinets*** or special cold-storage.
- Develop ***special controls for highly hazardous materials***.

A. INVENTORY CONTROL

- Purchase chemicals only in the quantities needed and in containers of the smallest practical size. Although the cost may be higher, significant savings will be gained by reduced hazardous waste disposal or clean-up costs. Consider purchasing pre-made molar or normal solutions.
- Avoid glass containers. Purchase plastic bottles, or shatter-resistant plastic coated glass bottles.
- Inventory your chemical supplies at least annually and actively share or distribute excess stocks with other departments to minimize waste. Dispose of all unused and outdated chemicals through the SI hazardous waste program.
- Products that could also be purchased for home use, such as soap, oil, or cleaning sprays, must be part of your chemical inventory and have an MSDS on file if the product will be used in an occupational setting and could cause a health exposure in the workplace. If someone brings in, say, an ant or cockroach insecticide from home to treat some areas of the collection, not only is that product now part of your industrial chemical inventory, but the activity is now regulated in the workplace as a pesticide application requiring a licensed applicator and proper work precautions and any disposal of the spray can must be included in the facility hazardous waste disposal program.
- **Before a scientist or researcher retires or leaves the lab, all leftover chemicals are to be inventoried and distributed or disposed**.

B. LABELING

- Laboratory staff should ensure that labels on containers of hazardous chemicals are not removed or altered, particularly the manufacturer's original label. Empty chemical containers must never be reused for another purpose, even if the labeling is changed. Reactions with new liquid and residual chemical could be extremely dangerous. All bottles, containers, and other apparatus containing chemicals shall be accurately and clearly labeled as to contents, hazards, and where practical, the appropriate precautions required when handling the chemical.

- In addition, **peroxide-forming** compounds must be labeled as to the **date of receipt by the lab and the date of opening**.

- Avoid the use of grease pencils or other markers that will wear off.

- **There are three levels of complexity to labeling**: original container, secondary transfer containers, and small container (vials, flask, beakers) for immediate, same-day use. The labels should serve as backup to your hazard communication training.

1. The manufacturer's original labels must contain the required OSHA information
    - name of chemical or solution
    - manufacturer name and emergency telephone number
    - hazard warning (health effect or target organs)

2. For laboratory-prepared solutions and when chemicals are transferred to secondary containers not intended for immediate use, labels should include:
    - Name (no abbreviations) of the chemical and its concentration.
    - For prepared solutions: date prepared.
    - Hazard warning on the most serious health or safety hazard posed (consult MSDS). Stickers can be applied indicating "corrosive", "carcinogen", "water-reactive", "flammable", etc.
    - If space allows, or if special precautions are critical, expand the hazard warning to include the target organ and the required protection (e.g. "Corrosive, esp. to skin and eyes. Use gloves and goggles").

3. Containers for immediate (same day) use should have:
    - Chemical name and its concentration

C. SAFE HANDLING AND TRANSFER

- Hand carried chemicals should be placed in unbreakable secondary containers such as bottle carriers or acid-carrying buckets. Wheeled carts used to transport chemicals should have side guards and lipped surfaces capable of containing a break, and sturdy wheels that move easily over uneven surfaces. DOT shipping containers make excellent secondary containment for transport across the building.

- Staff should wear protective aprons, gloves, and goggles when transporting chemicals.

- Freight-only elevators are to be used when possible. Do not use elevators with other passengers on board.

- Class I flammable liquids (any liquid having a flash point below 100^{o}F) shall not be stored or transferred from one vessel to another in an exit access corridor, open plan building, or ancillary spaces unprotected from the exit access corridor.

- Transfer of Class I liquids to smaller containers from bulk stock containers not exceeding 5 gallons in capacity shall be performed in a laboratory hood, in an area provided with ventilation adequate to prevent accumulations of flammable vapor exceeding 25% of the lower flammable limit, or within an inside liquid storage area approved for dispensing.

- Class I liquids shall not be transferred between conductive containers of greater than 1.1 gallons, unless the containers are <u>bonded</u> and <u>grounded</u> (the process of providing an electrically conductive pathway - usually by clipping connecting wires - between a dispensing container and a receiving container [bonding], and the receiving container and an earth ground).

D. SECONDARY CONTAINMENT AND SPILL CONTROL

- Liquid chemicals should be stored in corrosion-resistant trays or on spill pallets or other secondary containment to contain a break or leak.

- Concentrated acids and bases should be stored in acid or caustic storage cabinets. If possible, keep corrosives stored in their original (e.g. Styrofoam cubes) shipment containers.

- Your facility Hazardous Waste Coordinator has a spill control policy that should be posted in your laboratory and with which everyone in your lab should be familiar. In the event of a chemical spill, try to turn off all reaction apparatus, especially heat sources, notify supervision immediately and follow the response steps in your facility's "**Hazardous Chemicals Emergency Spill And Leak Control Procedures, Reporting Person's Check List".**

E. CABINET AND SHELF STORAGE - General Precautions

- Cabinets and other storage areas are to be marked with the general class of chemical stored, and any other pertinent warnings.

- Storage areas should have good general ventilation and be well-lighted.

- On shelves, containers should be staggered for easy access, with labels facing out. DO NOT ALPHABETIZE STORED CHEMICALS; SEPARATE BY COMPATIBILITY (see next section).

- Heavy and large containers are to be placed on bottom shelves. Chemicals, especially liquids, should be stored below eye level. Larger containers should be stored on lower shelves. Exposure to heat or direct sunlight must be avoided. Avoid storing chemicals on the floor unless in approved shipping containers. Minimize open shelf or bench top storage, except for those chemicals being currently used, to prevent accidental spills and reduce the risk of fires.

- Cabinets specifically for corrosives (either acids or bases) must have corrosion-resistant paint. Flammable storage cabinets must be constructed to meet the NFPA 30 - *Flammable and Combustible Liquids Code* - and provide an air tight seal; vent holes must be kept covered and flame-arrestor kept in place. Flammable liquids cabinets must be UL Listed or FM Approved for the purpose of storing flammable liquids.

- Oxidizers MUST be stored in separate cabinets from flammables and combustibles. Oxidizers, explosives, and organic peroxides must be separated from combustibles and placed in a metal cabinet, or in an approved dry, cool, and well-ventilated location.

- If acids and bases must be stored together in the same cabinet, place each in separate secondary containers (non-reactive trays) on opposite sides of the cabinet to minimize intermingling in case of a spill or drip (in other words, do not store all the acids on one shelf, and all the bases on the shelf below).

- Initially assign each chemical to broad hazard classes, for example: **flammable, corrosive (acids and bases), reactive oxidizer or reducer, special hazard (air/water reactive, peroxide forming chemical, store at reduced temperature or under an inert atmosphere, highly toxic).**

- Chemicals that possess more than one hazard (i.e., oxidizer and corrosive) are assigned to the class that, in the judgment of the LSO, represents the greater hazard for that laboratory.

- **Post incompatibility lists (Appendix E, and from your MSDSs) for reference**.

F. REFRIGERATORS and FREEZERS - Flammable Storage

- All refrigerators or freezers shall be distinctly marked as to whether it is suitable for the storage of flammable liquids.

- All refrigerators housing flammable liquids shall be of the “flammable safe” or explosion proof variety, and shall be UL Listed or FM Approved for such use. Standard household variety refrigerators shall not be used to store flammable liquids.

- Refrigerators, freezers, and cooling equipment located in a laboratory work area designated as a Class I location, shall be approved for use in a Class I, Division 1 or 2 location and shall be installed per the NEC.

- Flammable liquids stored in refrigerated equipment shall be in closed containers.

G. STORAGE OF CHEMICALS BY CLASS
(see also Appendices E through J)

Flammables and Combustibles
Flammables are chemicals that have a flash point less than 100^{o}F. Combustible chemicals have flash points that are 100-200^{o}F. If stored or used improperly, flammables and combustibles can be a fire hazard.

- *Examples:* benzene, alcohols, hydrogen sulfide, acetone, ethers, organic acids (i.e., glacial acetic acid)

- Handling and storage of flammable liquids shall comply with NFPA 30 – *Flammable and Combustible Liquids Code.*

- Chemical container types and maximum capacities shall comply with Table 7.2.3.2 of NFPA 45 (**Appendix F**). Consult with the LSO and OSEM as required, to determine what is permissible.

- The quantity of hazardous chemicals within a laboratory unit or in a laboratory work area, that is stored in the open, shall be limited to the minimum necessary to perform required tasks, but in no case should they exceed the quantity allowed by the laboratory unit classifications, as indicated within NFPA 45. (**Appendices G & H**).

- Bulk supplies of alcohol (such as pure material [95% EtOH] in drums) shall be stored in an approved flammable liquids storage room.

- To the greatest degree possible, the storage of flammable liquids in a laboratory work area, outside of an approved flammable liquids cabinet or storage room, should be limited to what is needed for a single day's use. Otherwise, flammable liquids should be stored within an approved flammable liquids cabinet when not in use.

Corrosives: Acids
Acids are corrosive and react violently with bases. There are two main groups of acids: organic acids, and inorganic (mineral) acids. Some inorganic (mineral) acids are oxidizers and will react with organics, increase burning rate of combustibles and contribute an oxygen source to a combustion reaction. Therefore, inorganic (mineral) acids should be stored separately from organic acids.

- *Examples of inorganic OXIDIZING acids:* perchloric acid (particularly dangerous at elevated temperature), chromic acid, nitric acid, sulfuric acid (particularly dangerous at elevated temperature).

- *Examples of inorganic MINERAL acids:* hydrochloric acid, hydrofluoric acid, phosphoric acid

- *Examples of organic acids:* acetic acid, formic acid, butyric acid, propionic acid, picric acid, acrylic acid.

- Nitric acid shall be stored separate from other acids.
- Segregate acids from bases and active metals such as potassium and magnesium.
- Segregate acids from chemicals that could generate toxic gases upon contact, such as sodium cyanide.
- Segregate acids from solvents such as toluene and xylene.
- Segregate **oxidizing inorganic acids** from organic acids, flammable and combustible materials. Most mineral acids can be stored together, except perchloric acid (see below).
- **Organic** acids (e.g., glacial acetic acid) are combustible and should be stored separately or with flammables rather than with inorganic acids. Several inorganic acids are oxidizers and therefore, incompatible with organics.
- **Perchloric acid** and **picric acid** require special handling.
  - ***Picric acid*** is reactive with metals or metal salts and is potentially explosive when dry. Contaminated picric acid is particularly dangerous, as picrate metal salts are potentially explosive compounds. Picric acid must be stored wet with at least 10% water. Store picric acid in a cool, dry, non-ventilated area away from incompatibles or ignition sources.
  - ***Perchloric acid*** at elevated temperature is a very strong oxidizer. It can react with metals, wood and other combustibles to form potentially explosive compounds. For information on the handling, storage and use of perchloric acid, contact your LSO.

- **Corrosives: Bases**
  Bases are corrosive and react violently with acids.
  - *Examples:* ammonium hydroxide, sodium hydroxide, calcium hydroxide, organic amines
  - Segregate bases from acids. Bases are also corrosive to skin and tissue. Pay meticulous attention to personal protective equipment when using bases.
- **Reactive: Oxidizers** (**Appendix I**)
  Oxidizers react vigorously with reducing materials. The reaction can lead to fires or explosions. Oxidizers will increase the burning rate of combustible materials and contribute oxygen to a combustion reaction.
  - *Examples:* halogens, ammonium persulfate, hydrogen peroxide, sodium dichromate, potassium permanganate, perchloric acid, at elevated temperature, ammonium nitrate (and other nitrate salts)

- Keep oxidizers away from flammables, combustibles (such as paper, wood) and other reducing agents.

- **Reactive: Reducers**
  Reducing materials react vigorously with oxidizers. The reaction can lead to fires or explosions.

  - *Examples:* ammonia, carbon, metals, metal hydrides, phosphorus, silicon, sulfur

  - Store reducing materials away from oxidizers.

- **Water-reactive Chemicals**
  Water reactive materials react with water, water solutions, moisture, or humidity in the air to produce heat and/or flammable gases, which can ignite.

  - *Examples:* sodium (elemental), potassium (elemental), calcium carbide, phosphorous pentachloride

  - Store water reactives away from any sources of water or moisture. Review manufacturer's recommendations for special storage conditions, such as under an inert atmosphere or, as in the case of elemental sodium, under mineral oil.

- **Peroxide Forming Chemicals** (**Appendix J**)
  Potentially explosive peroxides are formed by a free-radical reaction of hydrocarbons with molecular oxygen. Distillation, evaporation or other concentration of the peroxide can cause an explosion in contaminated hydrocarbons.

  - *Examples:* diethyl ether, tetrahydrofuran, acetaldehyde, isopropyl ether

  - Store peroxide-forming chemicals away from light and heat. Carefully label all containers with the date received and the date opened. Monitor container dates and avoid keeping peroxide-forming chemicals on hand for more than a year after receipt and 6 months after opening.

H. HIGHLY HAZARDOUS CHEMICALS

- Special attention is to be made in your LSP to work involving "**highly hazardous**" chemicals, defined as chemical carcinogens (**Appendices C & K**), reproductive toxins (MSDS plus web-based references), acutely toxic substances (**Appendix L**), and highly reactive materials (**Appendices I & J,** plus MSDS information).

- **Designate a Restricted Work Area.** Conduct all transfers and work with these substances in a "controlled area" (i.e., a restricted access hood, glove box, or portion of a lab designated for use of highly-toxic substances) for which all personnel with access are aware of the substances being used and the necessary precautions which must be taken. Only trained and authorized personnel are to work in or have access to controlled areas.

- **Signs and labels.** Assure that the controlled area is conspicuously marked with restricted access and warning signs, such as, "WARNING: Highly-Toxic Substance in Use: Authorized Personnel Only" or "WARNING: Cancer-Suspect Agent: Authorized Personnel Only." All containers of these substances must be appropriately labeled with identity and warning such as, "Warning: High Chronic Toxicity or Cancer Suspect Agent".
- **Storage.** Store containers of these chemicals in a ventilated, limited access area in appropriately labeled, unbreakable, chemically-resistant, secondary containers.

- **Establish Decontamination Procedures.** The need for routine decontamination of designated work area, equipment, or personnel depends on the laboratory circumstances. Your LSO and OSEM are to be consulted for specific appropriate decontamination procedures.

- **Medical surveillance.** When using a highly-toxic substance on a regular basis (e.g., 3 times per week), consult the Occupational Health Services Division (OSEM) concerning medical surveillance or other health concerns you may have.

- **Cleanup and Waste Disposal.** Use chemical decontamination whenever possible. Use a vacuum cleaner equipped with a High Efficiency Particulate Air (HEPA) filter, instead of dry sweeping when the toxic substance is a dry powder. A wet mop may also be used when the chemical is not water reactive or otherwise incompatible with water. Ensure that all vacuum filters, bag debris, mop heads or cleaning rags, as well as waste chemicals are transferred from the designated control according to the SI Hazardous Waste Disposal Program. Ensure that contingency plans, equipment, and materials are available to minimize exposures to personnel and property in the event of an accident. Do <u>not</u> ask/expect custodial staff to clean hazardous materials spills, unless they are already members of the facility's trained response team.

Chapter 10

PERSONAL PROTECTIVE EQUIPMENT

Although the goal of any protection program is to either eliminate the hazard or minimize the risk through engineering controls, some operations will still require additional personal protection. It is the responsibility of each supervisor to match the proper type of personal protective equipment to the hazard(s) involved with each laboratory operation.

A. EYE and FACE PROTECTION

All safety eye and face wear must meet the criteria established in OSHA Standards 29 CFR 1910.134-139, and the principles of ANSI Z87.1-2003, Occupational and Educational Personal Eye and Face Protection. Safety eyewear that complies with the ANSI standards will be marked with the symbol "Z87". Eye and face protection is required at all times in the laboratory when there is the potential for exposure to flying particles or sparks, molten metal, hazardous chemicals, biohazardous materials, or hazardous light radiation.

- **For protection against the impact of physical hazards** such as flying particles, glass or metal shards, **safety glasses** with side shields are to be worn in the laboratory. Safety glasses will not protect the eyes from mists, dusts, gases, vapors, or liquid splashes.

- **When working with liquid chemicals, gases, or fine particulates**, indirectly vented or unvented **safety goggles** will be used.

    - *Direct vented goggles offer the least protection and should not be used.*

    - *Indirect vented* goggles will deflect minor chemical splash from entering the goggles, while preventing fogging.

    - *Unvented goggles* are to be used when the hazard is a gas or vapor (such as ammonia or formaldehyde) which can be irritating to the eyes or easily absorbed through the eye.

- **When working with large volumes of hazardous materials**, when the potential exists for significant chemical splash to the face, neck, and ears, **face shields**, in addition to safety glasses or goggles, shall be worn.

- **When working with operations producing harmful light radiation** (i.e., welding, UV light, lasers), eye protection must have **filter lenses** with shading of a certain degree selected on the basis of the harmful wavelengths involved. Consult your LSO or OSEM for technical guidance.

- **Contact lenses** may be worn in hazardous environments when appropriate safety eye and/or face protection is also worn.

B. EMERGENCY EYEWASH and SAFETY SHOWERS

- Every laboratory room must be equipped with an eyewash connected to the domestic water supply that is capable of providing 15 minutes of continuous flushing. Safety showers shall be available within 100 feet of all laboratories.

- In the event of eye injury, eyes must be flushed with copious amounts of plain water for at least 15 minutes. Personnel must not attempt to neutralize or counteract the injury unless expressly instructed to do so by a physician. Local emergency medical personnel must be contacted immediately.

- All persons working in the laboratory shall be trained in the use of the emergency shower and eyewash.

- All emergency eyewashes shall be flushed weekly. All emergency eyewashes and showers shall be inspected at least twice a year. The date of the test and name of the inspector shall be recorded on a tag attached to the device.

C. SKIN PROTECTION

Gloves, lab coats, aprons, and other chemical protective clothing (CPC) are to be worn to protect the skin and prevent contamination on clothing, when exposed to hazards such as:

- Absorption of harmful chemicals,
- Chemical or thermal burns,
- Lacerations, abrasions, punctures,
- Harmful temperature extremes.

Selection: The barrier effectiveness of CPC against a particular chemical is rated (and advertised) in terms of each chemical's permeation rate, breakthrough time, and degradation potential on that material, in accordance with American Society of Testing and Materials (ASTM) standards. **Appendix M** provides additional elements to consider when selecting CPC. Compare the chemicals in use against selection charts published by manufacturers (check web sites) and suppliers (such as Fisher Scientific or Lab Safety Supply), or consult *“Quick Selection Guide to Chemical Protective Clothing”,* Forsberg & Mansdorf, available at the MSC/SIL, OSEM, or through your LSO.

- Permeation rate is the rate at which a known amount of chemical diffuses through a given area of clothing per unit time and can be detected on the inside surface. Breakthrough time is the time it takes for a given chemical to pass through a material from the start of contact on one side, to the detection of chemical on the other side. Units of breakthrough time are usually expressed in minutes or hours and a typical test takes up to 8 hours. If no measurable breakthrough is detected after 8 hours, the result might be reported as a breakthrough time of ">8 hours".

- Degradation (and loss of elasticity) potential of the material is rated in terms of a change in one or more physical properties after contact with the chemical: includes cracking, swelling, shrinking, stretching, and dissolving. It is a more subjective observation but factors into the recommendations of both manufacturers and independent raters. Note that a good degradation value does not mean the chemical will not permeate.

- Thin, surgical-type gloves (latex, vinyl, nitrile are most common) are somewhat protective against incidental contact with certain chemicals and allow dexterity but may not be protective against full immersion or prolonged contact.

- Latex (natural rubber) CPC must not be used by persons allergic to latex. If in doubt, use another material with equal or better protection rating for the chemical(s) used.

- Shoes that offer complete foot coverage (i.e., no sandals or open-toed shoes) are to be worn in the chemical laboratory or any work area with the potential for chemical spills or broken glass. Safety shoes will be recommended only when the process or task warrants such protection (i.e., if there is a danger from heavy objects falling or rolling over the foot).

Cleaning: Most gloves and CPC can be successfully cleaned, except for those used with highly toxic materials, and should be thoroughly washed before taking them off. Gloves for use with highly hazardous materials, such as those listed in Chapter 9, will most likely need to be disposed of after use. Consult your LSO or OSEM for selection assistance.

Lab coats should remain in the lab and be removed immediately upon significant contamination. Do not take lab coats home to be laundered. Use a dedicated washing machine in the facility. If lab coats are sent to an outside firm for laundering, the firm must be notified as to the presence of any hazardous substances/residues on the coats.

Inspection/Maintenance: All chemicals pass through barrier material eventually, so gloves should be replaced on a regular basis regardless of condition. Gloves should be checked before and after use for signs of cracking, leaks, thinning, and simple wear. Check gloves periodically for pinhole leaks (fill with water or air) especially where fingers connect. Stitched areas of seams should be checked. Likewise, pay attention to button and zipper areas on CPC. **Changes in color or hardening, particularly in irregular spots**, indicates degradation, requiring the gloves to be replaced.

D. RESPIRATORY PROTECTION

The use of respirators ("dust masks", or, air-purifying half- and full-face respirators with filters or chemical cartridges) should not be necessary in a properly designed laboratory with adequate engineering and work practice controls. If you believe that your experimental protocols are not properly controlled, or that you need a respirator to avoid an inhalation hazard, contact your LSO for a complete evaluation of your work processes. Respirators are required at the SI if personal exposure potential is 50% or greater of the allowable limits established by OSHA or SI policy. Respiratory protection needs will be determined in consultation with OSEM, and in accordance with the established Smithsonian respiratory protection program (Chapter 27 of the SI SD 419, Safety Handbook). Enrollment in the SI Respiratory Protection Program requires exposure determination, medical clearance examination, and fit-testing and training through OSEM.

E. HEARING PROTECTION

If you believe that hazardous levels of noise exist in your laboratory due to particular equipment or processes, contact your Safety Manager to arrange for an evaluation. Proper hearing protection and engineering controls to reduce noise levels will be recommended as necessary.

Chapter 11

VENTILATION CONTROLS

All work with hazardous materials must be conducted under properly designed and functioning local exhaust ventilation. The most effective and often the most cost-efficient local exhaust system is an **enclosure** hood, such as a chemical fume hood, glove box, biosafety cabinet, or toxic gas cabinet which completely contains the contaminant source. **Capture** hoods, such as "snorkel/elephant trunk" types, slot hoods, or downdraft tables are designed to provide a strong exhaust velocity at a certain distance from the source and can be used for control of materials with low-to-moderate toxicity, or for situations where point source control of hazardous materials cannot be achieved easily in an enclosure and the exposure risk has been assessed to be low-to-moderate.

SPECIAL NOTES!

- Canopy-type receiving hoods are **never** to be used for control of chemical hazards.

- Ductless fume hoods are **generally not recommended** unless specifically approved by OSEM for a particular application.

- Horizontal or laminar flow clean benches **are not** biological safety cabinets. They only provide a clean environment for the material being worked on (not the worker) and therefore, are never to be used for handling toxic, radioactive, infectious, or sensitizing materials.

- ***Perchloric acid*** must be used **ONLY in a wash-down hood** designed and labeled specifically for perchloric acid use.

- ***Radioisotope work*** is to be conducted in fume hoods dedicated to this purpose and under work conditions specifically approved through the OSEM Radiation Protection Program and applicable Nuclear Regulatory Commission license provisions.

- ***Toxic and flammable gases***, such as arsine, phosphine, silane, hydrogen chloride, ammonia, hydrogen phosgene, selenide, and nickel carbonyl, should be used in an approved gas storage cabinet, equipped with monitoring devices and failure alarms, and vented through a scrubbing system. OSEM is to be consulted on these installations.

A. PERFORMANCE MEASURES AND MAINTENANCE

- All lab hoods should have a real-time air flow monitor installed, which should include warning lights and alarms if the air flow deviates from a set safe operating range. Fume hood alarms must be installed on every new or upgraded fume hood at the SI.

- SI policy stipulates that the average face velocity of an enclosure hood should be 80-100 linear feet per minute (lfpm) for use with low to moderate toxicity materials, or 100-120 lfpm for use with high toxicity materials.

- Chemical fume hoods and capture hoods will be inspected at least annually by OSEM for proper air flow, through face velocity measurements and visual smoke tests. Stickers will be placed on the hood indicating the results and, as appropriate, the proper sash height necessary to achieve the required control face velocity or the maximum safe distance the capture hood can be placed away from the point source. The OFEO Office of Facilities Management and Office of Facilities Reliability engineers will be in charge of routine maintenance and repair of air exhaust systems in accordance with their service agreement with the facility. Preventive maintenance inspections on the alarm units themselves may be the responsibility of the facility itself, and should be clarified in the facility/OFEO service agreement.

- Biological safety cabinets require a more extensive certification of the effectiveness of the internal filtration, in accordance with National Science Foundation Standard No. 49, and are to be inspected and certified annually by an accredited Biological Cabinet Field Certifier. Contact OSEM for a list a local contractors.

- ***If the flow alarm triggers, regardless of activity in the hood, place a call to the proper building authorities and do not use the hood until the problem is identified and repaired.***

- ***If the hood is being used for reactions, and the flow alarm triggers or in the event of a power failure, or if you think the hood is not working properly, stop the reaction or other work in the hood, lower the sash, leave the lab and close the lab door, notify supervision and the proper building authorities.***

B. SPECIAL PROCEDURES FOR MSC CONSTANT VOLUME HOODS

- The hoods with Phoenix Controls have been balanced to operate at an average of 100 linear feet per minute, providing constant volume exhaust. If the exhaust becomes less than 80 lfm or greater than 120 lfm, air flow alarms will flash and sound.

- Normal fume hood use: When user is present and working at the fume hood the hood may open hood to full position, unless hood is otherwise marked. When not in use keep sash open 2-5 inches. This will put the fume hood into standby operation mode.

- MSC fume hoods will go into alarm if any of the following conditions exist:

  - **Flow alarm** – indicates that the fume hood is not safe to use. Either the airflow has deviated from the set safe operating range of 80-120 lfm, or the air baffles at the back of the hood are blocked. To correct, lower hood sash to 2-5 inches. Remove excess materials or place equipment and materials on blocks.
  - **Energy waste alert** – reminds users to lower fume hood sash when labs are unoccupied.
  - **Emergency exhaust** – indicates that emergency override switch has been activated and is purging the fume hood regardless of hood position. Press switch again to turn off.

- **Mute button** temporary silences the alarm while hood is actively being used and sash is set above 5 inches. If while the mute button is activated and the hood completely shuts down, the mute button will be over ridden and an audible alarm will sound.

DO NOT PERMANENTLY DISABLE THE MUTE BUTTON (e.g., taping over or inserting a stick). In a complete shutdown or other unsafe condition, the button will be unable to pop back to original position and sound an audible alarm to warn users of danger.

C. SAFE WORK PRACTICES FOR PROPER USE OF FUME HOODS

All laboratory employees utilizing chemical hoods are to receive training regarding the limitations and procedures for acceptable chemical hood use.

- Conduct all work in the hood at least 6 inches from the front edge of the hood (far enough to avoid turbulence at front of hood, but close enough so that arms are not unnecessarily exposed). A stripe on the bench surface is a good reminder.
- Never reach into the hood so far that you need to put your head into the hood!
- Lower the sash to a reasonable height to protect yourself from dangerous reactions, unless the fume hood sticker states a particular height for the sash to maintain proper airflow. (This will be the case for older conventional hoods without a bypass which do not adjust air volume at the face to compensate for changes in face opening area).
- Keep materials stored in hoods to a minimum. Do not allow blockage of air baffle openings at the back of the hood. Place large and bulky equipment, like ovens, on blocks to allow air to flow beneath and maintain an unobstructed path to the baffles.
- Look around to be sure that no other air stream is interfering with normal hood exhaust. Prevent cross drafts from open windows, open doors, fans, or air conditioners. Minimize foot traffic in front of hood. Keep lab doors closed, unless the lab room ventilation design requires the doors to be open.
- Do not leave paper towels inside the hood, or else they will be exhausted and block ductwork and fans.
- Electrical receptacles should always be mounted on the exterior of the hood. If outlets are inside the hood, there must be a marked and accessible disconnect switch within 50 feet of the hood. The hood air flow must be fully operational before starting any spark-producing equipment (e.g., burners) inside a hood used for flammable liquids or gases.

D. ADDITIONAL NOTES FOR PROPER USE OF CAPTURE HOODS

Capture hoods do not enclose the source but are designed to exhaust air at a velocity sufficient to move contaminated air into the hood from a distance. The acceptable working distance is a critical variable in the formula which must be provided to lab designers in order to provide a safe system for your needs. Conversely, for existing capture hoods, the OSEM hood test sticker should be noted, which will indicate the maximum distance the hood can be placed away from a source and still exhaust effectively (typically 80 lfm; with effective smoke test capture).

Chapter 12

RADIATION SAFETY / LASER SAFETY

The use, storage, and display of radioactive materials and lasers must be in compliance with the SI's Radiation Protection Program, as outlined in Chapter 30 of the SD 419. The Program ensures compliance with U.S. Nuclear Regulatory Commission regulations and licenses, as well as all applicable State agreements.

All users of radioactive materials must be in contact with the respective facility's assigned Radiation Safety Coordinator (RSC), who is responsible for:

- conducting routine health physics surveys of all laboratories and storage areas,
- supervising radioactive waste disposal,
- maintaining an inventory of all radioactive materials,
- authorizing procurement, receipt, and distribution of all radioisotopes, and
- distributing, receiving, and processing personnel monitoring devices.

The RSC and PI's work closely with the **SI Radiation Safety Officer in OSEM**, who provides oversight, training (see Chapter 15 of this Manual), and exposure monitoring; approves all protocols and LSPs involving radioactive materials; and prepares all licensing documents for submission to the Nuclear Regulatory Commission and applicable state agencies.

LASER SAFETY PROGRAM

All work with lasers, of any Class, or with instruments and equipment containing embedded laser systems, must follow the requirements of the SI Laser Safety Program, as described in Chapter 34 of SD 419, Safety Handbook. All laser use, safe work practices, and LSPs involving lasers, are to be approved by the SI Radiation Safety Officer in OSEM. The respective facilities are to maintain a laser inventory of class and parameters, use, principal operator, and location of both setup/use and non-use storage. The act of servicing and maintenance of normally inaccessible embedded laser systems will need to be evaluated for safety risks. Laser safety training is available for all laser operators. Safety training is required for operators of Class 3b and 4 lasers. Contact OSEM (202-275-1167) for scheduling.

Chapter 13

BIOHAZARDS and ZOONOSES

A. GENERAL

- Work involving **biological agents** in a laboratory setting shall be conducted consistent with the practices, safety equipment and facilities recommended by the U. S. Department of Health and Human Services (DHHS) guidelines, *Biosafety in Microbiological and Biomedical Laboratories*, 4th or latest edition, (also known as the CDC/NIH guidelines). Transfer of biological agents to or from SI facilities shall be in accordance with Centers for Disease Control 42 CFR 72, Requirements for Facilities Transferring or Receiving Select Agents , and any applicable U.S. Department of Agriculture permit requirements.

- The CDC/NIH guidelines describe various Biosafety Levels (BSL) of hazard containment corresponding to the infectious agent being used. These agent summary lists can be found in the document which is available for download at http://www.cdc.gov/od/ohs/biosfty/bmbl4/bmbl4toc.htm

- **No work shall be conducted at the SI exceeding BSL 2, due to the serious health risks associated with BSL 3 & 4 organisms, and the lack of BSL 3 or 4 containment facilities within the SI.**

- All laboratories handling biological agents shall be posted as a potential biological hazard area with the agents in use being identified. Supervisors shall ensure that employees are informed of biological hazards and that suitable biosafety controls are in place. Principal investigators and researchers conducting research in non-Smithsonian facilities shall ensure that adequate biosafety levels and practices are utilized by Smithsonian employees. As a minimum, all biological cabinets are to be certified at least annually for class 2+ biohazard operations. All biocabinets will be certified in accordance with National Sanitation Foundation Standard 49 - *Class II (laminar flow) Biosafety Cabinetry* - or manufacturer's recommendations.

- It is the policy of the SI to provide appropriate inoculations, medical testing and surveillance and to implement safe work practice controls to reduce the risk of employees contracting a **zoonotic disease** during field collection, specimen preparation, or collection handling. Zoonoses, or zoonotic diseases, are defined as infections and infestations shared by humans and other vertebrate animals. These include viral, bacterial, protozoan and other parasitic infections which can be transmitted from live animals and post-mortem specimens to humans.

- Individual facility-specific **zoonosis control programs**, where applicable, will be formulated with OSEM, and the program components incorporated into those facilities' LSPs and general safe work procedures. Elements of BSL-2 containment controls will be implemented, as a minimum, although more stringent controls may be needed depending on discovered pathogens in infected live animals, or suspected or tested pathogens in post-mortem specimens.

- Individuals working with **human tissue, blood, or body fluid** are to be enrolled in the SI **Blood-Borne Pathogen Program** through OSEM/OHSD, offered the necessary immunizations, and develop specific safe work practices, disinfection, and biohazard waste disposal programs for their lab.

B. BASICS OF BIOSAFETY LEVEL 1

Biosafety Level 1 (BSL1) practices represent a basic level of containment that relies on standard microbiological practices and basic safety equipment and lab design for laboratories in which work is done with defined and characterized strains of viable microorganisms not known to consistently cause disease in healthy adult humans. Many agents not ordinarily associated with disease processes in humans are, however, opportunistic pathogens and may cause infection in the young, the aged, and immuno-deficient or immuno-suppressed individuals.

BSL-1 Standard Microbiological Practices

1. Access to work areas is limited at the discretion of the principal scientist; doors should be closed during work with research materials.
2. Hands must be washed after handling biological materials, removing gloves, or before leaving work area.
3. No eating or drinking will be allowed in the work area.
4. Only mechanical devices will be used for pipetting.
5. Safety devices or non-sharps are to be used as an alternative to sharps. Sharps used are to be handled and disposed properly.
6. Activities that are likely to create splashes, sprays, or aerosols are to be minimized.
7. Work surfaces are to be decontaminated at least daily and after any spills.
8. Waste materials are to be decontaminated before disposal, by an approved method such as autoclaving.
9. A biohazard sign is to be posted on entrances to work areas where infectious agents are present.
10. Secondary containment and a cart are to be used when transporting biohazardous materials outside of the laboratory. Avoid public areas during transport.
11. An integrated pest management program must be in effect.

BSL-1 Safety Equipment (Primary Barriers)

1. BUTTONED lab coats are to be worn to protect street clothes.
2. Barrier (preferably non-latex) gloves are to be worn, particularly if hands have broken skin or a rash.
3. Appropriate eye/face protection (safety goggles as a minimum) is to be worn if splashes or sprays are anticipated, or if wearing contact lenses during lab work.

BSL-1 Laboratory Facilities (Secondary Barriers)

1. The lab must have a sink for handwashing.

2. The lab should have a door for access control, and, if windows open to the exterior, fly screens must be installed.

3. The lab fixtures and floors are easily cleanable (no carpets or rugs); benchtops are to be impervious to water and resistant to both moderate heat and the chemicals used to decontaminate the work surface and equipment.

C. BASICS OF BIOSAFETY LEVEL 2

Biosafety Level 2 is more restrictive than BSL-1 and is suitable for work involving agents of moderate potential hazard to personnel and the environment. It differs in that (1) laboratory personnel have specific training in handling pathogenic agents and are directed by competent scientists, (2) access to the laboratory is definitely limited when work is being conducted, (3) extreme precautions are taken with contaminated sharp items, and (4) certain procedures in which infectious aerosols or splashes may be created are conducted in biological safety cabinets or other physical containment equipment.

BSL-2 Standard Microbiological Practices

1. Persons wash their hands after they handle viable materials and animals, after removing gloves, and before leaving the laboratory.

2. Eating, drinking, smoking, handling contact lenses, and applying cosmetics are not permitted in the work areas. Persons who wear contact lenses in laboratories should also wear goggles or a face shield. Food is stored outside the work area in cabinets or refrigerators designated for this purpose only.

3. Mouth pipetting is prohibited; mechanical pipetting devices are used.

4. Policies for safe handling of sharps (when non-sharps are not available) are instituted.

5. All procedures are performed carefully to minimize the creation of splashes or aerosols.

6. Work surfaces are decontaminated at least once a day and after any spill of viable material.

7. All cultures, stocks, and other regulated wastes are decontaminated before disposal by an approved decontamination method, such as autoclaving. Materials to be decontaminated outside of the immediate laboratory are to be placed in a durable, leakproof container and closed for transport from the laboratory. Materials to be decontaminated at off-site locations from the laboratory are packaged in accordance with applicable local, state, and federal regulations, before removal from the facility.

8. An integrated pest management control program is in effect.

BSL-2 Special Practices

1. Access to the laboratory is limited or restricted by the laboratory director when work with infectious agents is in progress. In general, persons who are at increased risk of acquiring infection or for whom infection may be unusually hazardous are not allowed in the laboratory or animal rooms. For example, persons who are immunocompromised or immunosuppressed may be at risk of acquiring infections. The laboratory director has the final responsibility for assessing each circumstance and determining who may enter or work in the laboratory.

2. The laboratory director establishes policies and procedures whereby only persons who have been advised of the potential hazard and meet specific entry requirements (e.g., immunization) enter the laboratory or animal rooms.

3. When the infectious agent(s) in use in the laboratory require special provisions for entry (e.g., immunization), a hazard warning sign incorporating the universal biohazard symbol is posted on the access door to the laboratory work area. The hazard warning sign identifies the infectious agent, lists the name and telephone number of the laboratory director or other responsible person(s), and indicates the special requirement(s) for entering the laboratory.

4. Laboratory personnel receive appropriate immunizations or tests for the agents handled or potentially present in the laboratory (e.g., hepatitis B vaccine or TB skin testing).

5. When deemed appropriate by OSEM/OHSD, and considering the agent(s) handled, baseline serum samples for laboratory and other at-risk personnel are collected and stored. Additional serum specimens may be collected periodically, depending on the agents handled or the function of the facility.

6. A LSP with these biosafety provisions is prepared or adopted. Personnel are advised of special hazards and are required to read and to follow instructions on practices and procedures.

7. Laboratory personnel receive appropriate training on the potential hazards associated with the work involved, the necessary precautions to prevent exposures, and the exposure evaluation procedures. Personnel receive annual updates, or additional training as necessary for procedural or policy changes.

8. A high degree of precaution must always be taken with any contaminated sharp items, including needles and syringes, slides, pipettes, capillary tubes, and scalpels.

    - Needles and syringes or other sharp instruments should be restricted in the laboratory for use only when there is no alternative, such as parenteral injection, phlebotomy, or aspiration of fluids from laboratory animals and diaphragm bottles. Plasticware should be substituted for glassware whenever possible.

    - Only needle-locking syringes or disposable syringe-needle units (i.e., needle is integral to the syringe) are used for injection or aspiration of infectious materials. Used disposable needles must not be bent, sheared, broken, recapped, removed from disposable syringes, or otherwise manipulated by hand before disposal; rather, they must be carefully placed in conveniently located puncture-resistant containers used for sharps disposal. Non-disposable sharps must be placed in a hard-walled container for transport to a processing area for decontamination, preferably by autoclaving.

- Syringes which re-sheathe the needle, needle-less systems, and other safe devices should be used when appropriate.

- Broken glassware must not be handled directly by hand, but must be removed by mechanical means such as a brush and dustpan, tongs, or forceps. Containers of contaminated needles, sharp equipment, and broken glass are decontaminated before disposal, according to any local, state, or federal regulations.

9. Cultures, tissues, or specimens of body fluids are placed in a container that prevents leakage during collection, handling, processing, storage, transport, or shipping.

10. Laboratory equipment and work surfaces should be decontaminated with an appropriate disinfectant on a routine basis, after work with infectious materials is finished, and especially after overt spills, splashes, or other contamination by infectious materials. Contaminated equipment must be decontaminated according to any local, state, or federal regulations before it is sent for repair or maintenance or packaged for transport in accordance with applicable local, state, or federal regulations, before removal from the facility.

11. Spills and accidents which result in overt exposures to infectious materials are immediately reported to the laboratory director. Medical evaluation, surveillance, and treatment are provided as appropriate and written records are maintained.

12. Animals not involved in the work being performed are not permitted in the lab.

BSL-2 Safety Equipment (Primary Barriers)

1. Properly maintained biological safety cabinets, preferably Class II, or other appropriate personal protective equipment or physical containment devices are used whenever:

    - Procedures with a potential for creating infectious aerosols or splashes are conducted. These may include centrifuging, grinding, blending, vigorous shaking or mixing, sonic disruption, opening containers of infectious materials whose internal pressures may be different from ambient pressures, inoculating animals intranasally, and harvesting infected tissues from animals or eggs.

    - High concentrations or large volumes of infectious agents are used. Such materials may be centrifuged in the open laboratory if sealed rotor heads or centrifuge safety cups are used, and if these rotors or safety cups are opened only in a biological safety cabinet.

2. Face protection (goggles, mask, faceshield or other splatter guards) is used for anticipated splashes or sprays of infectious or other hazardous materials to the face, when the microorganisms must be manipulated outside the biosafety cabinet.

3. Protective laboratory coats, gowns, smocks, or uniforms designated for lab use are worn while in the laboratory. This protective clothing is removed and left in the laboratory before leaving for non-laboratory areas (e.g., cafeteria, library, administrative offices). All protective clothing is either disposed of in the laboratory or laundered by the institution; it should never be taken home by personnel.

4. Gloves are worn when handling infected animals and when hands may contact infectious materials, contaminated surfaces or equipment. Wearing two pairs of gloves may be appropriate; if a spill or splatter occur, the hand will be protected after the contaminated glove is removed. Gloves are disposed of when contaminated, removed when work with infectious materials is completed, and are not worn outside the laboratory. Disposable gloves are not washed or reused.

BSL-2 Laboratory Facilities (Secondary Barriers)

1. Each laboratory contains a sink for handwashing.

2. The laboratory is designed so that it can be easily cleaned. Rugs in laboratories are not appropriate, and should not be used because proper decontamination following a spill is extremely difficult to achieve.

3. Bench tops are impervious to water and resistant to acids, alkalis, organic solvents, and moderate heat.

4. Laboratory furniture is sturdy, and spaces between benches, cabinets, and equipment are accessible for cleaning.

5. If the laboratory has windows that open, they are fitted with fly screens.

6. A method for decontamination of infectious or regulated laboratory wastes is available (e.g., autoclave, chemical disinfection, incinerator, or other approved decontamination system).

7. An eyewash facility is readily available.

8. The laboratory should be at negative pressure with respect to areas outside the lab. Hoods and biosafety cabinets should be positioned away from doors, supply vents, windows, heavy traffic patterns and other crossdrafts.

Chapter 14

HAZARDOUS WASTE DISPOSAL

Every SI facility has a Hazardous Waste Coordinator (HWC) and a specific hazardous waste disposal protocol based on the regulations of the state or local government in which the facility is located. The facility HWC is to be consulted on procedures to follow within that facility, or to assist in classifying a material as hazardous waste. Details on SI regulations can also be found in the SI Safety Handbook, Chapter 26, SI Hazardous Waste Disposal Program.

Each container of hazardous waste is to be labeled with the following legends. Pre-printed labels are also available through the facility HWC.

"HAZARDOUS WASTE"
CONTENTS (be specific as to chemical):
ACCUMULATION START DATE:

If a reagent container label has been removed or becomes illegible, and the identity of the contents is unknown, the container must be disposed as soon as possible by arrangement with the facility hazardous waste coordinator.

Prior to the departure of staff or visiting scientist, chemicals for which that person was responsible are to be inventoried and discarded or returned to storage.

Pouring hazardous waste chemicals down the drain, adding them to regular trash, or evaporating them in a local exhaust hood are illegal actions !

Chapter 15

TRAINING

Training and education in laboratory safety need to be an ongoing process not just an annual presentation. The most effective way to reinforce good work practices is to involve staff from principal researchers to interns in regular, periodic reviews and updates of the Laboratory Safety Plan. Documentation of all forms of training is to be maintained in the laboratory as well as reported to the facility safety coordinator.

INITIAL LAB HAZARD AWARENESS TRAINING (as part of the Smithsonian Hazard Communication Program) must, as a minimum, be provided to all employees prior to actual lab work, and prior to assignments involving new potential exposures. This course can be scheduled with OSEM on a group basis or provided individually by the LSO and PI. Information should include:

- The location and availability of the LSP, chemical inventory, Material Safety Data Sheets (MSDSs), applicable regulatory exposure limits, and other reference material regarding the safe handling, storage, and disposal of hazardous chemicals (or hazardous collections) in the lab.
- Signs and symptoms associated with exposures to hazardous chemicals used in the laboratory, as well as the health hazards themselves.
- Methods that may be used to detect the presence or release of a hazardous chemical. This could include industrial hygiene monitoring, the use of continuous monitoring devices, visual appearance, or odors of chemicals.
- Methods employees can take to protect themselves from hazards, including work practices, personal protective equipment and emergency procedures listed in the LSP. This should include a discussion of the proper use and limitations of engineering controls and safety devices, including chemical and biological hoods.
- Emergency response plans established by each facility's Emergency/Disaster Response Plan, any medical or first aid response specifically recommended by OHSD (such as first response to hydrofluoric acid exposure), extinguishment of clothing fires (Stop, Drop, and Roll), and Chemical Spill Response Plans established by each facility.

SPECIALIZED TRAINING, when required, can be scheduled with OSEM through your LSO or Safety Manager. Check the OSEM Training Catalogue for a full list of classes offered (http://ofeo.si.edu/safety_health/OSEM%20Training%20Catalog.html):

- **Bloodborne Pathogen Exposure Control**. Two types of classes are available: Initial and annual re-training. These classes provide an overview of bloodborne diseases and their modes of transmission and prevention, and cover appropriate cleaning solutions for removing blood or other body fluid spills, disease transmission barrier devices and suggests ways to eliminate or decrease the possibility of contacting infectious disease. Completion of the training courses as noted meets the OSHA Bloodborne Pathogen Standard mandated initial or annual training/re-training requirement for employees classified as Category I or II for risk exposure to bloodborne pathogens on the job.

- **Electrical Safety.** Electrical hazards resulting from faulty maintenance or misuse of electrical wiring increase the risk of serious injury or fire. To minimize this potential, this class will cover basic building electrical distribution systems, over-current protection, people versus equipment protection, and common workplace electrical hazards.

- **Fire Extinguisher.** This class provides SI staff with instruction in the proper selection and use of portable fire extinguishers. Participants will learn how fires and fire extinguishers are classified, proper actions to take in the event of a fire, and will gain an understanding of their own abilities and limitations. Hands-on practice is offered.

- **Hazard Recognition and Control.** Designed especially for SI facility safety committee members, this course offers a comprehensive overview of conducting a safety inspection. Participants will learn how to identify and correct common workplace hazards and prepare more comprehensive and useful inspection reports.

- **Laboratory Safety and Health** (Expanded Seminar). This seminar provides detailed guidelines and templates for developing a laboratory safety and health plan, in accordance with SI policy. In addition to the concepts from the Basic Laboratory Chemical Hygiene Training course, this course includes expanded information on engineering and ventilation controls, safety hazards and controls for mechanical apparatus, electrical safety, pressure and vacuum systems, cryogenic safety, compressed gas cylinders, flammable gases, fire detection and suppression systems, fire safety issues for fluid collections, chemical storage and labeling, and hazardous waste management.

- **Lockout/Tagout Practices.** This training has been developed to assist safety coordinators, supervisors and employees in understanding the importance of the Lockout/Tagout Standard and implementing a facility specific Lockout/Tagout Program. It addresses the fundamental and essential elements of the Lockout/Tagout Program, including the control of hazardous energy (electrical, mechanical, pneumatic, etc.) sources which may affect employees. SI employees who repair, maintain, and/or adjust machinery or equipment should have this important training.

- **Radiation Protection.** Designed for SI staff working with ionizing and non-ionizing sources, this course reviews federal, state, and SI requirements/guidelines applicable to various types of radiation, projected use and Nuclear Regulatory Commission (NRC) regulations. Topics to be addressed will include:· The SI Radiation Safety Program, fundamentals of ionizing radiation, principles and practices of radiation protection, radiation surveys, monitoring, and instrumentation, health effects associated with exposure to various forms of radiation, health risk assessment and exposure guidelines, current and proposed federal, state, and NRC regulations. Site-specific topics will be addressed based upon the sources of radiation used by participants (radioisotopes, X-rays, VDTs, EMF, etc.).

- **Radiation Protection For Lasers.** This class is intended primarily for SI staff whose responsibilities include the use of lasers or work in the proximity of lasers. Topics will include: Bioeffects, ANSI Z-136 Standard, nominal hazard zone, control measures, beam characteristics, protective eyeware and barriers, and non-beam hazards. Site-specific applications may be used to tailor the class to more directly applicable situations.

- **Respiratory Protection.** This course is designed for those SI employees, volunteers, interns, and visiting researchers who have been approved by OSEM to wear respirators. The course discusses (1) the differences and limitations of various respirator types, (2) the nature of workplace hazards and specific respirator selection, (3) how to properly wear the respirator and check for fit and, (4) proper cleaning, inspection, storage, and maintenance. During the session, each individual will be fit-tested to determine which respirator model and size provides the best protection. This course is mandatory for OSEM-approved respirator users and their supervisors.

[Future Chapter 16]

[LABORATORY DESIGN AND CONSTRUCTION]

Appendix A - EXAMPLE OUTLINE: SITE-SPECIFIC LABORATORY SAFETY PLAN

Directions for Lab Staff Developing this Plan:

- It is intended that the Laboratory Supervisor or LSO have flexibility in the selection of format and preparation of contents for the LSP. The following format is offered as a downloadable guideline, with specific contents to be added by the laboratory.

- As an alternative for smaller operations, the lab could insert safety warning boxes into protocol documents.

- A large department might want to create a more generic LSP, with individual attachments for each research project or procedure.

- The Laboratory Safety Manual itself forms a valuable technical background for understanding the individual lab plans. Therefore, the Manual should be easily accessible and reviewed by staff.

- Each proposed section in the attached example Plan has some standard explanatory text that we recommend you keep or edit in your own LSP.

- Contact your facility Lab Safety Officer and/or Safety Manager for assistance on writing your Plan. To cut and paste sections from the Manual itself, go to the Office of Facilities Engineering and Operations (OFEO) web site on *Prism*, **ofeo.si.edu**, and access “Safety and Health”, “Environmental Man. Prog.”; scroll down to “Lab Safety and Health”.

LABORATORY SAFETY PLAN
[Department / Laboratory Name & Room No. if applicable]

<u>FACILITY EMERGENCY PROCEDURES</u>:

Security or other Number PER FACILITY'S EMERGENCY RESPONSE PLAN:
(for reporting emergencies, fires, & chemical spills):

<u>IMPORTANT CONTACTS</u>: [insert name & phone number for each below]

Principal Investigator or Responsible Supervisor:
- Responsible for ensuring laboratory workers understand the hazards of their work, follow the controls in the Lab Safety Plan, and are provided with the necessary controls and protective equipment.

Laboratory Safety Officer:
- Responsible for reviewing and approving individual LSPs within their assigned area, and acting as a liaison for technical information between the lab and the facility safety manager or OSEM.

Safety Manager/Coordinator:
- Responsible for management of SI safety and health policy within the facility, including ensuring that (and maintaining records to show that) required lab safety training is conducted and LSPs are reviewed annually.

Hazardous Waste Coordinator:
- Call in case of chemical spill, to ask about hazardous waste labeling and storage, or to arrange for its pickup and disposals.

(If applicable) Radiation Safety Coordinator:
- Manages the personnel dosimetry monitoring program, ensures compliance with NRC license requirements, conducts area monitoring of radiation use areas.

[Department] Safety Committee member:
- Serves as departmental liaison to the [facility] Safety Committee.

Occupational Health Services Clinic / OSEM: 202-275-2222

Section 1 – INTRODUCTION

This Laboratory Safety Plan (LSP) describes safe work practices, personal protective equipment, and other control measures necessary for the safe use of chemicals and other hazardous materials and procedures for this laboratory. All workers are to be made aware of this Plan, and are directed to follow the Plan. Staff, interns, visiting scientists, and volunteers are to receive initial hazard awareness training at the start of their employment in this lab. As protocols change, or on an annual basis (whichever comes first), this Plan is to be reviewed by all members of the laboratory team and updated as needed to heighten safety awareness.

Additional technical guidance can be found:

- In the SI Laboratory Safety Manual ***(located in …………),***
- In our Material Safety Data Sheets ***(located in …….)***
- In our Chemical Spill and Hazardous Waste Disposal guidelines ***(located in …………),***
- With our Laboratory Safety Officer ***(name)*** and Facility Safety Manager ***(name),***
- On the OFEO/Office of Safety and Environmental Management web site: ofeo.si.edu.
- From your Supervisor or laboratory Principal Investigator (PI).

The requirement for a site-specific LSP is based on SI policy (SD419 Safety Handbook) and the Occupational Safety and Health Administration (OSHA) Standard 29 CFR 1910.1450, *Occupational Exposure to Hazardous Chemicals in Laboratories.*

This Plan is to be used in conjunction with the SI Laboratory Safety Manual and the SD 419 Safety Handbook, for a full understanding of the principles and practices involved with safe work in your lab.

Section 2 - SPECIAL APPROVALS and WORKING ALONE

(Consult SI Laboratory Safety Manual Chapter 5)

1. Describe circumstances under which a particular experiment, procedure, or activity shall require special permission from the LSO and PI to conduct (such as those allowed to run unattended and/or with highly hazardous substances).
2. Highlight processes that cannot be conducted while working alone, or require special arrangements if allowed to work alone.

Section 3 - HAZARD IDENTIFICATION and ASSESSMENT

Using the resources described in Chapter 3 of this Manual, identify the hazards and probable risks associated with steps in the experimental process and with use of particular chemicals and equipment. Suggested format:

Process/Step	Possible Hazards	Likelihood (high-moderate-low)of Illness or injury
1.		
2.		
etc		

Section 4 - HAZARD CONTROLS and SAFE OPERATING PROCEDURES

The estimated health and safety risks inherent to the laboratory operation, as determined through exposure assessments and task safety analyses, will dictate the most effective control measures needed to eliminate those risks or, at least, reduce them to acceptable levels. The three general control methods are (in order of preference):

1. Engineering (ventilation) controls or complete product/process substitution
2. Good laboratory work practices.
3. Personal protective equipment (respirators, gloves, eye protection)

(Suggestion: Create a table of the major steps in your protocols and list the following information for quick reference. Consult applicable chapters in Manual.)

Major Steps in Process	Anticipated Health or Safety Hazards	Required PPE for Each Step	Required Work Practices, including local exhaust.	Special notes on compatible / safe storage & handling	Special Precautions for Highly Hazardous Materials.

(Another Suggestion, if your experimental protocol is short or straightforward: Insert the above information as highlighted text boxes at various points throughout the protocol document.)

Section 5 – ENSURE GOOD WORKING CONDITION OF CONTROLS

Describe the signs of control failure, such as cracks in gloves or poor air flow through a hood.

Describe how to routinely inspect safety controls (mechanical or PPE) to ensure that they are working properly before use.

Describe what steps to follow and who to notify should a control failure be discovered.

Section 6 – SPECIAL CHEMICAL STORAGE and HANDLING PRACTICES

Refer to Chapter 9 for details.

Describe any specific guidelines pertinent to the chemicals or processes in this lab.

Section 7 - CARCINOGENS, REPRODUCTIVE TOXINS, BIOHAZARDS and HIGHLY HAZARDOUS SUBSTANCES

Special procedures are to be developed for particularly hazardous substances, as defined in Chapter 9, subsection H. List these here.

- Establish a restricted work area, with warning signs and containment devices as needed, and segregated storage.
- Determine if special decontamination procedures for required for the area, material, and workers that contact the substance.
- Check with your facility hazardous waste coordinator about any special considerations for these chemicals.

Section 8 - HAZARDOUS WASTE DISPOSAL AND SPILL CONTROL

(Attach* "Hazardous Chemicals Emergency Spill And Leak Control Procedures, Reporting Person's Check List"** ***from facility spill plans. Optional: Attach facility hazardous waste disposal instructions and procedures)

Suggested wording for this section of the LSP:

[NAME] is to be consulted on hazardous waste disposal procedures, or to assist in classifying a material as hazardous waste. Details on SI regulations can also be found in the SI Safety Handbook, Chapter 26, SI Hazardous Waste Disposal Program.

Each container of hazardous waste is to be labeled with the following legends. Pre-printed labels are also available through **[NAME].**

"HAZARDOUS WASTE"

CONTENTS (be specific as to chemical):

ACCUMULATION START DATE:

If a reagent container label has been removed or becomes illegible, and the identity of the contents is unknown, the container must be disposed as soon as possible by arrangement with the facility hazardous waste coordinator.

Prior to the departure of staff or visiting scientist, chemicals for which that person was responsible are to be inventoried and discarded or returned to storage.

Pouring hazardous waste chemicals down the drain, adding them to regular trash, or evaporating them in a local exhaust hood are illegal actions !

Section 9 – TRAINING

Refer to Chapter 15 of this Manual and list the types and frequency of training courses applicable to the processes described by this LSP. Either maintain documentation of training with this LSP or specify where it is filed.

Appendix B - SAFETY AND HEALTH LITERATURE AT MSC/SIL
(Call numbers included)

"**Artist Beware**." McCann, Michael. New York: Watson-Guptill Publication, 1979. RC963.6.A78M32 1992X MSC

Presents current information on chemical and physical hazards and practical advice on how to eliminate or minimize them. Recommendations are specific for various art and craft techniques and materials that have been shown to be hazardous; those which are benign are so described.

"**Best's Safety and Security Directory**." Oldwick, N.J.: A.M. Best Co. T55.A1B56 MSC (1999 edition on shelf)

Contains the latest safety and security products and services, up-to-date OSHA standards, company profiles, training articles, and self-inspection checklists.

"**Casarett and Doull's Toxicology: The Basic Science of Poisons**." Casarett, Louis J. New York: Macmillan, 1995. RA1211.C296 1996X MSC Reference

A comprehensive guide to modern toxicology that includes information on general principles, specific toxic agents, environmental toxicology, and applications of toxicology including new coverage of risk assessment.

"**CRC Handbook of Laboratory Safety**." Edited by A. Keith Furr. 4th ed. Boca Raton, FL: CRC Press, 1995. QD51.C73 1995X MSC Reference

Provides information on planning and building a facility, developing an organization infrastructure, planning for emergencies and contingencies, choosing the correct equipment, developing operational plans, and meeting regulatory requirements. It is the ideal reference to OSHA safety standards and government regulations.

"**Fire Protection Guide on Hazardous Materials**." 6th ed. National Fire Protection Association. Boston [c1975] T55.3.H3N27 1997 MSC

Includes four NFPA documents that classify materials so that personnel can safely handle emergencies such as fires and accidental releases. Contains routine storage and handling guidelines for the full range of hazardous substances.

"**Fundamentals of Industrial Hygiene**." Edited by Barbara A. Plog and Jill Niland, 4th ed. Itasca, Ill.: National Safety Council, 1996. RC967.F85 1996X MSC Reference

Covers monitoring, recognition, evaluation, and control of workplace health hazards. Includes OSHA regulations, professional standards, permissible exposures, and workers' right-to-know information.

“**Handbook of Reactive Chemical Hazards**.” 5th ed. Bretherick, L. Oxford, UK: Butterworth-Heinemann, 1995. T55.3.H3 B73 1995 v.1 & 2 MSC Reference

A reference to the published accounts of reactive chemicals and their hazardous reactions, augmented with unpublished but otherwise documented information.

“**Hazardous Chemicals Desk Reference**.” 4th ed. Lewis, Richard J., Sr New York: John Wiley & Sons, 1997. T55.3.H3 L49 1997 MSC Reference

Derived from the Sax's Dangerous Properties of Industrial Materials database, this working guide provides detailed hazard information on some 6,000 chemical substances commonly encountered in the workplace, industry, laboratories, and the environment. Each entry concludes with a safety profile, a textual summary of the hazards presented by the entry. Also included are l-to-3 hazard ratings, which quickly and concisely identify the hazard or toxicity level of a chemical.

“**Laboratory Fume Hoods: A User's Manual**.” Saunders, G. Thomas. New York: Wiley, 1993. QD54.F85S38 1993X MSC

A thorough reference on adequate fume hood design and use. Dissects this device down to its bare essentials. Examines how and why a fume hood works.

“**The Merck Index: An Encyclopedia of Chemicals, Drugs, and Biologicals**.” Edited by Susan Budavari. 12th ed. Rahway, N.J., U.S.A.: Merck, 1996.
RS51.M4 1996X MSC Reference

This standard, trusted reference tool describes common organic chemicals and laboratory reagents, naturally occurring substances and plants, inorganic chemicals, endogenous substances and biological agents. Entries include the chemical abstracts name, alternate chemical names, percentage composition, molecular weight, molecular formula, patent and chemical information, literature references, biological and pharmacological information, structure (including stereochemistry, if relevant), physical data, drug code number, derivatives, trademarks and/or synonyms of derivatives, and therapeutic category (in humans).

“**NIOSH Pocket Guide to Chemical Hazards**.” Upland, PA: Diane Publishing Co., 1997.
T55.3.H3N105 MSC Reference
Also available in html format: **http://www.cdc.gov/niosh/npg/pgdstart.html**

Intended as a source of general industrial hygiene information on several hundred chemicals/classes for workers, employers, and occupational health professionals. The information found in the NPG should help users recognize and control occupational chemical hazards. Information includes chemical structures and formula, identification codes, synonyms, exposure limits, chemical and physical properties, incompatibilities and reactivities, measurement methods, respirator selections, signs and symptoms of exposure, and procedures for emergency treatment.

"**Patty's Industrial Hygiene and Toxicology**." 3d rev. ed. Patty, Frank Arthur. New York: Wiley, 1978. RC967.P37 1978X MSC - vols. 1, 2a and 2b

An earlier edition of the standard reference in occupational health and safety. A sampling of topics: pulmonary effects of inhaled mineral dust, occupational dermatoses, workplace sampling and analysis, potential endocrine disruptors in the workplace, and measurement and control of odors.

"Proctor and Hughes' Chemical Hazards of the Workplace." Proctor, Nick H. Edited by Gloria J. Hathaway. 4th ed. New York : Van Nostrand Reinhold, 1996.
RA1229.P76 1996X MSC Reference

Accurate analyses of over 600 potentially dangerous chemicals. Each description covers chemical formula, CAS number, Threshold Limit Value, physical properties, uses, route of exposure, toxicological details, carcinogenicity, mutagenicity, and fetotoxicity.

"**Prudent Practices in the Laboratory: Handling and Disposal of Chemicals**." National Research Council. Washington, D.C.: National Academy Press, 1995.
T55.3.H3P78 1995X MSC Reference

Explores the current culture of laboratory safety and provides an updated guide to federal regulations. Organized around a recommended workflow protocol for experiments, offers planning procedures and safe practices, with information on assessing hazards, managing chemicals, and disposing of wastes.

"**Quick Selection Guide to Chemical Protective Clothing**." 3rd edition Forsberg, Krister. New York: John Wiley & Sons, 1997 TP149 .F67 1997 MSC Reference

A pocket guide to the selection of protective clothing. It includes the names, addresses, and phone numbers of the suppliers and manufacturers of the chemical protective clothing (gloves, boots, suits and other items).

"**Safe Storage of Laboratory Chemicals**." 2nd edition. Edited by David A. Pipitone. New York: Wiley, 1991. QD51.S22 1991X MSC

Contains an introduction to fundamental principles of chemical storage and provides a logical framework for integrating storage concepts. Storage requirements for hazardous, flammable, unstable, and incompatible chemicals are also covered. It outlines procedures for labeling chemicals, addressing emergencies, and managing chemical safety with the aid of computers.

"**Ventilation, A Practical Guide**." Clark, Nancy. New York: Center for Occupational Hazards, 1984. TH7684.T3C53 1984X MSC

A guide to ventilating a lab, workshop, or studio for control of dangerous materials.

Appendix C - SAFETY AND HEALTH WEB-BASED RESOURCES AND OTHER PUBLICATIONS

Professional / Consensus-Standard Organizations with useful websites for laboratories

The Laboratory Safety Institute
http://www.labsafety.org/

American Chemical Society Division of Chemical H&S
http://membership.acs.org/c/chas/

American Institute for Conservation, Health & Safety Committee webpage
http://aic.stanford.edu/health/

Arts, Crafts, and Theater Safety
http://www.caseweb.com/acts/

National Fire Protection Association
http://www.nfpa.org

National Safety Council
http://www.nsc.org

American Industrial Hygiene Association
http://www.aiha.org

American Conference of Governmental Industrial Hygienists
http://www.acgih.org

American National Standards Institute
http://ansi.org

Regulatory Agencies with useful web sites for laboratories

Occupational Safety and Health Administration (OSHA) 29 CFR 1910 Standards, particularly 29 CFR 1910.1450, Occupational Exposure to Hazardous Chemicals in Laboratories.
http://www.osha.gov/pls/oshaweb/owastand.display_standard_group?p_toc_level=1&p_part_number=1910&v_description=General+Industry+-+%28Standards+-+29+CFR%29

U.S. Environmental Protection Agency (EPA)
http://epa.gov

U. S. Department of Transportation, Office of Hazardous Materials Safety
http://hazmat.dot.gov, Promulgates and enforces national transportation regulations, including shipment of hazardous materials.

Hazardous Substances Databases, especially toxicological information

American Conference of Governmental Industrial Hygienists (ACGIH), Threshold Limit Values (TLV), latest edition (copies sent annually to facility Safety Managers for internal SI use only). www.acgih.org

Agency for Toxic Substance and Disease Registry (ATSDR)
http://www.atsdr.cdc.gov; Agency helps prevent exposure to hazardous substances from waste sites on the U.S. Environmental Protection Agency's National Priorities List, and develops toxicological profiles of chemicals found at these sites. Publishes hazard info on various chemicals http://www.atsdr.cdc.gov/toxfaq.html

Centers for Disease Control and Prevention
http://www.cdc.gov; Working with states and other partners, CDC provides a system of health surveillance to monitor and prevent disease outbreaks (including bioterrorism), implement disease prevention strategies, and maintain national health statistics.

CDC: National Center for Environmental Health
http://www.cdc.gov/nceh; Research on environmental-public health issues.

CDC: National Institute for Occupational Safety and Health (NIOSH)
http://www.cdc.gov/niosh/homepage.html;
Conducts research and training in occupational safety and health issues; certifies respirators; issues health hazard alerts and other publications; conducts health hazard evaluations upon employer or employee request; maintains extensive databases of literature including NIOSHTIC. Funds Educational Research Centers located at many universities across the country, providing training courses and information to employees and employers.

Special link: NIOSH Chemical Protective Clothing selection guide
http://www.cdc.gov/niosh/npptl/chemprcloth.html

Special link: NIOSH Pocket Guide to Chemical Hazard
http://www.cdc.gov/niosh/npg/npg.html, on-line, includes many additional databases and literature citations not included in the printed version

National Toxicology Program; http://ntp-server.niehs.nih.gov/ Conducts long-term research studies on chemicals of concern; indicator of emerging hazard issues.

National Institute of Environmental Health Sciences
http://ehis.niehs.nih.gov; Information on adverse effects of environmental factors on human health.

National Library of Medicine
http://sis.nlm.nih.gov/

The Specialized Information Services Division is responsible for information resources and services in toxicology, environmental health, chemistry, HIV/AIDS, and specialized topics in minority health. Manages databases such as :

TOXNET http://www.nlm.nih.gov/pubs/factsheets/toxnetfs.html, and
The Household Products Data Base http://hpd.nlm.nih.gov/

IRIS: Integrated Risk Information System, of the US Environmental Protection Agency
http://www.epa.gov/ngispgm3/iris/subst/index.html

Duke University Occupational & Environmental Medicine WWW Resource Index
http://occ-env-med.mc.duke.edu/oem/index2.htm

Kodak Environmental Services
http://www.kodak.com/US/en/corp/environment/kes/pubs/index.jhtml

Other Resources:
Odor Thresholds for Chemical with Established Occupational Health Standards; American Industrial Hygiene Association: Fairfax VA 1989.

Carcinogens, Biosafety, Radiation Safety

(latest) Report on Carcinogens
U.S. Department of Health & Human Services, National Toxicology Program
http://ntp.niehs.nih.gov/index.cfm?objectid=72016262-BDB7-CEBA-FA60E922B18C2540

International Agency for Research on Cancer, http://www.iarc.fr
Monograph series on individual chemicals and carcinogenic agents,

National Cancer Institute, http://www.nci.nih.gov

Biosafety in Microbiological and Biomedical Laboratories (BMBL) 4th Edition, National Institutes of Health
http://www.cdc.gov/od/ohs/biosfty/bmbl4/bmbl4toc.htm

"**Guidelines for Research Involving Recombinant DNA Molecules**" Center for Disease Control, 1992

Safe Use of Lasers, ANSI Z136.1-2000; American National Standards Institute, 2000

Fire Safety References

- NFPA 10 - *Standard for Portable Fire Extinguishers*
- NFPA 30 - *Flammable and Combustible Liquids Code*
- NFPA 45 - *Standard on Fire Protection for Laboratories Using Chemicals*
- NFPA 55 - *Storage and Use of Liquefied and Compressed Gases in Portable Cylinders*
- NFPA 70 - *The National Electrical Code*
- NFPA 101 - *The Life Safety Code*
- OSHA 29CFR1910, Subparts E-Means of Egress, L-Fire Protection, and H-Hazardous Materials
- International Building Code (IBC) – Most recent edition.
- International Code Council (ICC) Performance Code for Buildings and Facilities - Most recent edition.

- "**Fire Protection for Laboratories Using Chemicals**", National Fire Protection Association (NFPA), 1982.

Controls: Ventilation and Personal Protective Equipment

Guidelines for Laboratory Design: Health and Safety Considerations, 2nd Ed. 1993 Louis DiBerardinis, et al, John Wiley & Sons.

ACGIH Industrial Ventilation: A Manual of Recommended Practice, 22nd Ed.

Safety in Academic Chemical Laboratories, 6th Ed. ACS Committee on Chemical Safety, American Chemical Society, Washington DC 1995.

Laboratory Ventilation, ANSI/AIHA Z9.5-2003, American National Standards Institute, 2003.

Appendix D - OSHA STANDARDS WITH EXPOSURE AND MEDICAL MONITORING REQUIREMENTS, AND OSHA SELECT CARCINOGENS

Code of Federal Regulations (CFR) Part 29

1910.95	Occupational noise exposure
1910.134	Respiratory protection
1910.139	Respiratory protection for M. tuberculosis
1910.1001	Asbestos (and 1926.1101 – Asbestos in Construction Industry)
1910.1003	Select Carcinogens 4-Nitrobiphenyl alpha-Naphthylamine Methyl chloromethyl ether 3,’-Dichlorobenzidine (and its salts) bis-Chloromethyl ether beta-Naphthylamine Benzidine 4-Aminodiphenyl Ethyleneimine beta-Propiolactone 2-Acetylaminofluorene 4-Dimethylaminoazo-benzene N-Nitrosodimethylamine
1910.1017	Vinyl chloride
1910.1018	Inorganic arsenic
1910.1025	Lead
1910.1027	Cadmium
1910.1028	Benzene
1910.1029	Coke oven emissions
1910.1030	Bloodborne pathogens
1910.1043	Cotton dust
1910.1044	1,2-dibromo-3-chlorpropane
1910.1045	Acrylonitrile
1910.1047	Ethylene oxide
1910.1048	Formaldehyde
1910.1050	Methylenedianiline
1910.1051	1,3-Butadiene
1910.1052	Methylene chloride
1910.1450	Occupational exposure to hazardous chemicals in laboratories

Appendix E - CHEMICAL INCOMPATIBILITIES, SELECTED LISTING

Sources: *University of New Hampshire-Biological and Chemical Safety Plan; Safety in Academic Chemistry Laboratorie*s, published by The American Chemical Society; *Prudent Practices in the Laboratory, 1995;* National Academic Press

The following list is to be used only as a guide. Specific incompatibilities are listed in appropriate MSDSs.

CHEMICAL	**INCOMPATIBLE WITH:**
Acetic acid	Chromic acid, nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides, permanganates
Acetone	Concentrated nitric and sulfuric acid mixtures
Acetylene	Chlorine, bromine, copper, fluorine, silver, mercury
Alkali and alkaline earth metals	Water, carbon tetrachloride or other chlorinated hydrocarbons, carbon dioxide, magnesium, calcium, lithium, halogens, sodium, potassium
Aluminum (powdered)	Chlorinated hydrocarbons, halogens, carbon dioxide, organic acids
Ammonia (anhydrous)	Mercury (e.g., in manometers), chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid
Ammonium nitrate	Acids, powdered metals, flammable liquids, chlorates, nitrites, sulfur, finely divided organic combustible materials
Aniline	Nitric acid, hydrogen peroxide
Arsenic materials	Any reducing agent
Azides	Acids
Bromine	Ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, benzene, finely divided metals, turpentine
Calcium carbide	Water, alcohol
Calcium oxide	Water
Carbon (activated)	Calcium hypochlorite, all oxidizing agents
Chlorates	Ammonium salts, acids, powdered metals, sulfur, finely divided organic or combustible materials

Chromic acid & chromium trioxide	Acetic acid, naphthalene, camphor, glycerol, alcohol, turpentine, flammable liquids in general.
Chlorine	*See bromine*
Chlorine dioxide	Ammonia, methane, phosphine, hydrogen sulfide
Copper	Acetylene, hydrogen peroxide
Cyanides	Acids
Fluorine	Isolate from all other chemicals
Hydrocarbons (such as butane, propane, benzene)	Fluorine, chlorine, bromine, chromic acid, sodium peroxide
Hydrocyanic acid	Nitric acid, alkali
Hydrofluoric acid (anhydrous) & hydrogen fluoride	Ammonia (aqueous or anhydrous)
Hydrogen peroxide	Copper, chromium, iron, most metals or their salts, alcohols, acetone, organic materials, aniline, nitromethane, flammable liquids, oxidizing gases
Hydrogen sulfide	Fuming nitric acid, oxidizing gases
Hypochlorites	Acids, activated carbon
Iodine	Acetylene, ammonia (aqueous or anhydrous) hydrogen
Mercury	Acetylene, fulminic acid, ammonia
Mercuric oxide	Sulfur
Nitrates	Acids (especially sulfuric acid)
Nitric acid (concentrated)	Acetic acid, alcohols, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids and gases, copper, brass, any heavy metals
Nitrites	Acids

Nitroparaffins	Inorganic bases, amines
Oxalic acid	Silver, mercury
Oxygen	Oils, grease, hydrogen; flammable liquids, solids and gases
Perchloric acid	Acetic anhydride, bismuth and its alloys, alcohol, paper, wood, grease, oils
Peroxides, organic	Acids (organic or mineral), avoid friction or shock, store cold
Phosphorous (white)	Air, oxygen, alkalis, reducing agents
Potassium	Carbon tetrachloride, carbon dioxide, water
Potassium chlorate	Sulfuric and other acids
Potassium perchlorate	Sulfuric and other acids, *see also chlorates*
Potassium permanganate	Glycerol, ethylene glycol, benzaldehyde, sulfuric acid
Selenides	Reducing agents
Silver	Acetylene, oxalic acid, tartaric acid, ammonium compounds, fulminic acid
Sodium	Carbon tetrachloride, carbon dioxide, water
Sodium nitrate	Ammonium nitrate and other ammonium salts
Sodium peroxide	Ethyl or methyl alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerin, ethylene glycol, ethylacetate, methyl acetate, furfural
Sulfides	Acids
Sulfuric acid	Potassium chlorate, potassium perchlorate, potassium permanganate (similar compounds of light metals, such as sodium, lithium)
Tellurides	Reducing agents
Zinc powder	Sulfur

Appendix F - FLAMMABLE/COMBUSTIBLE LIQUIDS: MAXIMUM ALLOWABLE CONTAINER CAPACITY

Maximum Allowable Container Capacity					
	Flammable Liquids			Combustible Liquids	
Container Type	IA	IB	IC	II	IIIA
Glass	500mL (1 pt)[1]	1L (1 qt)[1]	4L(1.1 gal)	4L (1.1 gal)	20L (5gal)
Metal (other than drums) or approved plastic	4L (1.1 gal)	20L (5 gal)	20L (5 gal)	20L (5 gal)	20L (5 gal)
Safety cans	10L (2.6 gal)	20L (5 gal)	20L (5 gal)	20L (5 gal)	20L (5 gal)
Metal container (DOT spec.)	4L (1.1 gal)	20L (5 gal)	20L (5 gal)	227L (60 gal)	227L (60 gal)
Polyethylene (DOT Spec. 34, UN1H1, or as authorized by DOT exemption)	4L (1.1 gal)	20L (5 gal)	20L (5 gal)	227 L (60 gal)	227L (60 gal)

[1] *Exception No.1: Glass containers as large 4L(1.1 gal) shall be permitted to be used if needed and the required purity would be adversely affected by storage in a metal or an approved plastic container, or if the liquid would cause excessive corrosion or degradation of a metal or an approved plastic container.*

Exception No. 2: Containers of not more than 227L (60 gal) capacity shall be permitted in a separate area inside the building if the inside area inside the building meets the requirements of NFPA 30, Flammable and Combustible Liquids Code.

* This table is based on Table 4.2.3 of NFPA 30, Flammable and Combustible Liquids Code, except for allowable quantities of flammable liquids in metal (DOT Specification) drums.

Appendix G - MAXIMUM QUANTITIES OF FLAMMABLE AND COMBUSTIBLE LIQUIDS AND LIQUIFIED FLAMMABLE GASES IN SPRINKLERED LABORATORY UNITS OUTSIDE OF INSIDE LIQUID STORAGE AREAS

Maximum Quantities of Flammable and Combustible Liquids and Liquefied Flammable Gases in Sprinklered Laboratory Units Outside of Inside Liquid Storage Rooms

		Excluding Quantities in Storage Cabinets* or Safety Cans				*Including* Quantities in Storage Cabinets** or Safety Cans			
		Max. Quantity per 100 ft.^{2} of Laboratory Unit		*Max. Quantity per Laboratory Unit*		*Max. Quantity per 100ft.^{2} of Laboratory Unit*		*Max. Quantity per Laboratory Unit*	
Laboratory Unit Fire Hazard Class	*Flammable and Combustible Liquid Class*	L	gal	L	gal	L	gal	L	gal
A	I*	38	10	2270	600	76	20	4540	1200
	I, II, and IIIA	76	20	3028	800	150	40	6060	1600
B	I*	20	5	1136	300	38	10	2270	600
	I, II, and IIIA	38	10	1515	400	76	20	3028	800
C	I*	7.5	2	570	150	15	4	1136	300
	I, II, and IIIA	15	4	757	200	30	8	1515	400
D	I*	4	1.1	284	75	7.5	2	570	150
	I, II, and IIIA	4	1.1	284	75	7.5	2	570	150

* This category includes Class I flammable liquids and liquefied flammable gases.

** Quantities of liquefied flammable gases shall be treated as if they were Class I flammable liquids; that is, (1.1 gal) of liquefied flammable gas is to be considered equivalent to (1.1 gal) of Class I flammable liquid.

Note: This table is based on Table 2.2.1(a) of NFPA 45 – Fire Protection for Laboratories Using Chemicals

Appendix H - MAXIMUM QUANTITIES OF FLAMMABLE AND COMBUSTIBLE LIQUIDS AND LIQUIFIED FLAMMABLE GASES IN NON-SPRINKLERED LABORATORY UNITS OUTSIDE OF INSIDE LIQUID STORAGE AREAS

Maximum Quantities of Flammable and Combustible Liquids and Liquefied Flammable Gases in Non-Sprinklered Laboratory Units Outside of Inside Liquid Storage Rooms									
		Excluding Quantities in Storage Cabinets* or Safety Cans				*Including* Quantities in Storage Cabinets** or Safety Cans			
		Max. Quantity per 100 ft.^{2} of Laboratory Unit		*Max. Quantity per Laboratory Unit*		*Max. Quantity per 100ft.^{2} of Laboratory Unit*		*Max. Quantity per Laboratory Unit*	
Laboratory Unit Fire Hazard Class	*Flammable and Combustible Liquid Class*	L	gal	L	gal	L	gal	L	gal
A	I*	NP	NP	NP	NP	NP	NP	NP	NP
	I, II, and IIIA	NP	NP	NP	NP	NP	NP	NP	NP
B	I*	NP	NP	NP	NP	NP	NP	NP	NP
	I, II, and IIIA	NP	NP	NP	NP	NP	NP	NP	NP
C	I*	7.5	2	284	75	15	4	570	150
	I, II, and IIIA	15	4	380	100	30	8	760	200
D	I*	4	1.1	140	37	7.5	2	284	75
	I, II, and IIIA	4	1.1	140	37	7.5	2	284	75

NP – Not Permitted

* This category includes Class I flammable liquids and liquefied flammable gases.

** Quantities of liquefied flammable gases shall be treated as if they were Class I flammable liquids; that is, (1.1 gal) of liquefied flammable gas is to be considered equivalent to (1.1 gal) of Class I flammable liquid.

Note: This table is based on Table 2.2.1(b) of NFPA 45 – Fire Protection for Laboratories Using Chemicals

Appendix I - HIGH ENERGY OXIDIZERS

(Source: CRC Handbook of Laboratory Safety, 5th Ed)

Ammonium perchlorate (NH_4ClO_4)

Ammonium permanganate (NH_4MnO_4)

Barium peroxide (BaO_2)

Bromine (Br)2

Calcium chlorate ($Ca[ClO_3]_2.2H_2O$)

Calcium hypochlorite ($Ca[ClO]_2$)

Chlorine trifluoride (ClF_3)

Chromium anhydride or chromic acid (CrO_3)

Dibenzoyl peroxide ($[C_6H_5CO]_2O_2$)

Fluorine (F_2)

Hydrogen peroxide (H_2O_2)

Magnesium perchlorate ($Mg[ClO_4]_2$)

Nitric acid (HNO_3)

Nitrogen peroxide (in equilibrium with nitrogen dioxide) N_2O_4; NO_2

Nitrogen trioxide (N_2O_3)

Perchloric acid ($HClO_4$)

Potassium bromate ($KBrO_3$)

Potassium chlorate ($KClO_3$)

Potassium perchlorate ($KClO_4$)

Potassium peroxide (K_2O_3)

Propyl nitrate (normal) ($CH_3 [CH_2]_2 NO_3$)

Sodium chlorate ($NaClO_3$)

Sodium chlorate ($NaClO_2$)

Sodium perchlorate (NaC1O4)

Sodium peroxide (Na_2O_2)

Appendix J - PEROXIDE-FORMING MATERIALS

Types of Compounds Known to Auto-Oxidize to Form Peroxides
(Source: Prudent Practices in the Laboratory,1995)

- Aldehydes
- Ethers, especially cyclic ethers and those containing primary and secondary alkyl groups
- Compounds containing benzylic hydrogens
- Compounds containing allylic hydrogens including most alkenes; vinyl and vinylidenes
- Compounds containing a tertiary C-H group

Classes of Chemicals that can Form Peroxides Upon Aging
(Source: Prudent Practices in the Laboratory,1995)

Unsaturated materials may polymerize violently due to peroxide initiation:

Acrylic acid	Methyl methacrylate	Vinyl chloride
Acrylonitrile	Styrene	Vinyl pyridine
Butadiene	Tetrafluoroethylene	Vinylidene chloride
Chlorobutadiene (chloroprene)	Vinyl acetate	
Chlorotrifluoroethylene	Vinyl acetylene	

Peroxide hazards upon concentration (distillation/evaporation):

Acetal	Dicyclopentadiene	Methyl acetylene
Cumene	Diethylene glycol dimethyl ether	Methyl cyclopentane
Cyclohexene	Diethyl ether	Methyl-I-butyl ketone
Cyclooctene	Dioxane	Tetrahydrofuran
Cyclopentene	Ethylene glycol dimethyl ether	Tetrahydronaphthalene
Diacetylene	Furan	Vinyl ethers

Peroxides derived from the following may explode without concentration:

Organic:	Inorganic:
Divinyl ether	Potassium metal
Divinyl acetylene	Potassium amide
Isopropyl ether	Sodium amide
Vinylidene chloride	

Appendix K - CARCINOGENS

Source: *Report on Carcinogens, Tenth Edition;* U.S. Department of Health and Human Services, Public Health Service, National Toxicology Program, December 2002 (http://ehp.niehs.nih.gov/roc/toc10.html).

Known Carcinogens
Substances or groups of substances, occupational exposures associated with a technological process, and medical treatments that are *known to be carcinogenic**.

* For the purpose of this list, "known carcinogens" are defined as agents with "sufficient evidence of carcinogenicity from studies in humans, which indicates a causal relationship between exposure to the agent, substance, or mixture, and human cancer.

Aflatoxins
Alcoholic Beverage Consumption
4-Aminobiphenyl
Analgesic Mixtures Containing Phenacetin (See Phenacetin and Analgesic Mixtures Containing Phenacetin)
Arsenic Compounds, Inorganic
Asbestos
Azathioprine
Benzene
Benzidine (See Benzidine and Dyes Metabolized to Benzidine)
Beryllium and Beryllium Compounds
1,3-Butadiene
1,4-Butanediol Dimethylsulfonate (Myleran®)
Cadmium and Cadmium Compounds
Chlorambucil
1-(2-Chloroethyl)-3-(4-methylcyclohexyl)-1-nitrosourea (MeCCNU)
bis(Chloromethyl) Ether and Technical-Grade Chloromethyl Methyl Ether
Chromium Hexavalent Compounds
Coal Tar Pitches (See Coal Tars and Coal Tar Pitches)
Coal Tars (See Coal Tars and Coal Tar Pitches)
Coke Oven Emissions
Cyclophosphamide
Cyclosporin A (Ciclosporin)
Diethylstilbestrol
Dyes Metabolized to Benzidine (See Benzidine and Dyes Metabolized to Benzidine)
Environmental Tobacco Smoke (See Tobacco Related Exposures)
Erionite
Estrogens, Steroidal
Ethylene Oxide
Melphalan
Methoxsalen with Ultraviolet A Therapy (PUVA)
Mineral Oils (Untreated and Mildly Treated)
Mustard Gas
2-Naphthylamine
Nickel Compounds (See Metallic Nickel and Nickel Compounds)
Radon
Silica, Crystalline (Respirable Size)
Smokeless Tobacco (See Tobacco Related Exposures)
Solar Radiation (See Ultraviolet Radiation Related Exposures)
Soots
Strong Inorganic Acid Mists Containing Sulfuric Acid

Sunlamps or Sunbeds, Exposure to (See Ultraviolet Radiation Related Exposures)
Tamoxifen
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD); (Dioxin)
Thiotepa
Thorium Dioxide
Tobacco Smoking (See Tobacco Related Exposures)
Vinyl Chloride
Ultraviolet Radiation, Broad Spectrum UV Radiation (See Ultraviolet Radiation Related Exposures)
Wood Dust

Probable Carcinogens
Substances or groups of substances, and medical treatments which may reasonably be anticipated to be carcinogens**.

** For the purpose of this report, substances "which may reasonable be anticipated to be carcinogens" are defined as those agents with:

- Limited evidence of carcinogenicity from studies in humans, which indicates that causal interpretation is credible, but that alternative explanations, such as chance, bias, or confounding factors, could not adequately be excluded," or

- Sufficient evidence of carcinogenicity from studies in experimental animals, which indicates there is an increased incidence of malignant and/or a combination of malignant and benign tumors (1) in multiple species or at multiple tissue sites, or (2) by multiple routes of exposure, or (3) to an unusual degree with regard to incidence, site, or type of tumor, or age at onset, or

- Less than sufficient evidence of carcinogenicity in humans or laboratory animals; however, the agent, substance, or mixture belongs to a well-defined, structurally related class of substances whose members are listed in a previous Report on Carcinogens as either known to be a human carcinogen or reasonably anticipated to be a human carcinogen, or there is convincing relevant information that the agent acts through mechanisms indicating it would likely cause cancer in humans.

Acetaldehyde
2-Acetylaminofluorene
Acrylamide Acrylonitrile
Adriamycin® (Doxorubicin Hydrochloride)
2-Aminoanthraquinone
ï -Aminoazotoluene
1-Amino-2-methylanthraquinone
2-Amino-3-methylimidazo[*4,5*-f]quinoline (IQ)
Amitrole
ï -Anisidine Hydrochloride
Azacitidine (5-Azacytidine®, 5-AzaC)
Benz[a]anthracene (See Polycyclic Aromatic Hydrocarbons)
Benzo[b]fluoranthene (See Polycyclic Aromatic Hydrocarbons)
Benzo[j]fluoranthene (See Polycyclic Aromatic Hydrocarbons)
Benzo[k]fluoranthene (See Polycyclic Aromatic Hydrocarbons)
Benzo[a]pyrene (See Polycyclic Aromatic Hydrocarbons)
Benzotrichloride Bromodichloromethane
2,2-bis-(Bromoethyl)-1,3-propanediol (Technical Grade)
Butylated Hydroxyanisole (BHA)
Carbon Tetrachloride
Ceramic Fibers (Respirable Size)
Chloramphenicol
Chlorendic Acid
Chlorinated Paraffins (C12, 60% Chlorine)

1-(2-Chloroethyl)-3-cyclohexyl-1-nitrosourea
bis(Chloroethyl) nitrosourea
Chloroform
3-Chloro-2-methylpropene
4-Chloro-ï -phenylenediamine
Chloroprene
p-Chloro-ï -toluidine and p-Chloro-ï -toluidine Hydrochloride (See p-Chloro-ï -toluidine and p-Chloro-ï -toluidine
Hydrochloride) Chlorozotocin
C.I. Basic Red 9 Monohydrochloride
Cisplatin
p-Cresidine
Cupferron Dacarbazine
Cupferron Dacarbazine Cupferron Dacarbazine
Danthron (1,8-Dihydroxyanthraquinone)
2,4-Diaminoanisole Sulfate
2,4-Diaminotoluene
Dibenz[*a,*h]acridine (See Polycyclic Aromatic Hydrocarbons)
Dibenz[*a,*j]acridine (See Polycyclic Aromatic Hydrocarbons)
Dibenz[*a,*h]anthracene (See Polycyclic Aromatic Hydrocarbons)
7H-Dibenzo[*c,*g]carbazole (See Polycyclic Aromatic Hydrocarbons)
Dibenzo[*a,*e]pyrene (See Polycyclic Aromatic Hydrocarbons)
Dibenzo[*a,*h]pyrene (See Polycyclic Aromatic Hydrocarbons)
Dibenzo[*a,*i]pyrene (See Polycyclic Aromatic Hydrocarbons)
Dibenzo[*a,*l]pyrene (See Polycyclic Aromatic Hydrocarbons)
1,2-Dibromo-3-chloropropane
1,2-Dibromoethane (Ethylene Dibromide)
2,3-Dibromo-1-propanol
tris (2,3-Dibromopropyl) Phosphate
1,4-Dichlorobenzene
3,3'-Dichlorobenzidine and 3,3'-Dichlorobenzidine Dihydrochloride (See 3,3'-Dichlorobenzidine and 3,3'-Dichlorobenzidine
Dihydrochloride)
Dichlorodiphenyltrichloroethane (DDT)
1,2-Dichloroethane (Ethylene Dichloride)
Dichloromethane (Methylene Chloride)
1,3-Dichloropropene (Technical Grade)
Diepoxybutane
Diesel Exhaust Particulates
Diethyl Sulfate
Diglycidyl Resorcinol Ether
3,3'-Dimethoxybenzidine (See 3,3'-Dimethoxybenzidine and Dyes Metabolized to 3,3'-Dimethoxybenzidine)
4-Dimethylaminoazobenzene
3,3'-Dimethylbenzidine (See 3,3'-Dimethylbenzidine and Dyes Metabolized to 3,3'-Dimethylbenzidine)
Dimethylcarbamoyl Chloride
1,1-Dimethylhydrazine
Dimethyl Sulfate
Dimethylvinyl Chloride
1,6-Dinitropyrene (See Nitroarenes)
1,8-Dinitropyrene (See Nitroarenes)
1,4-Dioxane
Disperse Blue 1
Dyes Metabolized to 3,3'-Dimethoxybenzidine (See 3,3'-Dimethoxybenzidine and Dyes Metabolized to 3,3'-Dimethoxybenzidine)
Dyes Metabolized to 3,3'-Dimethylbenzidine (See 3,3'-Dimethylbenzidine and Dyes Metabolized to 3,3'-Dimethylbenzidine)

Epichlorohydrin
Ethylene Thiourea
di(2-Ethylhexyl) Phthalate
Ethyl Methanesulfonate
Formaldehyde (Gas)
Furan
Glasswool (Respirable Size)
Glycidol
Hexachlorobenzene
Hexachlorocyclohexane Isomoers
Hexachloroethane
Hexamethylphosphoramide
Hydrazine and Hydrazine Sulfate (See Hydrazine and Hydrazine Sulfate)
Hydrazobenzene
Indeno[*1,2,3-c*d]pyrene (See Polycyclic Aromatic Hydrocarbons)
Iron Dextran Complex
Isoprene
Kepone® (Chlordecone)
Lead Acetate (See Lead Acetate and Lead Phosphate)
Lead Phosphate (See Lead Acetate and Lead Phosphate)
Lindane and Other Hexachlorocyclohexane Isomers
2-Methylaziridine (Propylenimine)
5-Methylchrysene (See Polycyclic Aromatic Hydrocarbons)
4,4'-Methylenebis(2-chloroaniline)
4-4'-Methylenebis(N,N-dimethyl)benzenamine
4,4'-Methylenedianiline and 4,4'-Methylenedianiline Dihydrochloride (See 4,4'-Methylenedianiline and its Dihydrochloride Salt)
Methyleugenol
Methyl Methanesulfonate
N-Methyl-N'-nitro-N-nitrosoguanidine
Metronidazole
Michler's Ketone [4,4'-(Dimethylamino)benzophenone]
Mirex
Nickel (Metallic) (See Nickel and Nickel Compounds)
Nitrilotriacetic Acid
ï -Nitroanisole
6-Nitrochrysene (See Nitroarenes (selected))
Nitrofen (2,4-Dichlorophenyl-p-nitrophenyl ether)
Nitrogen Mustard Hydrochloride
2-Nitropropane
1-Nitropyrene (See Nitroarenes)
4-Nitropyrene (See Nitroarenes)
N-Nitrosodi-n-butylamine
N-Nitrosodiethanolamine
N-Nitrosodiethylamine
N-Nitrosodimethylamine
N-Nitrosodi-n-propylamine
N-Nitroso-N-ethylurea
4-(N-Nitrosomethylamino)-1-(3-pyridyl)-1-butanone
N-Nitroso-N-methylurea
N-Nitrosomethylvinylamine
N-Nitrosomorpholine
N-Nitrosonornicotine
N-Nitrosopiperidine
N-Nitrosopyrrolidine
N-Nitrososarcosine
Norethisterone

Ochratoxin A
4,4’-Oxydianiline
Oxymetholone
Phenacetin (See Phenacetin and Analgesic Mixtures Containing Phenacetin)
Phenazopyridine Hydrochloride
Phenolphthalein
Phenoxybenzamine Hydrochloride
Polybrominated Biphenyls (PBBs)
Polychlorinated Biphenyls (PCBs)
Polycyclic Aromatic Hydrocarbons (PAHs)
Procarbazine Hydrochloride
Progesterone
1,3-Propane Sultone
â -Propiolactone
Propylene Oxide
Propylthiouracil
Reserpine Safrole
Selenium Sulfide
Streptozotocin
Styrene-7,8-oxide
Sulfallate
Tetrachloroethylene (Perchloroethylene)
Tetrafluoroethylene Tetranitromethane Thioacetamide Thiourea
Toluene Diisocyanate
ï -Toluidine and ï -Toluidine Hydrochloride(See ï -Toluidine and ï -Toluidine Hydrochloride)
Toxaphene Trichloroethylene
2,4,6-Trichlorophenol
1,2,3-Trichloropropane
Ultraviolet A Radiation (See Ultraviolet Radiation Related Exposure)
Ultraviolet B Radiation (See Ultraviolet Radiation Related Exposure)
Ultraviolet C Radiation (See Ultraviolet Radiation Related Exposure)
Urethane
Vinyl Bromide
4-Vinyl-1-cyclohexene Diepoxide

Appendix L – ACUTE TOXICANTS

This discussion is adapted from *Prudent Practices in the Laboratory*, 1995, National Academy Press.

Acute toxicity is the ability of a chemical to cause a harmful effect 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, selected with due regard for the possible routes of exposure. These values can be found in the MSDS for the chemical, or in any number of literature or web-based references noted in Appendices B and C of this Manual. It is useful to classify and compare your chemicals and their values with the following table taken from *Prudent Practices*, page 42.

Hazard Level	Toxicity Rating	Oral LD50 (rats per kg)	Skin Contact LD50 (rabbits, per kg)	Inhalation LC50 (Rats, ppm for 1 hr)	Inhalation LC50 (Rats, mg/m3 for 1 hr)
High	Highly Toxic	<50 mg	<200 mg	<200	<2,000
Moderate	Moderately toxic	50 to 500 mg	200mg to 1 g	200 to 2,000	2,000 to 20,000
Low	Slightly toxic	500 mg to 5 g	1 to 5 g	2,000 to 20,000	20,000 to 200,000

Substances with values qualifying for “High” hazard levels meet the definition of highly hazardous for the purpose of special controls, per Chapter 9, subsection H, of this Manual.

Appendix M – CONSIDERATIONS FOR SELECTING GLOVES AND OTHER CHEMICAL PROTECTIVE CLOTHING

The degree of chemical protection afforded by a certain material is a function of chemical type, the task length, and the level of activity. Consider all of the following factors in making your decision:

1. **Toxicity of the chemical**: For a highly toxic material, particularly one with high skin absorption rates, gloves may not even be an appropriate final control. Review the MSDS and other literature with your LSO and consult OSEM for guidance.

2. **Physical Requirements of the Work**: Remember, the most perfect glove is useless if easily cut, torn, or damaged. For highly physical work, double gloving is an alternative, or using dipped (multi-compound) or multilayered gloves. Consider the following:

   - Will tasks lead to puncture, abrasion, or tearing of the glove? (i.e., will palms or fingers need to be lined with abrasion-resistant material).
   - Will tactile sensitivity or extra grip be needed?
   - Will the weight of heavy gloves impair work or lead to fatigue and other related safety hazards? (may need to alter the task or institute more frequent breaks).
   - Will there be extreme temperature or humidity conditions ? (if so, check with manufacturer on what effect this may have such as brittling or faster breakthrough; permeation & breakthrough tests are done at a specified temperature).
   - Will the glove be used extensively outdoors? Will sunlight, ozone, UV degrade the product more quickly?
   - Is the glove material flammable? Or, flame resistant?

3. **Research published rating charts.** Scan safety catalogues for a wide variety of CPC manufacturers, then review each manufacturer's charts for your specific chemicals. Do not rely on charts that indicate the protective ability of a certain material against an entire class of chemicals, such as "acids". Reputable manufacturers will list at least permeation data. Call the manufacturer with questions and be comfortable that the product was tested under similar work and environmental conditions. Forsberg & Mansdorf recommends starting with a material that has at least a 4 hour breakthrough time, then looking at permeation rates.

4. **Chemical Mixtures.** Remember that no one clothing material will be a barrier to all chemicals; it may be more efficient to purchase different gloves for distinct purposes than to search for a "wonder" glove. In fact, the OSHA Standard recommends that for mixtures of chemicals, a glove should be selected on the basis of the chemical component with the shortest breakthrough time.

5. **Manufacturer Variability.** The chemical resistance of a certain material may vary widely from manufacturer to manufacturer, depending on construction methods, (and even from lot to lot for a given source). So check with a specific manufacturer on the match (i.e, not everyone's nitrile glove protects equally). Also, check with the manufacturer on specific storage or shelf-life requirements of its products.

6. **Material Thickness/Immersion Time.** Usually, the thicker the glove, the slower the permeation rate for a given chemical. Likewise, your potential exposure to a chemical increases if you are immersing your entire hand in a chemical as opposed to just handling a contaminated surface with fingertips. Once again, know your task.

7. **"Persistent Permeation".** Note, also, that once a chemical has begun to diffuse into a plastic/rubber material, it will continue to diffuse toward the interior (a phenomenon known as "persistent permeation") even after the surface has been wiped clean with soap and water. The next workday, some absorbed chemical may reach the inside of the glove. This amount should be insignificant through a glove of highly resistant material. However, it may be a critical factor if purchasing gloves for highly toxic or carcinogenic materials (of which any amount inside a glove is undesirable) or highly viscous materials (which are difficult to remove).

8. **Consider quality construction of the CPC.** Clothing (lab coats, aprons, etc) are rated in same manner, with same standards. However, the swatch of material does not include seams. Seams are either stitched (which can leave holes) or welded with a welding/cementing tape over the stitching. The latter seam type is more expensive but offers the best splash protection. Quality gloves will have stitched seams overlaid with tape or sealed with a coating. For clothing, multiple layers of fabric overlap should be present to avoid penetration of chemical.

9. **A special note on latex gloves.** If using surgical-type barrier gloves for handling objects, they should be vinyl material, <u>not latex</u>. Latex gloves, particularly when powdered, can cause a mild-to-severe allergic reaction in sensitive individuals. The use of vinyl barrier gloves (disposed after use) is highly recommended when handling objects potentially contaminated with residual particulate preservatives and pesticides. If cotton gloves are desired for tactile reasons, they should be worn in addition to vinyl gloves for full dermal protection (cotton alone will act as a contaminant "wick" to the skin, especially if moistened by perspiration).

Office of Health and Safety (OHS)

Biosafety in Microbiological and Biomedical Laboratories (BMBL) 4th Edition

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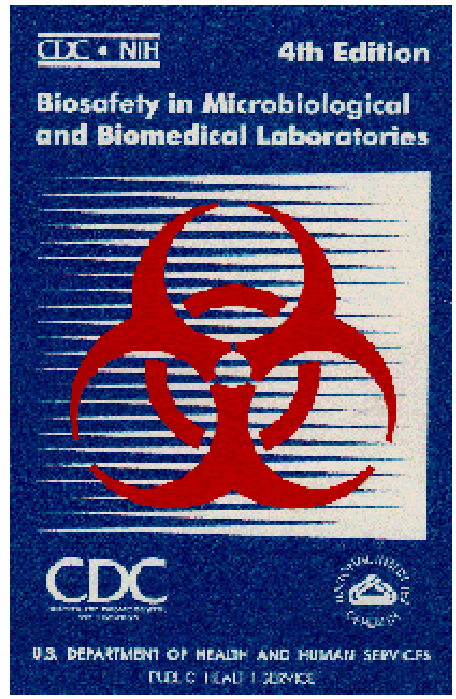

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention
and
National Institutes of Health
Fourth Edition, May 1999

US Government Printing Office
Washington: 1999

Errata sheet for hard copy booklet

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